Department of Primary Industries
Department of Regional NSW

Northern NSW research results 2022

RESEARCH & DEVELOPMENT – INDEPENDENT RESEARCH FOR INDUSTRY

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Front cover image: Dual purpose grazing trial at Tamworth Agricultural Institute, Tamworth.

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Foreword

The Northern Cropping Systems Unit of NSW Department of Primary Industries (NSW DPI) again pleased to be able to offer you an overview of results from R&D undertaken in the Northern Grains Region of NSW. For over 11 editions the book has aimed to make available the findings and outcomes of this research, which can be used to guide and inform practice change throughout the region. Our target audience includes grain growers, agribusiness, consultants and other research bodies.

The majority of this work is conducted in partnership with the Grains Research and Development Corporation (GRDC), using grower's levies and NSW government investment to address key production and sustainability constraints and opportunities for growers across both summer and winter cropping systems of the region.

The NSW DPI Northern Cropping Systems Unit is based across the Northern Grains Region of NSW with the key research hubs at Trangie, Tamworth, Narrabri and Grafton, and satellite sites at Breeza and numerous on-farm locations. This geographical spread allows work to be replicated across differing environments creating greater rigor of the findings and recommendations.

The papers are based on scientifically sound and independent research and take into account the situation, location and season in which the work has been conducted. With two of the wettest years on record in most regions following three of the driest years on record it is an important reminder to consider research in the context of the season that it is conducted and to consider long term results where possible.

These experiments cover disciplines from agronomy to plant breeding, crop protection, along with phenology, soils and nutrition research. This is the 12th Edition, which in many cases provides updates on research that has been conducted over several years and locations.

Critical to successful research is collaboration with growers, advisors and consultants who work with our research teams throughout the year. These collaborators are individually acknowledged at the end of each paper. NSW DPI is fortunate to partner with other organisations such as universities, CSIRO, grower groups and other state-based agricultural departments.

We hope you find the papers to have some value to your business and appreciate any feedback that will help improve future editions of the Northern NSW Research Results book.

Guy McMullen,
Director Northern Cropping Systems,
Tamworth Agricultural Research Institute,
On behalf of the Northern Cropping Systems Unit,
NSW Department of Primary Industries.

Contents

Effects of early and late waterlogging on phytophthora root rot and chickpea resistance

Nicole Dron[1,2], Steven Simpfendorfer[1], Tim Sutton[2,3], Georgina Pengilley[1] and Kristy Hobson[1]

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Key findings

- Waterlogging had a greater effect on chickpea yield when compared with phytophthora root rot (PRR) disease.
- Commercial chickpea varieties, such as PBA HatTrick⁽ᴾ⁾, were more affected by waterlogging during the late vegetative growth stage (83% yield loss) than the early vegetative growth stage (26% yield loss).
- Late waterlogging plus PRR infection resulted in rapid plant death and up to 98% yield loss.
- Waterlogging reduces the plant's ability to overcome PRR infection, even in varieties with higher resistance PRR.

Keywords waterlogging, chickpea, phytophthora, yield loss, PRR

Introduction

Under high soil moisture conditions, PRR is explosive where inoculum is present. Under waterlogging conditions where water level is above field capacity the disease is exacerbated even further. PRR and waterlogging are difficult to differentiate in chickpea during a wet season, as symptoms are quite similar.

PRR symptoms include:

- reduced or stopped growth rate
- leaf chlorosis
- foliage desiccation
- premature senescence
- wilting
- lateral root decay
- reddish-brown stem canker
- yield loss.

Symptoms of waterlogging are identical except that there is rapid onset in warmer conditions and the absence of stem canker and unique root lesions (Moore 2015).

This study aimed to describe the effect of soil waterlogging on PRR disease, including chickpea varieties with moderate levels of resistance to PRR. This information can be used to understand the risks associated with both waterlogging and PRR; describing when integrated disease management (IDM) practices might be successful.

Site details

Location	Shade house – Tamworth Agriculture Institute, Tamworth, NSW. Shade house temperatures described in results section.

Soil media	1:1:1, loam, sand, Greenlife® garden blend, pH_{Ca} 7.6 in 100 L bins as deep pots.
Experiment design	• Four replicates in a factorial split plot design • Waterlogging (*n* = 3) × *Phytophthora medicaginis* (pm) inoculation (*n* = 2) as the main plot treatment level • Chickpea genotypes (*n* = 8) the subplot treatment level.
Sowing date	29 June 2020.
Fertiliser	After 8 weeks all plants were fertilised fortnightly with 30 mL Yates® Thrive soluble all-purpose fertiliser.
Plant population	Target 30 plants/m^2.
Harvest date	19 October 2020.

Treatments

Varieties (4)

Four chickpea genotypes:

- Moderately resistant: 04067 (wild chickpea backcross breeding line)
- Moderately susceptible: Yorker$^{\phi}$ and PBA HatTrick$^{\phi}$
- Susceptible: Rupali$^{\phi}$.

Disease and waterlogging

Six treatments:

1. a nil control (no PRR or waterlogging)
2. PRR infection
3. early waterlogging
4. late waterlogging
5. PRR infection with early waterlogging
6. PRR infection with late waterlogging.

Measures

Measures were analysed using a generalised linear mixed model with 5–95% confidence intervals, measures included: Grain weight (g/plant) and root health score (1=good; 9=bad) were taken from above the seed.

Results

Waterlogging had the greatest effect on grain weight (F = 305, *P*<0.001), when compared with genotype (F = 33, *P*<0.001) and PRR (F = 10.2, *P*<0.05), respectively (Figure 1). Reductions in grain weight were seen to be associated with plant stunting and early senescence following early waterlogging; and plant death resulting from late waterlogging. None of the 4 genotypes was able to fully recover seed weight following early or late waterlogging.

PBA HatTrick$^{\phi}$ yield of was reduced by 26% and 83% following early and late waterlogging respectively. Late waterlogging had a more detrimental effect than early waterlogging (Figure 1) due to a significantly greater root disease incidence under waterlogging conditions (Figure 2). PRR in combination with waterlogging further reduced grain weight in some genotypes (Figure 1) and increased root disease (Figure 2), with 74% and 98% losses observed in PBA HatTrick$^{\phi}$ after early and late vegetative waterlogging, respectively.

The PRR treatment (without waterlogging) displayed no foliar symptoms or seed weight reduction compared with the non-waterlogged uninoculated control (Figure 2). With greater soil moisture, which was difficult to maintain in the light soil media in this study, higher levels of root disease due to PRR is expected especially in susceptible varieties. Under field capacity, PRR-caused root damage was more severe in the very susceptible genotype Rupali[⊕] (Figure 2), and although this was not significantly different from the uninoculated Rupali[⊕], it still supports using varieties with better PRR resistance where Pm inoculum is present.

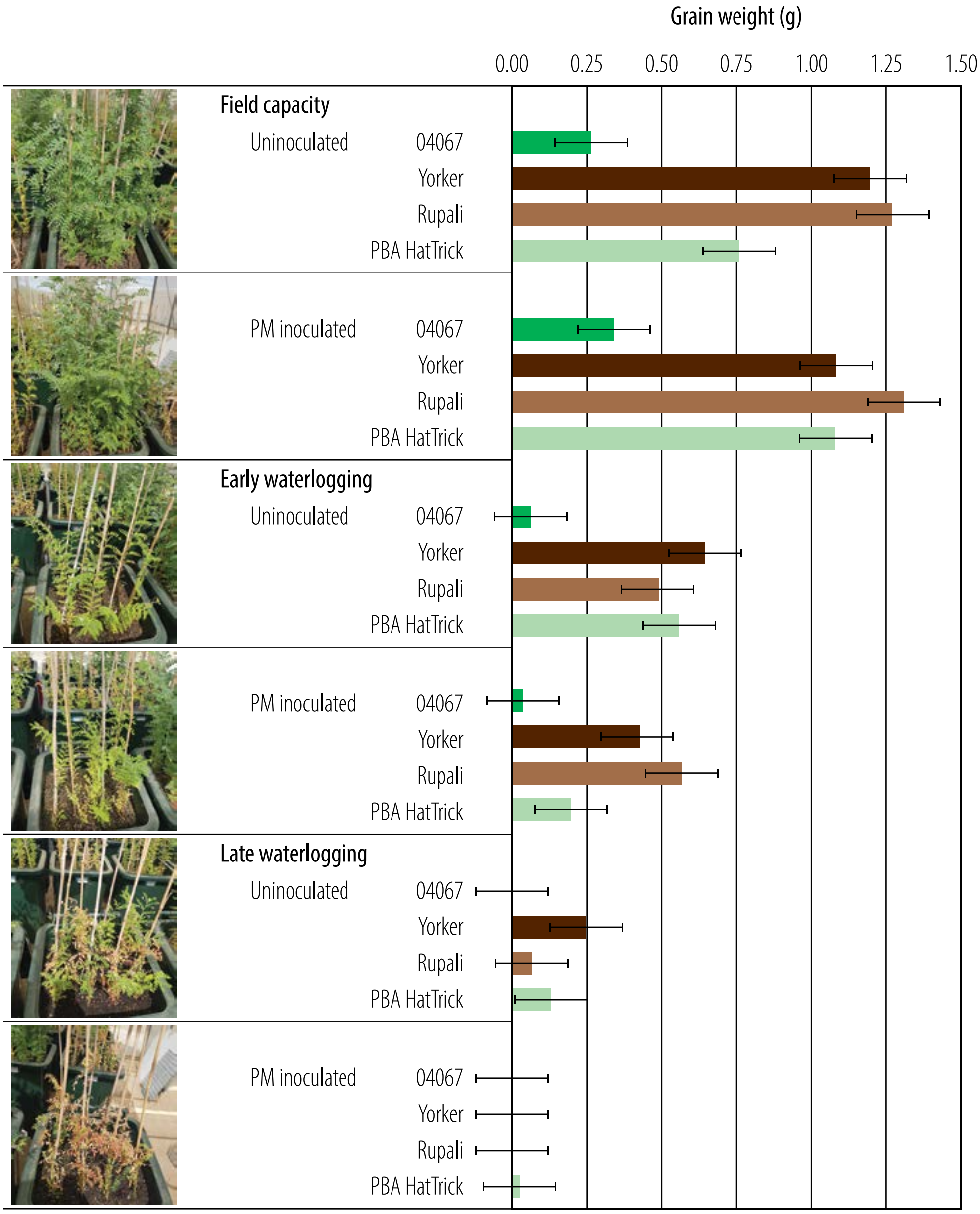

Figure 1 Mean grain weight and 5–95% confidence intervals for treatments: Field capacity or early and late vegetative waterlogging, uninoculated or *Phytophthora medicaginis* (Pm) inoculated; for 4 chickpea genotypes. *P* value for the 3-way interaction is <0.05.

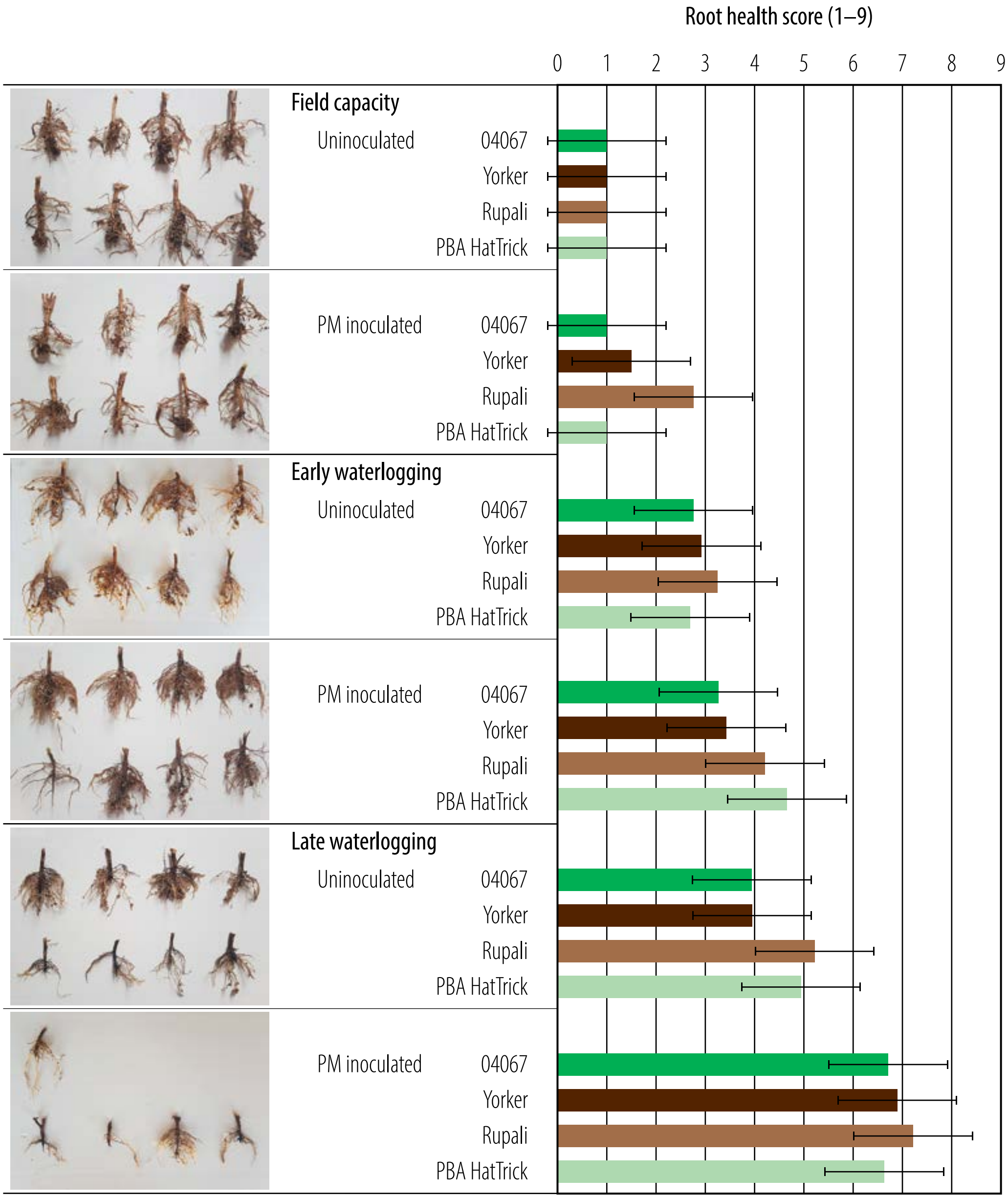

Figure 2 Mean root health score and 5–95% confidence intervals for treatments: Field capacity or early and late vegetative waterlogging, uninoculated or *Phytophthora medicaginis* (Pm) inoculated; for 4 chickpea genotypes. *P* value for the 3-way interaction is <0.001.

Final redox measures (mV), a measure of waterlogging severity, were not significantly different between early and late waterlogging treatments. However, the soil temperature and ambient temperatures were 12.1 °C and 7.8 °C warmer during the late waterlogging treatment than during the early waterlogging treatment, respectively (Figure 3). Higher temperatures increase the rate of plant transpiration and respiration, which in turn puts the plants under greater stress when waterlogged, particularly during the late vegetative and flowering stages (Cowie and Voesenek L 1996).

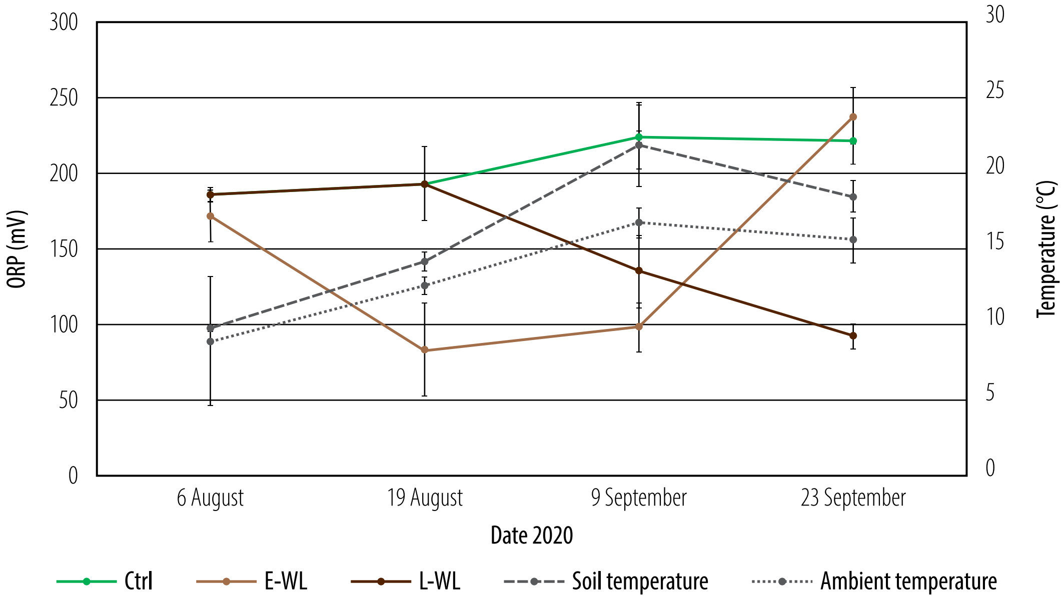

Figure 3 Soil redox (oxidation reduction potential, ORP) an indicator of oxygen availability, ambient and soil temperatures during early and late waterlogging treatments. E-WL: Early waterlogging, L-WL: late waterlogging, Ctrl: control.

Conclusions

This study shows that waterlogging alone can cause major disease and yield losses, with waterlogging timing also having a significant effect. The findings show that the likelihood of plant survival and recovery from waterlogging (in the absence of PRR inoculum) is higher when waterlogging occurs during early growth stages. These findings are supported by waterlogging results of chickpea and other crop species, where waterlogging causes both root damage and physiological constraints (water and nutrient uptake) that reduces the plants ability to overcome stress (Colmer and Voesenek 2009, Palta et al. 2010). Therefore, in a scenario where both waterlogging and PRR inoculum is present, chickpea will have greater yield reductions.

The ability to predict PRR and waterlogging-induced yield losses could be used to reduce late season in-crop inputs, as there is currently no economic in-crop control. The findings support currently recommended practice to avoid paddocks with:

- a known presence of PRR
- a history of chickpea, lucerne or medic weeds
- low-lying areas particularly when above average rainfall is forecast
- growing chickpea varieties with higher levels of PRR resistance.

Moreover, using conservative agronomy and soil improvement practices could be used to reduce waterlogging as IDM for PRR, as waterlogging alone results in plant stunting, yield loss and a reduced resistance to PRR in chickpea.

For more further detail please follow the link https://www.mdpi.com/2073-4395/12/1/89 (Dron et al. 2022).

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The effect of ascochyta blight on chickpea yields and economics when infection occurs at 3 different growth stages

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Key findings

- Variety choice remains a critical management tool under high disease pressure: gross margin (GM) loss of $300/ha in Kyabra⁽ᵖ⁾ compared with gains of up to $1000 in PBA Seamer⁽ᵖ⁾ when no fungicide was applied.
- Preventative fungicide applications before seedling infection have the greatest effect in reducing disease severity.
- Salvage fungicide applications on seedling infections in susceptible varieties is insufficient in preventing yield loss
- Applying fungicide during early podding might reduce yield loss if ascochyta blight (AB) is present and a wet-season finish is predicted.

Keywords Ascochyta, chickpea, yield, growth stage, economic, Trangie, Tamworth, 2020, 2021, northern

Introduction

Ascochyta blight management in chickpea across southern Queensland and north-central New South Wales regions is based on controlling early season infection. This strategy has been developed through agronomist feedback and past DPI pulse pathology experiments in the north where infection is simulated after the first post-emergent rain event. Chickpea is also susceptible to AB infection later in the season during flowering and podding, depending on varietal resistance. Limited studies have been conducted on effective AB management when infection occurs during the chickpea flowering and podding stages in Australia.

In 2020 an experiment was conducted at Trangie Agricultural Research Centre to establish that early disease management and higher AB varietal resistance continues to be the most profitable management strategy, compared with uncontrolled infections in susceptible varieties. However, the 2020 results raised further questions about what would happen if the fungicide application was reactive after the first post emergent rainfall event, or if no fungicide was applied until pod infection. These treatments were added to the 2021 experiments conducted both at Trangie Agricultural Research Centre and Tamworth Agricultural Institute to assess the economic effect of AB infection at 3 separate growth stages on chickpea varieties with different levels of AB resistance.

Site details

Location	**Tamworth**: Tamworth Agricultural Institute (31° 9′ 44.3988″ S, 150° 59′ 7.9548″ E) **Trangie**: Trangie Agricultural Research Centre (31° 8′ 50.0928″ S, 150° 59′ 0.006″ E).
Paddock history	2020 Wheat
Soil type	Light clay
Growing season rainfall and humidity	Trangie: 1209 mm rain; Tamworth: 930.2 mm rain (Figure 1).

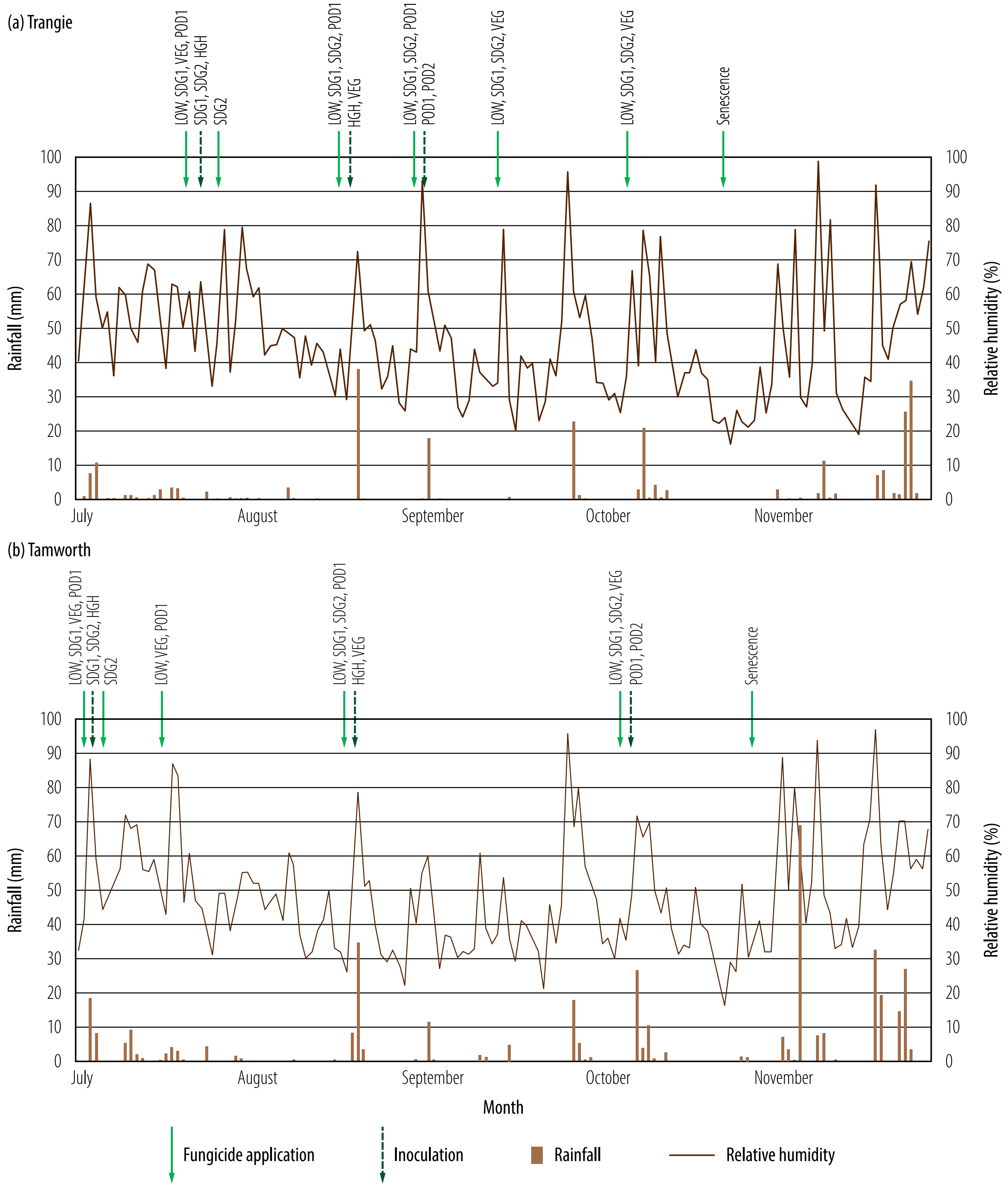

Figure 1 Rainfall and relative humidity for Trangie (top) and Tamworth (bottom) for the growing season with corresponding treatment application timings.

Experiment design	Randomised block design with fungicide management strategies as the main block and varieties as the sub-plots; 4 replications.
Sowing date	• 16 May at Tamworth • 29 May at Trangie.

Fertiliser	Pulse Starter Z at sowing and rhizobia group N (NewEdge Microbials Pty. Ltd. Albury, NSW).
Sowing rate	Target 35 plants/m^2
Weed management	Trangie: • Pre-sowing: 1.7 L/ha TriflurX 480® (480 g/L trifluralin), 5 May. • Post-sowing, pre-emergent: 0.86 kg/ha Terbyne Xtreme 875® (875 g/kg terbuthylazine), 28 May. • In-crop: 100 ml/ha Verdict grass herbicide (520 g/L haloxyfop) 8 July. Tamworth: • Pre-sowing: 1.7 L/ha Treflan® (trifluralin 480 g/L), 2 L/ha Avadex® (Triallate 500 g/L), 16 April. • Applied 2 L/ha Spray.Seed 250® (paraquat 135 g/L, diquat 115 g/L), 13 May. • Post-sowing: 0.86 kg/ha pre-emergent Terbyne® Xtreme® (terbuthylazine 875 g/kg), 21 May.
Insect management	Trangie • Targeting *Helicoverpa* spp: 1.0 L/ha Pyrinex Super insecticide® (400 g/L chlorpyrifos + 20 g/L bifenthrin) and 70 g/ha Altacor® insecticide (350 g/kg chlorantraniliprole) on 28 May and 11 November respectively. Tamworth: • Targeting *Helicoverpa* spp: 1.5 L/ha Electra 225® (Methomyl 225 g/L).
Disease management	• Targeting seed-borne AB and botrytis seedling disease: 200 mL per 100 kg of seed P-Pickel T® pre sowing. • Targeting in crop AB (as part of the experiment's management strategies): 1 L/ha chlorothalonil (720 g/L).
Harvest date	• 13 December at Trangie • 19 December Tamworth.

Treatments

Varieties (3) and AB resistance

1. Kyabra⦶: VS = very susceptible
2. PBA HatTrick⦶: MS = moderately susceptible
3. PBA Seamer⦶: MS = moderately susceptible.

Fungicide management strategy per variety

- **No disease (LOW)**: Uninoculated and chlorothalonil fungicide applied before rain or irrigation.
- **High disease (HGH)**: Inoculated with AB at seedling (3–4 nodes) and vegetative (7–8 nodes) growth stages with no fungicide.
- **Seedling 1 (SDG1)**: Preventative fungicide application at the seedling stage 2–3 node stage and inoculated with AB (3–4 nodes). Disease to progress for 2–3 rain events, then fungicide applied for the rest of the season.
- **Seedling 2 (SDG2)**: No preventative fungicide treatment, inoculated with AB at seedling stage (3–4 nodes). Disease to progress for 2–3 rain events, then fungicide applied control for the rest of the season

- **Vegetative (VEG)**: Foliar fungicide strategically applied from emergence to vegetative growth stage then inoculated with AB. Disease to progress for 2–3 rain events or to first pod; fungicide strategically applied for of the rest of the season
- **Podding 1 (POD1)**: Protected with foliar fungicide from emergence to first pod then inoculated with AB.
- **Podding 2 (POD2)**: No foliar fungicide applied then inoculated with AB at the podding stage.

Data collection and analysis

Crop protection

- AB severity was assessed on a 1–9 scale (Table 1).
- Treatment HGH represented the positive control for each variety.
- LOW represented the negative control compared with all other treatments.
- Disease assessments were taken at least 2 weeks after disease inoculation and corresponding fungicide management treatment application.
- The Tamworth trial was scored on 17 August, 29 September and 25 October.
- The Trangie trial was scored on 13 September, 28 September and 27 October.
- The gross margin was calculated based on the PIRSA (Department of Primary Industries and Regions South Australia) gross margin for chickpea.

Table 1 Summary of AB disease scale.

No. score	Definition
1	Disease symptoms not detected
2	Leaf lesions on the lower canopy are rare, no leaf lesions on the upper canopy
3	Leaf lesions on the lower canopy are rare, leaf lesions on the upper canopy rare
4	Leaf lesions on the upper canopy common
5	Stem lesion rare, leaf lesions on upper canopy common
6	Stem lesions uncommon, leaf lesions on upper canopy common
7	Stem lesions common, leaf lesions on upper canopy common, stem breakage uncommon
8	Leaf and stem lesions are common but stem breakage has not occurred.
9	All plants are dead

Results

Disease severity

- The positive control (HGH) treatments for susceptible variety Kyabra⁽ᴾ⁾ scored the highest for disease severity at both Trangie and Tamworth.
- For the moderately susceptible varieties PBA HatTrick⁽ᴾ⁾ and PBA Seamer⁽ᴾ⁾ at Trangie, the highest scores were ≥8 and ≥3 respectively. The same varieties at Tamworth scored ≥4 and ≥3 respectively.
- At both Trangie and Tamworth there was little to no disease in the negative control (LOW) treatments (Figure 2).
- Overall, Trangie appeared to have consistently higher scores than Tamworth.
- Across treatments at both Trangie and Tamworth, Kyabra⁽ᴾ⁾ SDG2 had the highest scores with significantly higher disease severity than the negative control (LOW) treatment.
- At both Trangie and Tamworth, there was a significant difference between the Kyabra⁽ᴾ⁾ SDG1 and SDG2 treatments at all assessment timings with lower disease severity in the SDG1 treatment, which had a fungicide applied at the 2–3 node stage before inoculation at the 3–4 node stage.
- In all other treatments at Tamworth (apart from the SDG2), disease severity significantly decreased when compared with the control, except in PBA Seamer⁽ᴾ⁾.

- Disease severity was significantly higher than the negative control (LOW) in the Kyabra⌽ SDG1 treatments at both locations and all varieties in SDG2 and VEG treatments at Tamworth.
- Disease severity was significantly greater in Kyabra⌽ and HatTrick⌽ POD1 and POD2 treatments at Trangie and Kyabra⌽ POD1 and POD2 treatments at Tamworth compared with the negative control (LOW) at both locations.
- Disease severity also differed between HatTrick⌽ POD1 and POD1 at Trangie (Figure 2a).

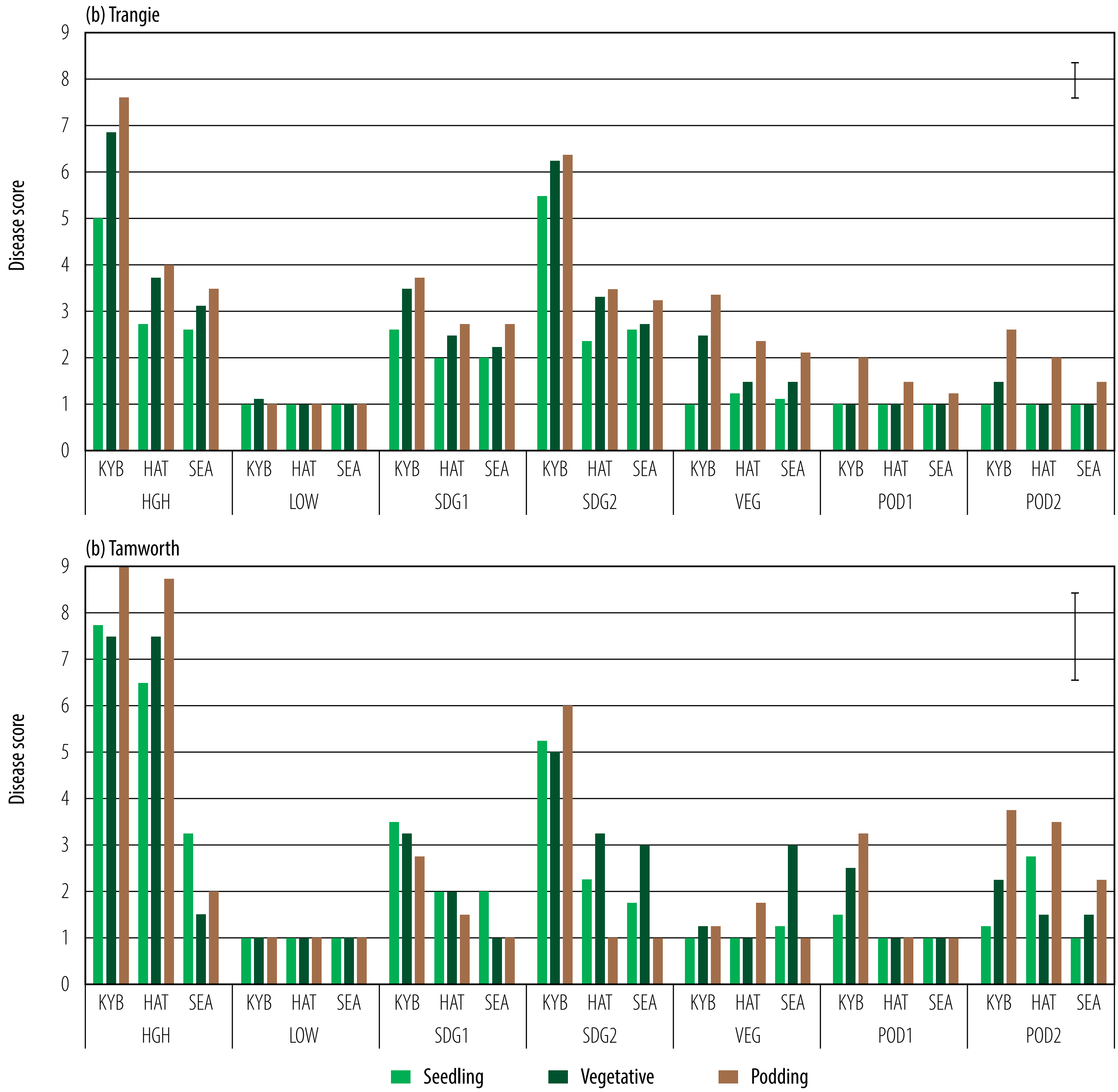

Figure 2 Ascochyta blight disease scores taken 2 weeks post seedling, vegetative and podding infection timings at (a) Trangie and (b) Tamworth in 2021.

Yield

Significant yield differences were recorded between negative control (LOW) and positive control (HGH) treatments at both Trangie and Tamworth.

In the positive control (HGH) treatments, there was a yield loss for Kyabra⌽, PBA HatTrick⌽ and PBA Seamer⌽ of 97%, 52% and 18% respectively at Trangie. Losses were similar at Tamworth with Kyabra⌽, PBA HatTrick⌽ and PBA Seamer⌽ at 97%, 60% and 36% when no fungicide was applied.

When SDG1 and SDG2 treatments were compared with the negative control (LOW) with no disease present, the greatest loss was SDG2 at 34% and 90% for Kyabra⟨ꟾ⟩ at Trangie and Tamworth respectively. This is compared with the moderately susceptible varieties PBA HatTrick⟨ꟾ⟩, which lost 3% (Trangie) and 36% (Tamworth) and PBA Seamer⟨ꟾ⟩ that lost 9% (Trangie) and 0% (Tamworth) of their yield to ascochyta infection.

This indicates that despite the disease scores, varieties with better resistance ratings will maintain yield when AB infection occurs. There were no differences in yield loss between the negative control (LOW) and VEG treatments.

At Trangie, there was a significant difference observed between the negative control, POD1, and POD2 for all varieties with losses of up to 18%, indicating that there could be benefits to applying fungicide at the early podding stage in a year with a predicted wet finish (Table 2).

Table 2 Effect of AB infection timing on grain yield (t/ha) at Trangie and Tamworth in 2021.

Treatment	Fungicide management strategy	Variety	Yield (t/ha)	
			Trangie	Tamworth
HGH	No fungicide	Kyabra	0.10	0.08
		PBA HatTrick	1.60	0.86
		PBA Seamer	2.80	1.22
LOW	Every rainfall	Kyabra	3.50	2.51
		PBA HatTrick	3.30	2.17
		PBA Seamer	3.40	1.92
SDG1	Before infection	Kyabra	3.40	1.45
		PBA HatTrick	3.00	1.90
		PBA Seamer	3.10	2.21
SDG2	After infection	Kyabra	2.30	0.25
		PBA HatTrick	3.20	1.38
		PBA Seamer	3.10	1.93
VEG	Before and after infection	Kyabra	3.50	2.01
		PBA HatTrick	3.10	1.80
		PBA Seamer	3.10	1.85
POD1	Before pod infection	Kyabra	3.60	1.86
		PBA HatTrick	3.10	2.17
		PBA Seamer	3.00	1.50
POD2	No fungicide	Kyabra	3.10	1.76
		PBA HatTrick	2.70	1.66
		PBA Seamer	3.00	1.78
P-value			<0.001	0.005
l.s.d ($P = 0.05$)			0.361	0.759

Gross margin (GM)

The greatest economic loss occurred at both locations when AB was not controlled at any growth stage (HGH) in the susceptible variety Kyabra⟨ꟾ⟩ (>$300/ha loss) (Table 3).

The greatest discrepancy in GM at both locations occurred in the susceptible variety Kyabra⟨ꟾ⟩ with a >$500 difference between SDG1 and SDG2 treatments. This is because Kyabra⟨ꟾ⟩ lacks plant defences against AB and required early protection as in SDG1 to maintain profit against disease.

Table 3 Collective effect of AB fungicide management strategies on GM across 2020 and 2021 at Trangie and Tamworth.

Treatment	Variety	Gross margin ($/ha)*		
		Trangie 2020	Trangie 2021	Tamworth 2021
HGH	Kyabra	–300	–334	–348
	PBA HatTrick	–160	413	42
	PBA Seamer	842	1010	221
LOW	Kyabra	701	1287	822
	PBA HatTrick	678	1187	653
	PBA Seamer	857	1237	527
SDG1	Kyabra	–	1237	292
	PBA HatTrick	–	1038	516
	PBA Seamer	–	1087	673
SDG2	Kyabra	–399	689	–305
	PBA HatTrick	174	1137	258
	PBA Seamer	843	1087	534
VEG	Kyabra	506	1301	690
	PBA HatTrick	518	1102	585
	PBA Seamer	934	1102	608
POD1	Kyabra	862	1365	496
	PBA HatTrick	765	1116	651
	PBA Seamer	898	1066	318
POD2	Kyabra	–	1159	490
	PBA HatTrick	–	959	440
	PBA Seamer	–	1109	500

* Gross margin based on December 2021 chickpea price of $498 per tonne, fungicide application cost of $14.25 per ha and other contributing production costs of $385.15 per ha; based on 2021 (PIRSA gross margin calculator for chickpea crops).

Conclusions

- The choice of a variety with improved AB resistance remains the most important tool for protection against yield loss in chickpea. Applying a fungicide at the seedling stage before the initial rain will have the greatest effect on reducing disease severity.
- Moderately susceptible varieties can maintain yield potential if that initial seedling fungicide application is missed, however, preventative fungicide should remain the primary control method.
- No conclusions can yet be made regarding AB infection at the vegetative growth stage.
- Fungicide application is recommended at early podding if AB is detected and wet seasonal conditions are predicted, to protect yield and reduce the risk of economic losses.

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Metalaxyl seed treatment reduces phytophthora root rot yield losses of chickpea under light to moderate disease pressure

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Key findings

- Metalaxyl seed treatment reduced phytophthora root rot (PRR) yield loss in chickpea in 3 of the 4 experiments in 2021.
- At the 3 sites with low to moderate PRR disease pressure, the minimum benefit of metalaxyl was close to 1 t/ha of grain.
- At a fourth site where the overland flow of water lead to high disease pressure, metalaxyl did not provide protection against PRR yield losses.

Introduction

Four experiments in the 2021 season aimed to compare the effect of metalaxyl seed treatment on PRR yield losses of 3 current commercial chickpea varieties and an advanced breeding line at 3 sites:

- Two at Trangie Agricultural Research Centre (TARC), Trangie with 2 differing soil types, a grey and a red vertosol.
- Australian Cotton Research Centre (ARCI), Narrabri with a grey vertosol.
- Piallamore, Tamworth, with a light textured brown alluvial soil.

This information will be used to update current PRR management recommendations for chickpea in the northern grains region.

Phytophthora root rot of chickpea is caused by *Phytophthora medicaginis*. Metalaxyl seed dressing is registered for *Phytophthora megasperma*, but not *P. medicaginis*. *P. medicaginis* was separated from a larger group of species that came under the name of *Phytophthora megasperma*. *P. megasperma* is considered mildly pathogenic to chickpea and can co-occur with *P. medicaginis* in chickpea paddocks. A metalaxyl seed dressing can be applied after the application of other seed dressings. Prior studies have shown that metalaxyl provides protection for about 8 weeks and that crops can still become infected and die later in the season if PRR infection occurs once this protection has worn off.

Site details

Location	Table 1 provides the location, sowing date, some basic soil characteristics and in-crop rainfall for the 4 experiments. Chickpeas had not been grown previously at any of the 4 experimental sites.
Fertiliser	60 kg/ha Granulock Z (N:P:S; 11:21.8:4) placed in-furrow with the seed.
Sowing rate	Target 35 plants/m^2.
Harvest date	• Main TARC – 14 December 2021 • Micks TARC – 14 December 2021 • ACRI Narrabri – 17 December 2021 • Piallamore – 6 January 2022

Table 1 Site location details and basic soil chemical characteristics for 4 experiments at TARC, Trangie, ARCI Narrabri and Piallamore in 2021.

Site	Main TARC	Micks TARC	ACRI, Narrabri	Piallamore
GPS co-ordinates	31°96'73.57" S 147°95'40.32" E	31°97'64.96" S 147°92'57.84" E	30°20' 28.84" S 149°59' 80.39" E	31°10' 1165" S 151°03' 351" E
Sowing date	2/6/21	2/6/21	29/7/21	13/8/21
In-crop rainfall, mm	360	360	351	457
Soil type	Grey vertosol	Red chromosol	Grey vertosol	Light textured brown alluvial
pH_{Ca}	7.6	5.6	6.5	6.2

Crop protection

Experiment design

- The PRR treatment was applied to main plots as a split plot design.
- Metalaxyl treatment and varieties were sub-plots.
- Four replicates.

Treatments

Metalaxyl seed and phytophthora treatments

All seed was treated with 360 g/L thiram and 200 g/L thiabendazole.

Seed was then treated with metalaxyl (+Met, 350 g/L metalaxyl-M, 75 mL/100kg seed) or a nil (–Met) treatment.

The PRR treatment was comprised of either:

- *P. medicaginis* inoculated (+Phyto) treatment, applied as an in-furrow application of a solution oospores and mycelium at sowing
- An uninoculated control (–Phyto) treatment.

The phytophthora treatment was comprised of blended *P. medicaginis* agar plates of 1500 oospores/seed at sowing of isolate TR7842.

Rhizobia (*Mesorhizobium ciceri*) was applied in-furrow at sowing.

Between each main split plot of a –Phyto and a +Phyto treatment, buffer plots of metalaxyl treated PBA Seamer⦻ were planted to prevent movement of *P. medicaginis* between treatments.

Extra, sacrifice plots, of +Phyto –Met and –Phyto +Met treatments were planted for each of the 4 varieties. Plants from these extra plots were dug and roots were assessed for PRR infection.

Varieties (4)

CBA Captain⦻, PBA Seamer⦻, Kyabra⦻ and CICA1328

Results

Establishment and PRR disease levels

At all 4 experiments establishment was successful. At the TARC Main site, there was evidence of the PRR inoculation affecting chickpea emergence.

There was a significant reduction in the plant density at the July assessment for the +Phyto –Met, but not for the +Phyto +Met treatment (Table 2).

The TARC Main site also had mice damage to emerging seedlings, but this was not significantly correlated with particular treatments.

The late planting at ACRI lead to assessments being later than the Trangie experiments. In none of the experiments were there any significant genotype effects on plant establishment.

In each of the experiments from the sacrifice plots, PRR lesions were observed on the roots of the +Phyto –Met treatments and isolates of *P. medicaginis* were successfully isolated (Figure 1). No PRR lesions were observed on the roots of samples from the –Phyto +Met treatment.

Figure 1 Kyabra[ⓓ] plots on 2 November for a) +Phyto + Met and b) + Phyto – Met treatments at ACRI.

For the final assessment for the TARC Main and ACRI experiments where PRR disease pressure was highest, there were significantly fewer healthy plants in the +Phyto –Met than the +Phyto +Met treatment (Table 2).

There were no significant variety effects or interactions in any of the 4 experiments for the plant assessments.

At the Micks TARC experiment, plant counts in September showed no significant (P>0.05) treatment effects. However, the development of late season PRR symptoms were observed in late October. Counts of symptomatic plants (dead plus chlorotic) provided a significant (P<0.05) PRR × metalaxyl × variety interaction (Table 3). The interaction was due to different variety responses, with CICA1328 having the lowest symptomatic plant counts. This did not differ significantly among the +Phyto –Met and +Phyto +Met treatments, whereas the ranking of the 3 other varieties differed in each of these treatments. Under the +Phyto +Met treatment, the counts of CICA1328 were lower than PBA Seamer[ⓓ] and counts for both CBA Captain[ⓓ] and Kyabra[ⓓ] were higher than PBA Seamer[ⓓ]. However, for the +Phyto –Met treatment CICA1328, and PBA Seamer[ⓓ] both had a lower number of infected plants than Kyabra[ⓓ] and CBA Captain[ⓓ].

The fourth experiment at Piallamore, the site was not flat and following heavy rains in September and October, water ran diagonally through approximately 50% of the plot areas. This carried *P. medicaginis* inoculum from some of the + PRR treated plots to some non-PRR treated plots. Large areas of the control plots had plants die from PRR and areas of + PRR treated plots that received the run-off water also quickly developed severe PRR disease (results not presented). Waterlogging effects may have also contributed to plant death in low lying areas.

Grain yield

In the 3 experiments there were significant yield increases (P<0.05) for the +PRR+Met treatments relative to the +PPR-Met treatments (Table 4). At the TARC main site, there was a large yield increase of 1.5 t/ha for the +Met treatment compared with the –Met treatment for the +Phyto treatments. There was, no significant yield benefit in the –PRR treatment where +Met was applied.

The same pattern for yield responses for this treatment was observed for the Micks TARC and ACRI Narrabri experiments, although the benefits of the +Met in the +Phyto treatments was lower at 0.9 to 1 t/ha.

Table 2 Early and final 2021 season healthy plant number (plants/m²) for the 3 experiments a) Main TARC, b) Micks TARC and c) ACRI Narrabri.

Experiment	Treatment	Healthy plants (number/m²)			
		−Phyto	+Phyto	−Phyto	+Phyto
		20 July		21 September	
a) Main TARC	−Met	29.8	15.3	28.6	9.1
	+Met	29.2	29.5	27.2	23.3
	LSD	6.89*		11.9*	
		20 July		20 September	
b) Micks TARC	−Met	29.4	28.8	28.0	24.2
	+Met	28.1	29.5	28.9	28.3
	LSD	3.63		2.40	
		2 September		1 November	
c) ACRI	−Met	36.5	37.8	36.4	15.5
	+Met	35.0	36.1	34.7	27.7
	LSD	2.45		9.91*	

*$P<0.05$

Table 3 Dead and chlorotic plant number (plants/m²) on 20 October for the phytophthora inoculation (−Phyto, +Phyto), metalaxyl (−Met, +Met) and chickpea genotype at Micks TARC experiment.

	Dead and chlorotic plants (number/m²)			
Genotype	−Phyto		+Phyto	
	−Met	+Met	−Met	+Met
CBA Captain	0	0	11.0	6.7
CICA1328	0	0	3.9	2.0
Kyabra	0	0	12.0	3.2
PBA Seamer	0	0	7.7	2.7
LSD	2.42			

*$P<0.05$

Table 4 Grain yield (t/ha) for 3 experiments for the PRR inoculation (−Phyto, +Phyto) and metalaxyl seed (−Met, +Met) treatments at a) Main TARC, b) Micks TARC and c) ACRI.

Experiment	Treatment	Grain yield (t/ha)	
		−Phyto	+Phyto
a) Main TARC	−Met	4.03	1.33
	+Met	3.85	2.84
	LSD	0.818*	
b) Micks TARC	−Met	3.60	2.68
	+Met	3.58	3.66
	LSD	0.195*	
c) ACRI Narrabri	−Met	2.37	1.38
	+Met	2.26	2.29
	LSD	0.394*	

*$P<0.05$

Similarity to the plant count results, only in one experiment, Micks TARC, was there a significant (P<0.05) yield interaction with variety (Table 5). This interaction was largely due to CICA1328 having a lower yield potential than other varieties in absence of PRR. In addition, CICA1328, which had the highest level of PRR resistance, did not have yields reduced by the presence of PRR. The other differential variety effect was for Kyabra⁽ᴰ⁾ to have a significantly lower yield in the presence of PRR if not protected with metalaxyl compared with other varieties.

Table 5 Grain yield (t/ha) for the PRR inoculation (–Phyto, +Phyto), metalaxyl (–Met, +Met) and chickpea genotype at the Micks TARC.

Genotype	Grain yield (t/ha)			
	−Phyto		+Phyto	
	−Met	+Met	−Met	+Met
CBA Captain	3.95	3.82	2.73	3.86
CICA1328	3.06	3.22	3.03	3.32
Kyabra	3.69	3.66	2.17	3.68
PBA Seamer	3.70	3.63	2.82	3.79
LSD	0.297*			

*P<0.05

For the Piallamore experiment that received the overland water flow containing *P. medicaginis* inoculum across both the control and +Phyto treatments, the results could not be analysed as all treatments had been confounded. However, the grain yields from–Phyto +Met plots which received the overland PRR inoculum showed that the metalaxyl was not able to prevent substantial yield losses from PRR across all varieties.

Conclusions

The 4 experiments experienced a range of PRR disease pressure as indicated by the counts of healthy plants. At the late sown site in Piallamore where water containing *P. medicaginis* inoculum flowed across the site in September and October, results showed that a metalxyl seed could not protect any of the varieties tested from severe PRR yield losses.

For the three experiments where the overland water flow did not occur and there was low to moderate PRR disease pressure, yield benefits from the metalxyl seed treatments were demonstrated. These experiments showed that early season protection provided by metalaxyl seed treatment can lead to improved yields, when severe PRR does not occur following the early season protection period.

The benefit of chickpea varieties with improved PRR disease resistance proved effective only at the site, Micks TARC, with the lowest PRR disease pressure.

Metalaxyl seed treatment can provide reduced PRR yield losses under conditions where there is low to moderate levels of PRR disease pressure.

Acknowledgements

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Optimising sorghum production, Breeza 2020–21

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Key findings

- Establishing sorghum at soil temperatures cooler than the commercial standard of 16–18 °C, is a viable option to move flowering and grain fill periods earlier. This helps to avoid heat and moisture stress at flowering and grain fill.
- Targeting soil temperatures of greater than 12 °C for 7 days after planting, and planting into good seedbed moisture, are critical for even establishment when choosing to plant early.
- In this experiment, plant establishment was close to the target population, however, soil temperatures were also warmer than normal for the first planting date (PD1; 16 September) at 16.2 °C.
- Early planting results in slower crop development. PD1 was the slowest to reach 50% flowering (average 79 days) but still flowered 4–5 weeks earlier than PD3 (early December compared with early to mid January).
- Early planting results in higher tillering and more fertile tillers than planting at the normal (PD3) time.
- While we found plant growth differences, there was no yield effects between planting dates in this experiment.

Summer crops

Key words sorghum, Breeza, 2020, 2021, soil temperature, early planting

Introduction

Dryland grain sorghum production is driven by the need to produce high yields to obtain positive gross margins for growers. One of the major limiting factors to achieving reliability and increasing sorghum yields, is the combination of hot temperatures and moisture stress These conditions often occur during flowering and grain fill for crops planted in the traditional late October to the end of November window on the Liverpool Plains. This planting window is based on targeting the recommended soil temperatures of 16–18 °C for planting and avoiding frosts in the early growth stages.

Alternative, earlier planting times, have been proposed through this research, where soil temperatures at planting could be as low as 12 °C. This research aims to develop knowledge about how early growers can start planting, what levels of tolerance different hybrids have to cold soils, and seedling tolerance to frosts.

Two sites were harvested in the 2020–21 season: a dryland experiment at Breeza on the Liverpool plains and a dryland site at Bogamildi, north of Moree. Two other dryland sites were planted at Bullawarrie north of Mungindi and Morialta south of Mungindi, but were abandoned due to mice damage.

Site details

Location:	Liverpool Plains Field Station, Breeza. 31° 10′ 52.3″ S, 150° 25′ 55.0″ E.
Co-operator:	NSW DPI, Liverpool Plains Field Station Breeza.

Soil type and nutrition

The site was cored for starting nutrition level (Table 1) and was found to have 173 kg/ha of mineral nitrogen (N).

Table 1 Site soil chemical characteristics.

Characteristic	Depth (cm)				
	0–10	10–30	30–60	60–90	90–120
pH_{Ca}	7.8	8.1	8.2	8.2	8.5
Nitrate N (mg/kg)	11	14	21	14	5
Sulfur (mg/kg)	1.6	5.7	16.5	19.3	30.4
Phosphorus (Colwell) (mg/kg)	46	29	22	30	37
Organic carbon (OC) (%)	1.33	1.00	0.74	0.56	0.43

Starting soil water and rainfall

The site was soil cored after each planting date (PD) to measure starting plant available water (PAW) to 1.2 m deep. The PAW was measured as:

- PD1: 157.6 mm
- PD2: 151.7 mm
- PD3: 148.8 mm.

A total of 450 mm of in-crop rainfall was recorded at the site between September 2020 and March 2021 (Table 2).

Planting date 1 received 431.1 mm, while PD2 received 415.3 mm and PD3 received substantially less in-crop rain of 310.9 mm.

Seasonal conditions

- The site started with a reasonably good soil moisture profile and was supplemented by above average in-crop rain.
- Soil temperatures were very warm for PD1 and averaged 14.9 °C at 8 am over the following 7 days.
- A small rainfall event followed each planting date, which helped to ensure that seedbed moisture was not limiting.
- It was drier during November with only 15 mm of rain. This was combined with a heat wave in late November where temperatures reached close to 40 °C for several days.
- The rainfall in late December was excellent, benefiting both PD1 and PD2, which were both at grain fill by this time. PD 3 flowered in early–mid January and received only 20 mm of rain during this period.

Fertiliser

- Granulock Z @ 43 kg/ha, applied to all plots at planting.
- Urea @ 116 kg/ha, applied at planting.

Desiccation and harvest

- PD1: desiccated 19 February; harvested 2 March 2021
- PD2: desiccated 19 February harvested 2 March 2021
- PD3: desiccated 3 March; harvested 10 March 2021.

Table 2 In-crop rainfall in 2020–21 and long-term average rainfall at Breeza.

	Rainfall (mm)							
Month	September	October	November	December	January	February	March	Total
2020–21	10.6	128.6	15.0	150.1	19.4	126.4	88.8	538.9
Long-term average	42.5	51.8	68.1	75.4	84.6	69.6	45.0	437.0

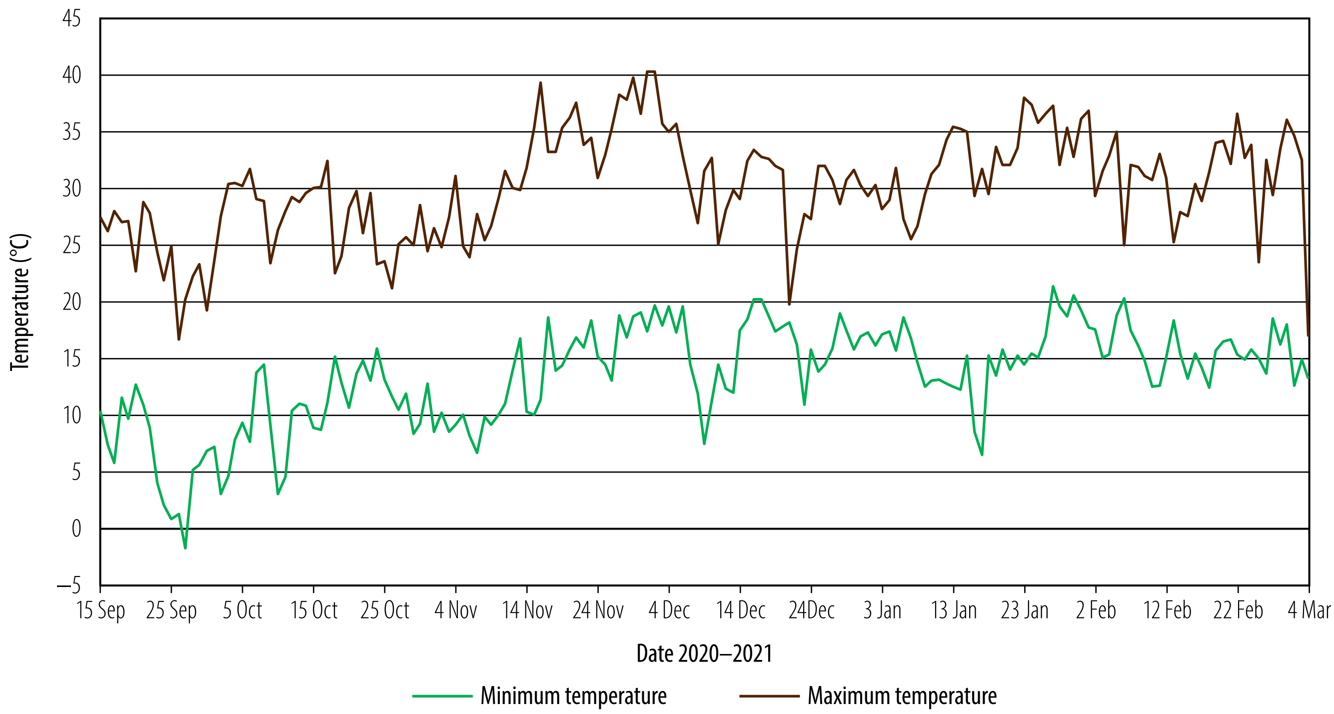

Figure 1 Maximum and minimum temperatures at Breeza during 2020–21.

Treatments

Planting date and soil temperatures

- PD1: 16 September; soil temperatures 16.2 °C at 8 am for 7 days after planting
- PD2: 6 October; soil temperatures 19.4 °C at 8 am for 7 days after planting
- PD3: 3 November; soil temperatures 20.1 °C at 8 am for 7 days after planting.

Hybrids (10)

MR Buster, MR Bazley, MR Taurus, G33, HGS114, Cracka, Agitator, A66, Sentinel IG, A75.

Target plant populations (4)

- 3 plants/m^2 (30,000 plants/ha)
- 6 plants/m^2 (60,000 plants/ha)
- 9 plants/m^2 (90,000 plants/ha)
- 12 plants/m^2 (120,000 plants/ha).

Experiment design

- Split, split plot design with PD as the main block, then blocked for plant density.
- Hybrids randomised.
- 100 cm solid plant rows.

Results

Plant establishment

The established plant population at Breeza was close to the target plant population for most hybrids (Figure 2). A66, Cracka and MR Taurus had lower plant establishment compared with the other hybrids, establishing fewer plants than the target for all populations.

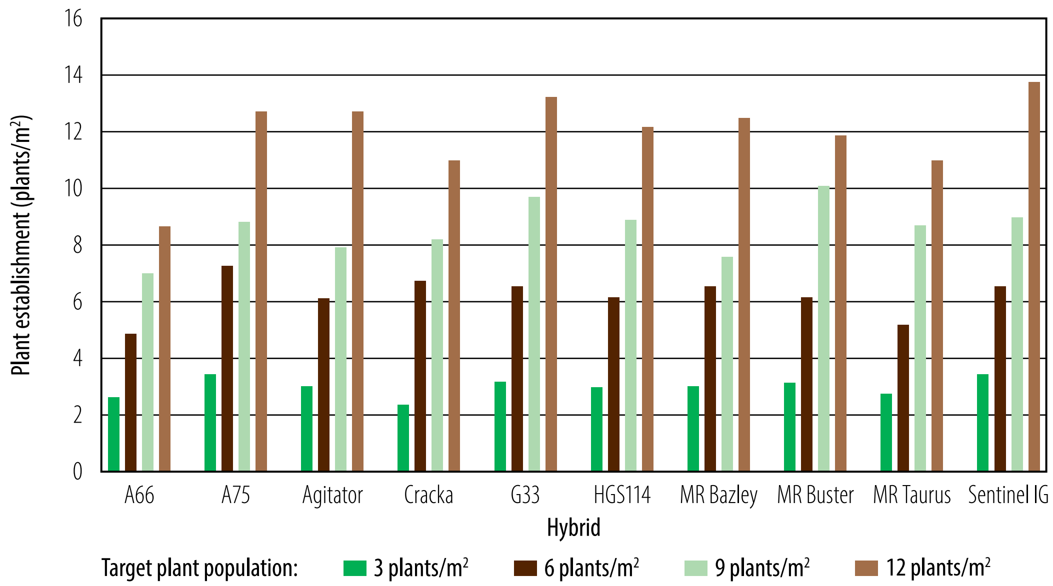

Figure 2 Actual plant establishment at Breeza in 20/21 compared to the target population.

Tiller production

Fewer tillers were produced as the planting date was delayed (Figure 3a) and fewer were fertile (Figure 3b). The largest reduction in tillering was between PD2 and PD3. There was no difference fertile tiller production between PD1 and PD2, but the reduced number of fertile tillers for PD3 was significant.

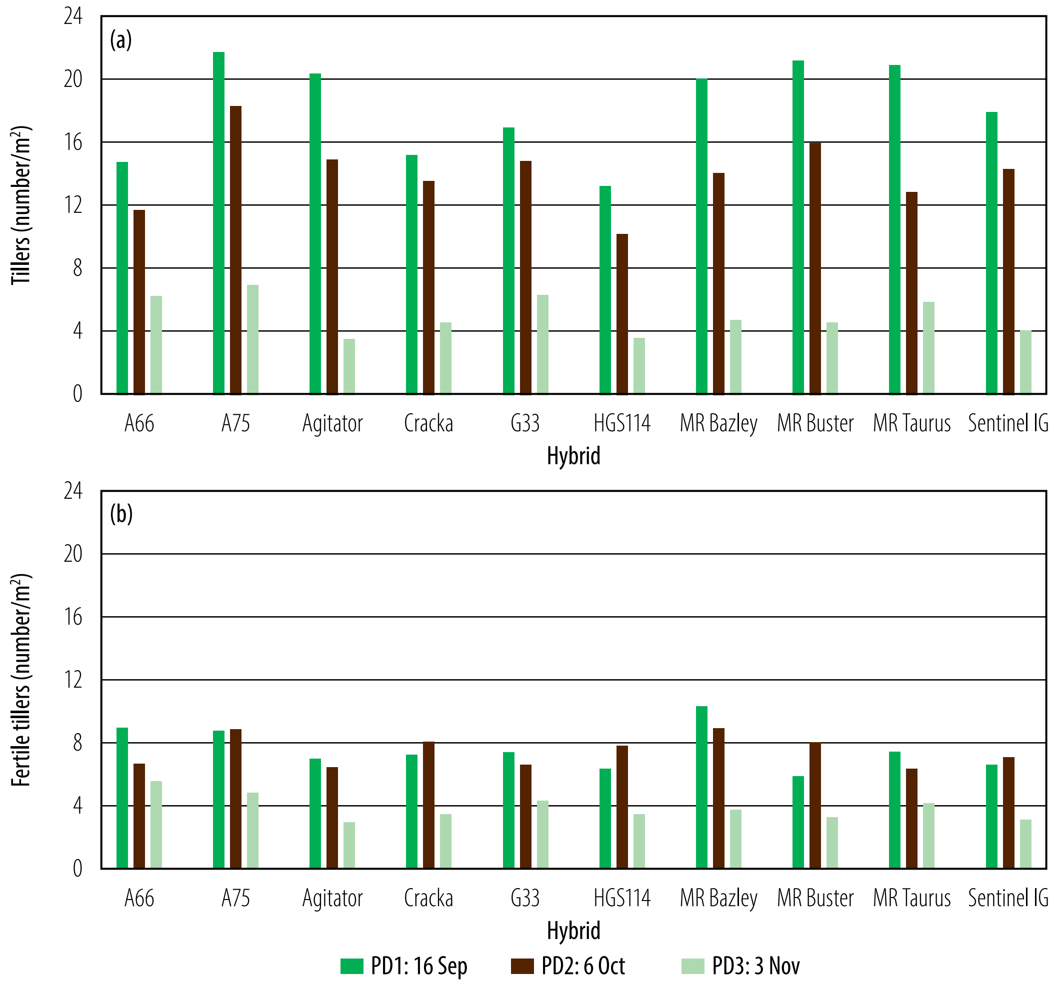

Figure 3 (a) Total tiller production (/m^2), and (b) Fertile tiller production (/m^2) across hybrids and planting dates.

Increasing plant population reduced the number of fertile tillers/m^2. The largest reduction in fertile tillers was in response to increasing the plant population from 9 plants/m^2 to12 plants/m^2 (Figure 4). Fewer fertile tillers tends to occur as more plants with primary heads are being grown in the same space. Competition for light and nutrients means fewer tillers can survive to become fertile.

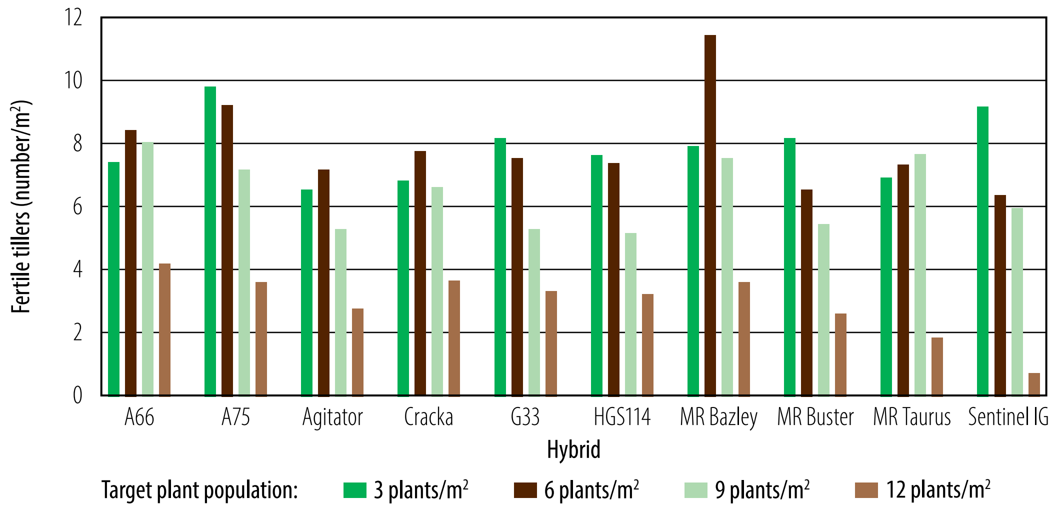

Figure 4 Fertile tiller number reduces in response to increasing plant population.

Head production

Plant population had a strong effect on the number of heads produced per square metre with lower populations producing fewer heads for all hybrids. The difference between head production was less obvious when comparing the 9 plants/m^2 and 12 plants/m^2 populations (Figure 5).

Planting date also influenced head production, with less heads produced as planting date was delayed.

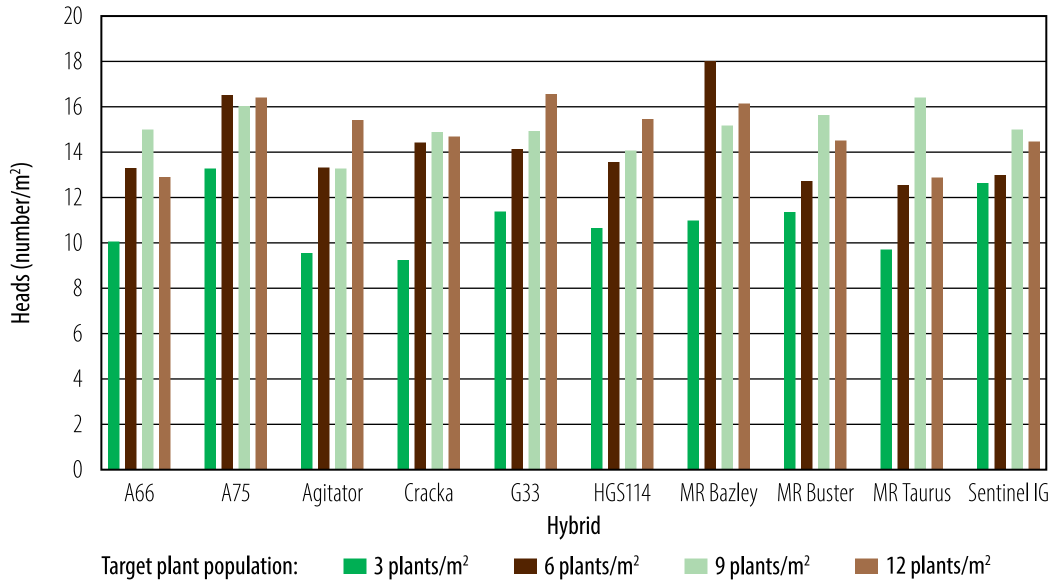

Figure 5 Plant population and hybrid interactions with head production.

Days to 50% flowering

Planting earlier means the crop is growing in cooler temperatures and so it takes more days to reach 50% flowering. In this experiment it took on average of 79 days for PD1, 73 days for PD2 and 69 days for PD3 to reach 50% flowering.

There was also an interaction between planting date and hybrid. There was a difference of 5 days between the quickest hybrid, Agitator, at 77 days and the slowest hybrid, HGS114 at 82 days to reach 50% flowering from PD1 (Figure 6). All hybrids were quicker to reach flowering from PD3. Some of the hybrids such as HGS114 became quicker relative to the other hybrids as the planting date was delayed, showing some flex in the hybrid's maturity. There was also a response to plant population, with higher plant populations reaching 50% flowering quicker (data not shown).

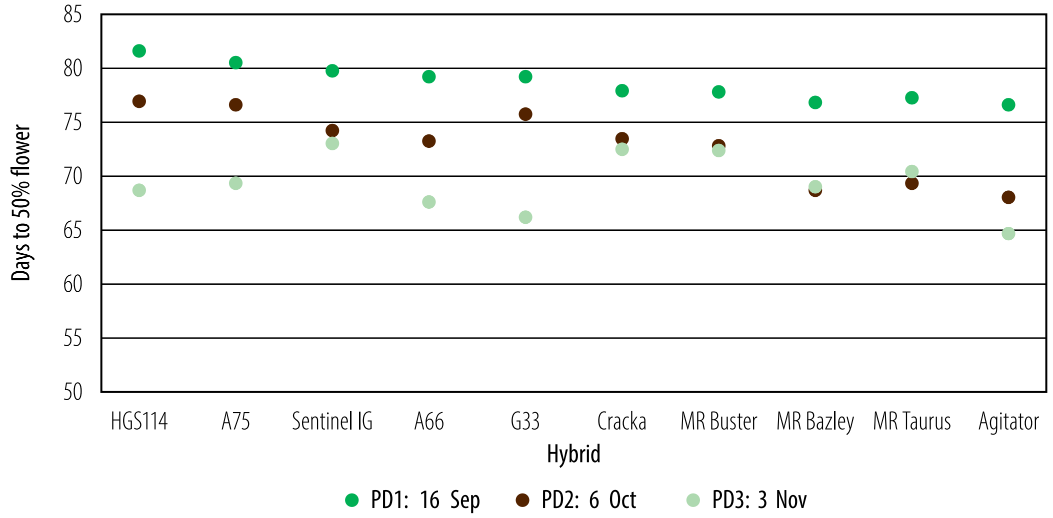

Figure 6 Days to 50% flowering for planting date.

Dry matter (DM) production

Planting date influenced DM production. More biomass was produced as the planting date was delayed, however the difference was only statistically valid between PD1 and PD3.

There was a significant response between planting date and plant population. Biomass production was highest from PD3, but statistical differences between plant populations were not evident (data not shown).

There were differences in DM production between hybrids. The most notable was for Agitator and Cracka, which produced the least DM, compared with Sentinel IG, A66, HGS114, A75 and G33, which produced the most biomass (data not shown).

Harvest index

Harvest index (HI) is a measure of efficiency within the plant. The ratio compares the amount of grain produced with the amount of biomass produced. In this experiment, the samples collected to measure the DM production were separated into primary and tiller stems for each sample, then heads were removed and threshed to obtain the HI. Samples were partitioned to compare the contribution of primary heads versus tillers to final grain yield.

Varying plant population on the primary stem had no effect on HI, however, there was an interaction between PD and hybrid. In Figure 7 below, the hybrids have been ordered from highest HI to lowest. MR Buster had high primary stem harvest index at all 3 PDs; HGS 114 also showed a similar response. In contrast, hybrids such as the quick maturity Agitator had the lowest HI at PD1, but was one of the highest for PD2 and PD3. There was not a linear response to PD; the response varied depending on the hybrid.

The HI was lower for tillers at all PD's, ranging between 17–40% (Figure 7) compared with 38–54 % for the primary stems; this was hybrid dependent. There was also a lot more separation between the PD's for their HI. PD2 had a higher harvest index for most hybrids (data not shown).

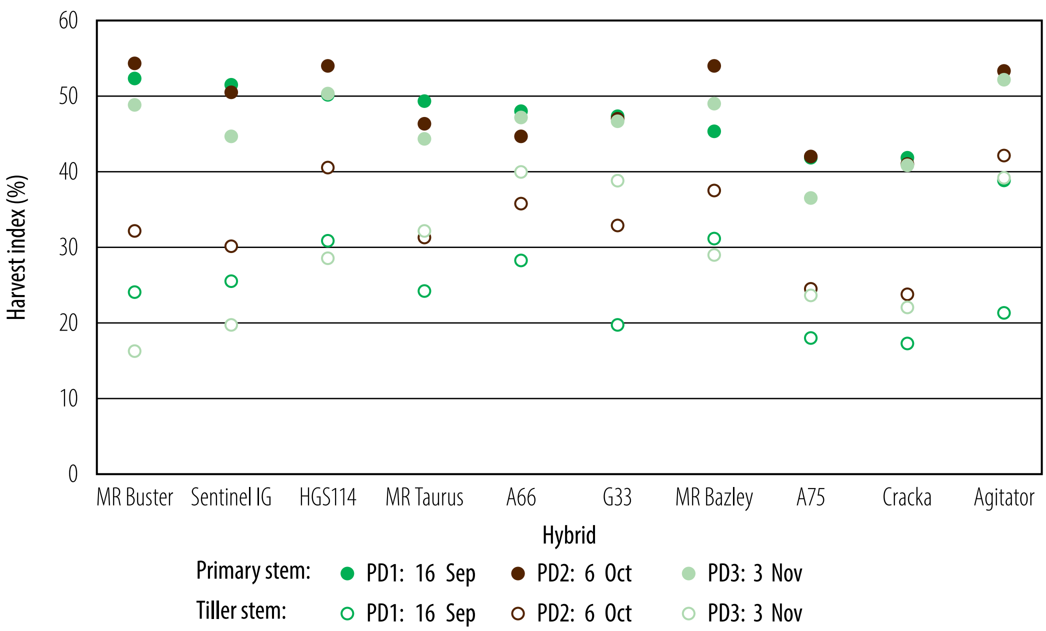

Figure 7 Interaction between planting date and hybrid on (a) primary stem and (b) tiller stem harvest index.

Grain yield

The site mean yield was 4.6 t/ha at the receival standard moisture content of 13.5%. There was an interaction between plant population and hybrid, and between planting date and hybrid, for grain yield.

Planting date did not significantly affect yield for most hybrids (Figure 8). A small number of hybrids such as HGS114 showed clear differences between planting dates, for example, HGS114 at PD2 was higher yielding than PD1 and PD3, and Agitator yielded less for PD1 than for PD2 and PD3.

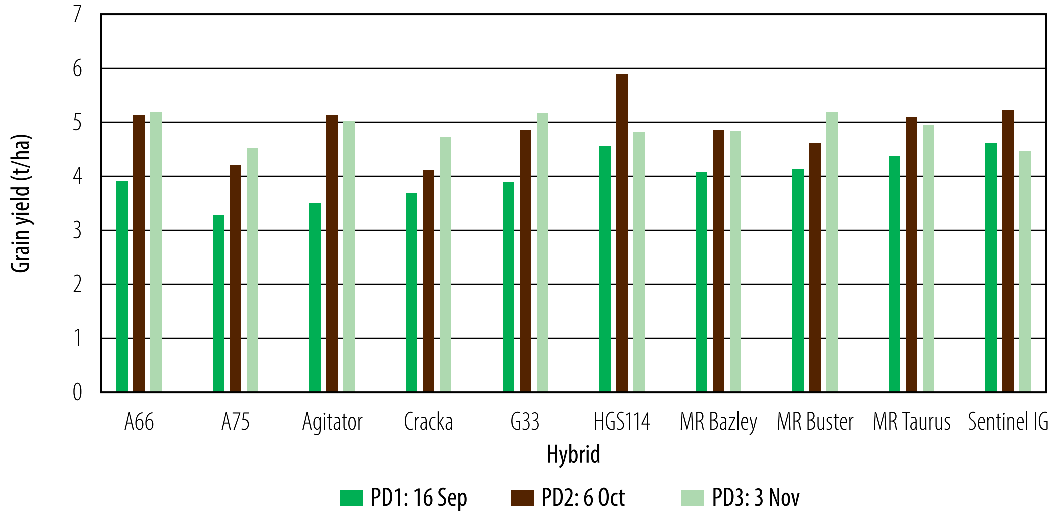

Figure 8 Planting date and hybrid influenced grain yield (at 13.5% moisture) in 2020–21.

Plant population influenced hybrid yields. Like the varied response between hybrids for planting date, some hybrids were affected by varying plant population while others were not (Figure 9). G33, A66, Agitator and MR Bazley were not responsive to varying plant population (Figure 9). In contrast MR Buster and Sentinel IG had lower yields from the lowest plant population of 3 plants/m^2 (Figure 9).

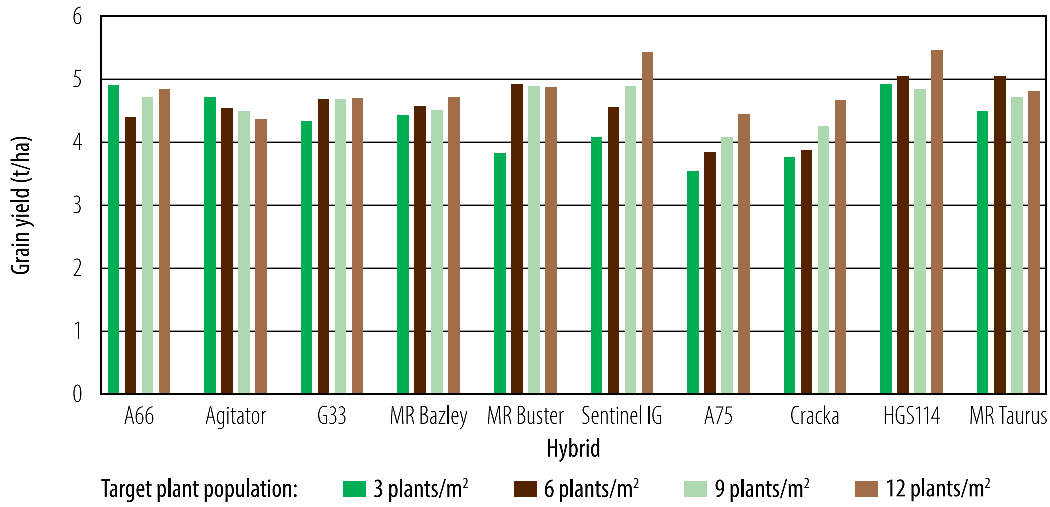

Figure 9 Grain yield (at 13.5% moisture) was influenced by plant population and hybrid.

Grain quality

Grain protein (GP)

The primary interest in GP in sorghum is as an indicator of N deficiency, which limits yield. There is not a receival standard for GP in sorghum as it is primarily sold into the stockfeed market. The average grain protein content was 11.9% in this experiment. This indicates that N was not limiting yield.

There was an interaction between plant population and hybrid, although the response varied between hybrids. A75 and HGS114 were not responsive to varying plant population, even though A75 produced some of the highest protein contents and HGS114 some of the lowest. Several other hybrids had declining protein contents as the plant population increased, such as Sentinel IG and Cracka (Figure 10).

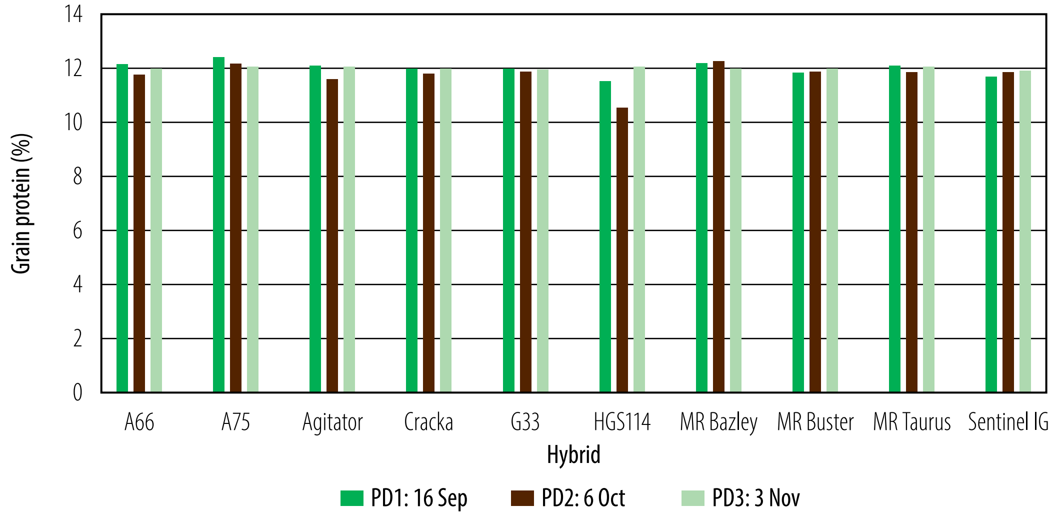

Figure 10 Response to varying plant population of 10 hybrids.

Test weight

Test weights averaged 67.14 kg/hL, with most of the treatments below the limit to be classified as Grade 1 sorghum (>71 kg/hL). There was a strong response to planting date, with PD2 producing the highest test weights (Figure 11).

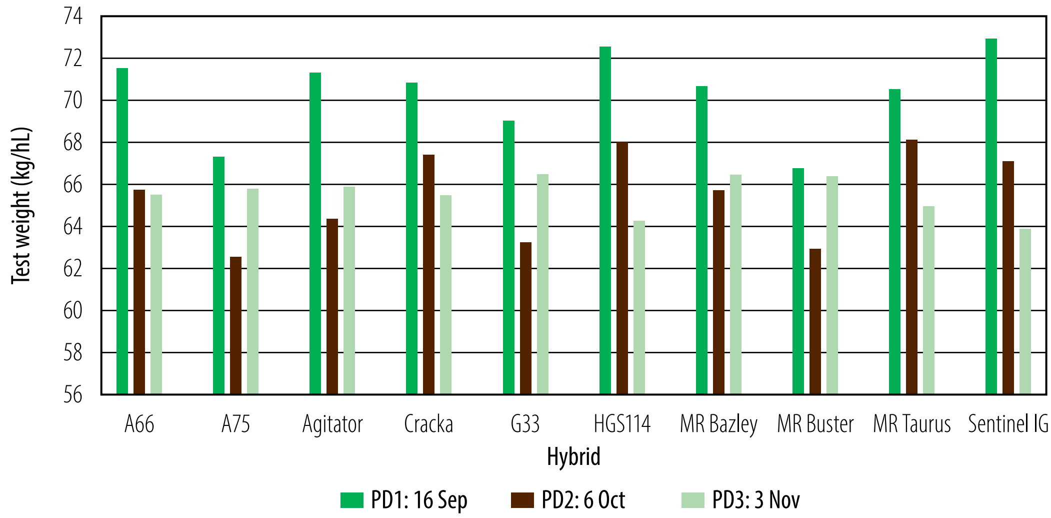

Figure 11 Response to varying planting date of grain test weight.

Screenings

The average screenings level was 3.6%, which is acceptable for delivery into Sorghum 1grade. The strongest response was to planting date, whereby screenings reduced as planting date was delayed (data not shown).

Thousand grain weight

The thousand grain weight averaged 32.8 grams. Thousand grain weight increased as planting date was delayed. There was also an effect as plant population increased (data not shown).

Conclusions

Planting sorghum early (mid September) at Breeza in 2020–21 produced a uniform plant stand, close to the targeted plant populations. In this season, soil temperatures were warmer than normal for PD1.

Planting early increased the number of days taken to reach 50% flowering, compared with a normal November planting. However, PD1 resulted in the crop flowering in early December, compared with flowering in early to mid January for PD3.

Early planting produces more tillers, and a higher number of those tillers are retained to become fertile tillers that continue to become grain-producing heads.

Grain yield responses to planting date depended on hybrid and plant population. A small number of hybrids showed clear yield responses to planting date for example HGS114 and Agitator. Overall, the response to planting date was not consistent. Similarly, plant population did not consistently affect hybrid yields.

The variation in hybrid responses to planting date and plant population in this experiment reinforces the importance of matching the optimum management, agronomy, and hybrid combinations in every paddock to obtain the maximum yield. The challenge continues to identify these optimum combinations in each local area.

The 2021–22 season will present an opportunity to further investigate the effect of earlier planting on other crop factors such as in-crop water use and crop development stages.

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Gross margin analysis: spring planted soybean variety Gwydir⁽ᴾ⁾, Nunderi 2021–22

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Key findings

- The Gwydir⁽ᴾ⁾ soybean crop was planted on 6 September 2021 and yielded 4.91 t/ha with a grain protein (GP) concentration of 44% dry matter (DM) basis.
- The crop gross margin (GM) was $2026/ha.
- Significant weathering damage occurred due to above average rainfall and higher average temperatures in February, resulting in a lower grain price.
- Compared with traditional December planting dates, this spring planted Gwydir⁽ᴾ⁾ crop had a longer vegetative growth phase, however, this did not result in excessive plant biomass, plant height or lodging.
- A second crop of soybean (variety Hayman⁽ᴾ⁾) was planted on 11 February 2022, immediately after the crop of Gwydir⁽ᴾ⁾ was harvested, however, it was lost due to flooding on 28 February.
- The risk factors for soybean crops planted 4–8 weeks before the start of the traditional coastal planting window include:
  - inadequate soil moisture to establish dryland crops
  - slower germination and emergence due to cold soil temperatures
  - early incursions of insect pests particularly pod sucking bugs
  - the potential for leaf diseases such as powdery mildew or soybean leaf rust to develop during cooler spring conditions.
- This experiment tested the potential to plant 2 soybean crops in the spring and summer sugarcane fallow period, boosting income and grain production and providing benefits to the cane farming system including nitrogen fixation and weed control.

Keywords soybean, spring, Nunderi, pest, disease, soil moisture, gross margin, 2021, coastal, sugar cane

Introduction

The soybean variety Gwydir⁽ᴾ⁾ was bred by the Australian Soybean Breeding Program (ASBP) and has shown potential for producing high yields from early planting dates in previous experiments conducted at NSW DPI, Grafton. In an experiment planted at Grafton on 8 September 2020, Gwydir⁽ᴾ⁾ yielded 5.79 t/ha, which was significantly higher than other varieties evaluated including the industry standards Richmond (5.01 t/ha) and Moonbi (3.97 t/ha, lsd 0.58).

To further investigate the potential of this variety, a Gwydir⁽ᴾ⁾ was planted by soybean growers Mark and Beverly North at Nunderi, NSW as an initiative of the NSW DPI and GRDC project Soybean expansion in high rainfall zones of northern NSW. A complete GM analysis was conducted on the crop.

Summer crops

Immediately following harvest, a second crop of soybean was planted to assess the ability for coastal sugarcane farming systems to produce 2 soybean crops in the sugarcane fallow period between September and June, using varieties suited to very early and very late planting dates.

Site details

Location	Clothiers Creek Road, Nunderi, NSW 2484 Latitude 28° 18′ 48.95″ S, Longitude 153° 27′ 9.12″ E
Paddock history	• The site had been cropped to sugar cane for the previous 6 years. • Raised beds on 1.9m wheel spacings.
Soil type and nutrition	• Light peat with high levels of organic matter. • Table 1 details the oil analysis for the 0–20 cm depth.
Temperature and rainfall	A total of 1853 mm of rain was received during the growing season, which was 964 mm more than the long-term average (889 mm) for the same period (Figure 1). The growing degree day (GDD) calculation from planting to harvest was 1677.9 °C days (using a base of 10 °C).

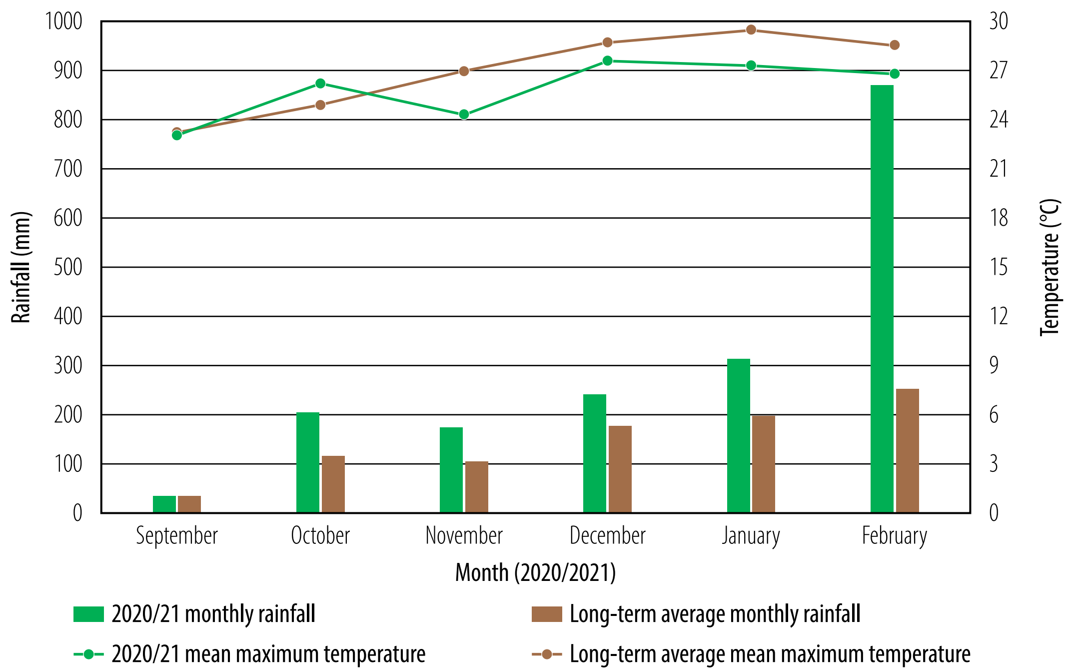

Figure 1 Temperature and rainfall for the 2021–22 growing season compared with long-term averages at Murwillumbah NSW.

Planting date	6 September 2021.
Fertiliser	• Lime broadcast at 5 t/ha. • Mill mud banded at 70 t/ha (Sunshine Sugar nutrient analysis: 230 kg/ha N, 161 kg/ha P, 35 kg/ha K, 21 kg/ha S, 336 kg/ha Ca, 56 kg/ha Mg).
Plant population	• Target establishment 300,000 plants/ha • Established population 317,000 plants/ha.

Weed management	Pre-emergent application of Roundup® 1 L/ha (540 g/L glyphosate) and Dual Gold® 1 L/ha (960 g/L S-metolachlor).
Insect management	Decis Options® (27.5 g/L deltamethrin) @ 500 mL/ha to control soybean looper and red-banded shield bug.
Harvest date	11 February 2022.

Table 1 Soil chemical analysis of the experiment site at Nunderi, NSW.

Characteristic/analyte	Unit	Soil depth 0–20 cm
pH_{Ca}	pH units	4.9
pH (Water)	pH units	5.9
Electrical conductivity	dS/m	0.06
Sulfur (KCl 40)	mg/kg	14.0
Bray phosphorus (P)	mg/kg	140.0
Colwell P	mg/kg	85.0
Phosphorus buffer index		390.0
Organic carbon	%	2.5
KCl extractable ammonium-N	mg/kg	7.8
KCl extractable nitrate-N	mg/kg	36.1
Total nitrogen	%	0.2
Chloride	mg/kg	10.0
Boron	mg/kg	0.6
DTPA Cu	mg/kg	1.9
DTPA Zn	mg/kg	1.9
DTPA Mn	mg/kg	9.5
DTPA Fe	mg/kg	210.0
Exchangeable aluminium (Al)	cmol(+)/kg	0.8
Exchangeable calcium (Ca)	cmol(+)/kg	7.8
Exchangeable potassium (K)	cmol(+)/kg	0.6
Exchangeable magnesium (Mg)	cmol(+)/kg	2.5
Exchangeable sodium (Na)	cmol(+)/kg	0.2
CEC	cmol(+)/kg	11.9
Calcium/magnesium	%	1.8
Aluminium saturation	%	8.3
Exchangeable Ca	%	64.0
Exchangeable K	%	5.2
Exchangeable Mg	%	20.8
Exchangeable Na	%	1.4

Results

Yield and grain protein

The Gwydir⁽ᴾ⁾ crop yielded 4.91 t/ha with an average GP concentration of 44% (DM basis). This yield is comparable with the Gwydir⁽ᴾ⁾ planted in NSW DPI experiments in September 2020–21 where it yielded 5.79 t/ha. To be considered as a benchmark for yield comparisons, commercial varieties used by the ASBP must yield 4.0 t/ha or above in this environment.

Although grain quality was compromised due to extended rain periods, these yield results are promising and can potentially significantly increase the planting window and profitability for coastal soybean growers in NSW. A second crop of Hayman$^{\Phi}$ was planted the same day that the Gwydir$^{\Phi}$ crop was harvested, but was subsequently lost due to flooding.

Observed changes in growth

Early planted soybean crops have slower germination and emergence due to colder soil temperatures. The grower, Mark North, observed that Gwydir$^{\Phi}$ emerged at 10 days after planting (DAP) compared with 5–7 DAP for soybean planted at the traditional December date.

Gwydir$^{\Phi}$ had both longer vegetative and reproductive phases compared with long-term ASBP data for early December plantings. From the planting date of 6 September, Gwydir$^{\Phi}$ took 157 days to reach physiological maturity (P95 stage), compared with the long-term average of 132 days when planted in early December at Grafton (ASBP data).

The September-planted Gwydir$^{\Phi}$ at Nunderi grew to 50.4 cm in height, compared with the long-term average of 75.4 cm for Gwydir$^{\Phi}$ planted in early December at Grafton (ASBP data).

Plant biomass was not measured, but the earlier planting date resulted in a lower plant height and overall shoot biomass compared with observations of Gwydir$^{\Phi}$ crops planted in early December. This could be due to a lack of heat during the vegetive phase, in particular November, which had lower than average temperatures (Figure 1). Further measurement of growing degree days could help to explain these effects. The lower plant height and biomass did not adversely affect yield (Figure 2).

Figure 2 Soybean variety Gwydir$^{\Phi}$ planted on 6 September 2021. Photo taken 53 days after planting.

Gross margin analysis

Table 2 details the full GM analysis of this crop. The total crop GM was $2026/ha for crushing grade ($600/t).

Table 2 Gross margin analysis of soybean variety Gwydir, Mark and Beverly North, Nunderi, NSW.

Soybean gross margin analysis – NSW DPI Grafton									
Crop: Soybean variety Gwydir⑷				**Location: Nunderi, NSW**				**Date: 2021–22**	
Income/ha:				$600 /tonne		Crushing grade			2,946.00
Grain	4 .91 t/ha @			$750 /tonne		Edible grade			
A. Total income $/ha									**2,946.00**
Variable costs/ha:		**Machinery ex-GST**			**Inputs ex-GST**				**Total Cost $/ha**
Operation	**Date**	**Hrs/ha**	**Cost $/hour**	**Total $/ha**	**Rate /ha**	**Unit**	**Cost $/unit**	**Total $/ha**	
Pre-sowing operations									
Broadcast lime	24 Jun 2021	0.96	19.13	19.13	5.0		120.00	15.00	**34.13**
Banded mill mud	28 Jun 2021	0.96	19.13	19.13	120.0	kg		50.00	**69.13**
Rotary hoe	1 Aug 2021	1.20	35.00	35.00					**35.00**
Zonal rip	5 Aug 2021	1.20	35.00	35.00					**35.00**
Zonal rip	7 Aug 2021	1.20	35.00	35.00					**35.00**
Rotary hoe	10 Aug 2021	1.20	35.00	35.00					**35.00**
Bedform	20 Aug 2021	1.20	35.00	35.00					**35.00**
Sowing									
Gwydir⑷ soybean seed	6 Sep 2021	0.35	22.87	7.94	70.00	kg	1.50	105.00	**112.94**
Inoculant	6 Sep 2021	with above							
In-crop plant protection (herbicide, insecticide, fungicide)									
Pre-emergent: Dual Gold	7 Sep 2021	0.14	20.17	2.80	1.50	L	19.09	28.64	**31.44**
Pre-em: Broadstrike	7 Sep 2021	0.14	20.17	2.80	0.025	kg	440.00	11.00	**13.80**
Pre-em: Gramoxone	7 Sep 2021	0.14	20.17	2.80	1.00	L	11.50	11.50	**14.30**
Post-em: Verdict	8 Oct 2021	0.14	20.17	2.80	0.15	L	57.27	8.59	**11.39**
Post-em: Spinnaker 700 WG	11 Oct 2021	0.14	20.17	2.80	0.14	kg	105.00	14.70	**17.50**
Insecticide: Decis	29 Nov 2021	0.14	20.17	2.80	0.50	L	12.50	6.25	**9.05**
Pre-harvest: Reglone	5 Feb 2021	0.14	20.17	2.80	2.80	L	20.00	56.00	**58.80**
Contract harvesting – minimum rate per ha per ha							172.73	per ha	**172.73**
plus increment for higher yields greater than			0.00	t/ha @			–	per 100 kg	**0.00**
plus fuel			–	L/ha @			–	per L	**0.00**
or own plant			–	ha/hr @			–	per hour	**0.00**
Costs related to income	Your notes								
Levies	http://www.agriculture.gov.au/ag-farm-food/levies/rates#field-crops						1.02%	income/ha	**30.05**
Insurance								income/ha	**0.00**
Other								income/ha	**0.00**
Costs related to yield	Your notes								
Cartage/freight	Cost of transport of grain to receival centre						34.55	/tonne	**169.62**
Levies							–	/tonne	**0.00**
B. Total variable costs $/ha:									**919.88**
Enterprise Unit: 1 ha									
C. Gross margin (A–B) $/ha:									**2,026.12**
Total gross margin for 1 hectare									**2,026.12**

Quality and marketing

Extreme weather events at harvest resulted in a downgrade of grain quality and a lower grain price ($600/t for crushing grade compared with $750/t for edible grade).

There was higher than average rainfall and warm conditions in February 2022 as this crop reached physiological maturity stage (P95) early in the month. Soybean crops planted on the traditional December to January dates in this region usually reach maturity during late March or April. These later-planted crops can also have high rainfall, but it is generally with lower temperatures compared with February.

Weather damage at harvest is a known risk for soybean in Australia, particularly in coastal production environments. The ASBP has released varieties (e.g., Richmond⟑ and Gwydir⟑) with improved levels of tolerance to weathering damage. Spreading planting dates to spread the risk of crop damage or loss due to adverse weather is a strategy worth considering for soybean and other summer crops. In the 2021–22 season, >90% of the coastal NSW soybean crops that were planted in December were destroyed by floods and prolonged rainfall in late February and March 2022.

Conclusions

The variety Gwydir⟑ has produced a profitable GM from an early September planting at this site, although grain quality was downgraded due to some weathering damage before harvest.

Research is required to determine planting rates that optimise yield and minimise lodging. Soybean crops are typically not grown for grain at this early planting date and minimal data is available.

As some soybean varieties (e.g., Hayman⟑) are suited for planting until February in coastal NSW, the results of this experiment suggest that coastal sugar cane farming systems might have the opportunity to complete a spring-planted soybean crop followed by a second soybean crop if appropriate varieties are used.

The soybean variety Hayman⟑ is proven high yielding and with high-quality grain when planted in late summer (i.e., February) in coastal NSW. February-planted soybean crops usually mature around mid June, which fits the sugarcane planting window (>September). Production of around 8 t/ha could be possible from 2 soybean crops in a sugarcane fallow period. This would greatly enhance grower GM and boost the soybean industry's production. Soybean is an important rotation for sugar cane with several benefits including nitrogen fixation, weed and disease management.

In environments near the coast the risk of frosts in June is usually low, however, this risk must be considered as soybean is not frost tolerant. Growers are advised to monitor soil temperatures in the early spring period to ensure they are adequate for optimum plant establishment. Soybean germination requires a minimum soil temperature of 13 °C.

Due to the multi-year nature of the sugarcane phase that follows a soybean crop, the risk of building up diseases and insect pests such as lucerne crown borer (*Zygrita diva*) in the soybean phase is anticipated to be low, however, validation from subsequent experiments is required.

September is traditionally the driest month of the year in north-eastern NSW, therefore, having adequate moisture available at planting in non-irrigated crops is critical. To reduce this risk, it is recommended that planting only occurs on a full soil moisture profile using minimum tillage farming systems.

Early planted coastal soybean crops could increase the risk of an early incursion of pod sucking bugs such as green vegetable bug (*Nezara viridula*) and redbanded shield bug (*Peizodorus oceanicus*), as were observed in this experiment. Growers are advised to be vigilant with insect monitoring and consider choices of insecticide sprays and IPM strategies in early planted crops.

Future studies are required to understand weathering risks and soybean crop seed quality that are planted in spring and harvested in February.

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Can sorghum establishment be improved under sub-optimal soil temperatures? Gurley 2021–2022

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Key findings

- Establishing sorghum into soils cooler than the commercially recommended 16–18 °C is a viable option to move flowering and grain fill periods earlier. Planting earlier can help avoid heat and moisture stress at flowering and grain fill.
- Targeting soil temperatures greater than 12 °C for 7 days after planting, and planting into good seedbed moisture, can help even plant establishment, which is important when choosing to plant early.
- Under sub-optimal soil temperatures, establishment is often less than desired (approximately 80%). Three factors were tested to see if establishment percentages could be improved including:
  - varying planting depth
  - using better quality seed
  - using different seed treatments to promote quicker seed germination and emergence
- Seed treatment did not affect plant establishment compared with the untreated control.
- Seed quality did affect establishment. The good quality MR Bazley seed established around 10% more plants than the poor quality seed lot, regardless of planting depth or seed treatment.
- There were no differences in tiller or head production, grain yield or grain quality across any of the treatments.

Keywords sorghum, Gurley, 2020, 2021, soil temperature, early planting

Introduction

Research conducted over the last 4 years by the optimising sorghum agronomy project team, has developed industry confidence to plant sorghum earlier, in late winter (from mid-August), in northern NSW. Early planting is being used as a key tool for reducing the risk of heat and moisture stress at flowering in sorghum.

However, earlier planting times where soil temperatures at planting could be 12 °C or less in the days following planting, have highlighted that establishment percentages are less than ideal (<80% established) in these sub-optimal temperatures.

The three factors being considered as options to improve seed establishment are:

1. the seed quality used at planting, both for germination and vigour
2. planting deeper to reach warmer and more stable soil temperatures
3. seeing if seed treatments can be used to improve seed establishment.

Three dryland experiments were planted in the 2021–22 season:

1. Breeza on the Liverpool plains
2. Gurley, south of Moree
3. Morialta, south of Mungindi.

This paper describes the results from the Gurley experiment only.

Site details

Location	Kelvin, Gurley, 29° 43′ S, 149° 43′ E
Co-operator	Scott Carrigan.
Soil nutrient analysis	The site was soil cored for starting nutrient levels (Table 1) and was found to have 482 kg/ha of nitrogen (N). A large proportion (~370 kg of N), was in the 60–120 cm depth. This was most likely due to residual N unused from previous crops and mineralisation.

Starting soil water and rainfall

- The site was soil cored to a depth of 1.2 m. at planting to determine starting plant available water.
- The starting plant available water was 233 mm.
- A total of 250.4 mm of in-crop rainfall was recorded at the site between August 2021 and the end of January 2022 (Table 2).
- The long-term average for Bellata is 332.9 mm for this period.

Seasonal conditions

- The site started with a reasonably full soil moisture profile following a long fallow after wheat.
- Seedbed moisture was excellent, allowing good crop establishment and growth.
- In-crop rainfall was excellent during September and during the flowering and grain fill periods (November and December). Rainfall during January was low, but the crop had sufficient stored soil moisture for the rest of the season and produced excellent yields.
- Daily minimum and maximum temperature at Gurley in 2020–21 is presented in Figure 1.

Experiment design

- Split plot design: sowing depth as the main block, then seedlot and seed treatment were fully randomised.
- All plots were planted at a population of 74,074 seeds/ha; the target was 60,000 plants/ha established.
- Planted on 100 cm solid plant rows using a Monosem precision planter.

Planting date and soil temperatures

- Planted: 17 August 2021.
- Soil temperatures averaged 11.36 °C at the shallow sowing depth at 8 am for 7 days after planting.

Fertiliser

- 43 kg/ha Granulock Z was applied to all plots at planting.

Desiccation and harvest date

- Desiccation: 13 January
- Harvest: 24 January 2022.

Table 1 Site soil chemical characteristics.

Characteristic	Depth (cm)				
	0–10	10–30	30–60	60–90	90–120
pH_{Ca}	6.3	7.5	7.8	7.7	7.6
Nitrate N (mg/kg)	7	10	18	41	51
Sulfur (mg/kg)	2.4	3.1	8.9	148.4	838.8
Phosphorus (Colwell) (mg/kg)	22	3	2	<2	4
Organic carbon (OC) (%)	0.79	0.74	0.43	0.31	0.14

Table 2 In-crop rainfall at Gurley in 2021–22 and long-term average rainfall Bellata.

	Monthly rainfall (mm)						
Month	August	September	October	November	December	January	Total
2021–22	23.0	74.6	28.8	64.2	50.0	9.8	250.4
Long-term average	34.3	35.8	49.2	63.1	67.6	82.9	332.9

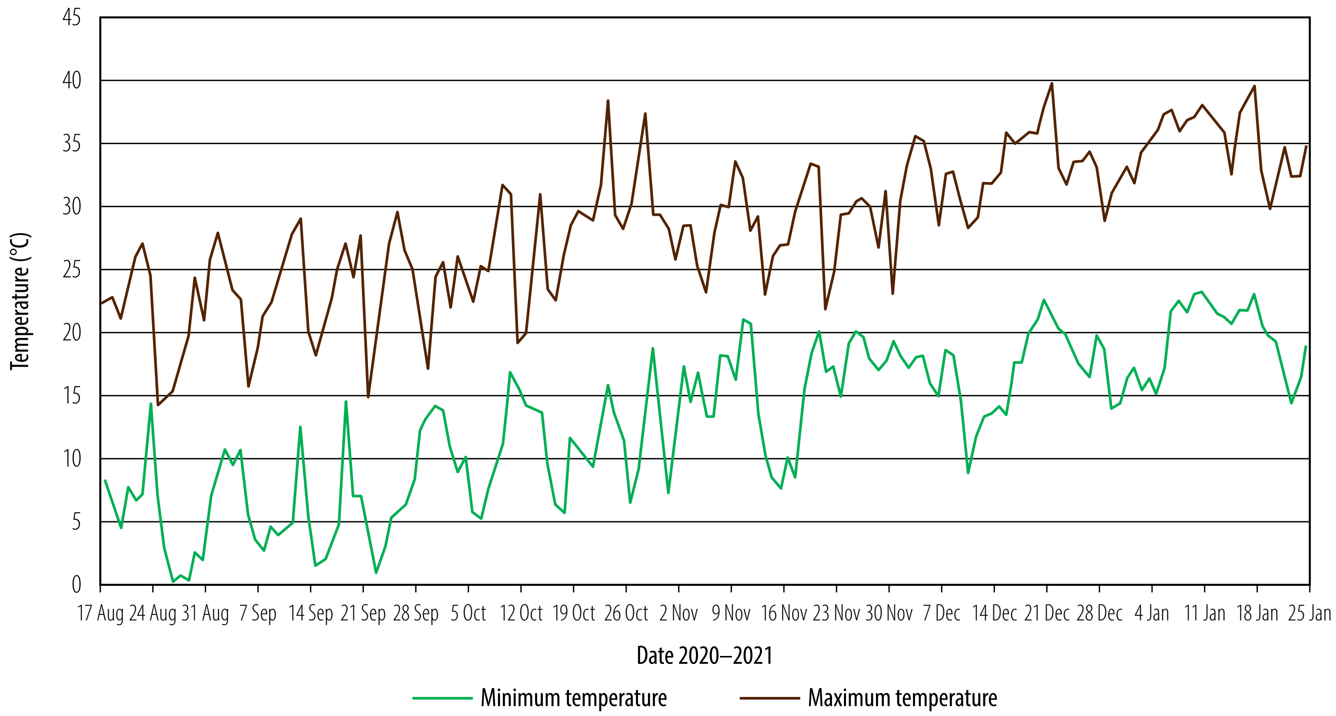

Figure 1 In-crop maximum and minimum temperatures at Gurley, 2021–22.

Treatments

Planting depth (2)

- Shallow: 5.5 cm
- Deep: 7.0 cm.

Seed lot (2)

Two different seed lots were used based on their germination percentage after 7 days at 20 °C.

- MR Bazley good quality – seed source 2021/22 seedlot with 88 % germination
- MR Bazley poor quality – seed source 2020/21 seedlot with 64 % germination.

Seed treatments (6)

Five commercially available seed treatments were selected based on existing literature reviews in other crops or situations. The intended effect of the seed treatments was to improve the rate and establishment of plants per square metre in the field. A control was included for comparison with the seed treatments. All seed lots were treated with MaximXL®, Cruiser 600 FS® and Epivio C®, before applying the seed treatments to compare establishment.

1. Control (nil treatment)
2. Zinc ammonium acetate – low rate (250 ml/tonne) (ZnAA – low)
3. Zinc ammonium acetate – high rate (500 ml/tonne) (ZnAA – high)
4. Gibberellic acid – low rate (400 g/kg) 10 uM (Gibb – low)
5. Gibberellic acid – high rate (2000 g/kg) 50 uM (Gibb – high)
6. Indole-3-butyric acid (8 g/L) (In-3-butyric).

Results

Plant establishment

Plant establishment was measured weekly following the start of emergence by counting the number of emerged plants in set areas within each plot to determine the number of plants/m^2. At the first count on 1 September, 16 days post sowing, the first plants were just emerging. At this count there was a significant effect from the seed lot and seed treatments. This response was still significant at the second plant count one week later.

There were more plants established from the shallow depth compared with the deeper depth at the first plant count, however, this effect was not apparent at later plant counts. The difference between planting depths was approaching significance at the 5% level.

The good quality MR Bazley had double the number of emerged plants at the first plant count than the poor quality seed lot (Table 3). Although this difference was less at the second, third, fourth and fifth weeks of the plant counts, it was still significantly higher for the good seed lot.

The good quality seed lot had a germination of 71%, compared with only 62% from the poor quality seed lot. This was an interesting result as the difference in germination of the 2 seed lots was 24%, however, the difference in establishment was much smaller; only 9%.

Table 3 Plant establishment (plants/m^2) comparison between seed lots at Gurley, 2021–22.

Date	Good seed lot	Poor seed lot	l.s.d.
1 September	1.04 ^{a}	0.54 ^{b}	0.29
7 September	4.39 ^{a}	3.69 ^{b}	0.35
13 September	5.11 ^{a}	4.42 ^{b}	0.34
20 September	5.22 ^{a}	4.63 ^{b}	0.33
27 September	5.26 ^{a}	4.63 ^{b}	0.33

Note: treatment cells which contain the same letters are not significantly different at $P = 0.05$

Differences in establishment were also measured at the first and second establishment counts for the different seed treatments (Table 4). The two gibberellic acid treatments had more plants established than the two ZnAA and Indole-3-butyric treatments at the first count, but were not significantly different to the untreated control. These differences were not evident beyond the second plant count.

Table 4 Comparing plant establishment (plants/m^2) between seed treatments at Gurley 16 days post planting

Date/seed treatment	Control	Gibb – low	Gibb – high	ZnAA – low	ZnAA – high	In-3-butyric	l.s.d.
1 September	0.69 [ab]	1.17 [a]	1.12 [a]	0.58 [b]	0.58 [b]	0.58 [b]	0.36
7 September	3.90 [ab]	4.83 [a]	4.35 [ab]	3.48 [c]	3.92 [bc]	3.79 [bc]	0.61

Note: treatment cells which contain the same letters are not significantly different at $P = 0.05$

Tiller production

- There was no significant difference in the number of tillers produced between planting depths, seed lots or seed treatments (data not shown).
- On average each plant produced 2.2 tillers.

Head production

There was no significant difference in the number of heads produced per plant in any of the seed treatments except for the good quality seed lot; the good quality seed lot produced more heads per metre than the poor quality seed lot (14.5 versus 13.3), however, the result was not significant. This can be explained because there were more plants established from the good quality seed lot than the poor seed lot, while each individual plant was still producing the same number of heads.

Grain yield

The site mean yield was 8.07 t/ha at the receival standard moisture content of 13.5%. There was no significant difference between any of the treatments for grain yield.

The lack of difference in grain yield is likely to be due to compensation through grain number, a main determinant of yield.

Grain quality

Grain protein (GP) and test weight (TW)

The average GP was 10%, which indicates that N did not limit yield at this site. This was expected due to the very high starting soil N levels. There was a significant interaction between planting depth and seed treatment for GP. In this experiment, the deep planting depth with a high rate of gibberellic acid and the shallow planting depth with a low rate of gibberellic acid had lower GP levels of 9.8%, compared with the control at 10%.

The mean TW was high at 78.03 kg/hL, well above the minimum test weight of 71 kg/hl, which is the industry standard for sorghum No.1 grade. The shallow planting depth resulted in a slightly higher TW compared with the deep planting depth (data not shown), but both were still well above the minimum standard.

Screenings and 1000 grain weight

The average screenings level at this site was a low 1.8% across all treatments. No treatment had a significant effect on screenings.

Seed size, as measured by thousand grain weight, was quite high at 30.6 grams.

The low screenings level and high grain weight are both testament to the excellent seasonal conditions.

Conclusions

There were few significant differences between treatments in this experiment. The variation in establishment between the good quality seed versus poor quality seed lots was the main difference. The poor quality seed lot established around 10% fewer plants than the good quality seed lot.

While there was no effect on grain yield or most of the quality parameters from the different seed treatments, the effect of good quality seed on establishment reinforces an important message.

When sowing early into soils that are cooler than normal, good quality seed plays an important role in helping to ensure optimal establishment. The good quality seed had a germination percentage of 88% compared with 64% for the poor seed lot, a difference of 24%. The final difference in plant establishment was 9%, indicating that even good quality seed is exposed to other stresses from early planting that can reduce establishment. The definition of good and poor quality seed in this experiment was based on germination percentage alone, however, other factors such as vigour should also be considered.

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Key findings

- Gwydir⁽ᴾ⁾ soybean variety was planted in spring (5 October 2021) and harvested on 23 March 2022, yielding 4.6 t/ha.
- The total crop gross margin was $1738/ha, based on a grain price of $600/t.
- Above average rainfall during the growing season (including a major flood event before harvest), resulted in the grain being downgraded due to weather damage from resulting in a lower grain price.
- In coastal NSW, spreading planting dates is advantageous to spread the risk of crop loss due to extreme weather events.
- Planting, Gwydir⁽ᴾ⁾ in early spring resulted in a longer vegetative phase, compared with traditional planting dates of early December, however, this did not result in greater plant biomass, plant height or excessive lodging.

Key words soybean, Codrington, 2021, spring, gross margin

Introduction

The soybean variety Gwydir⁽ᴾ⁾ was bred by the Australian Soybean Breeding Program (ASBP) and has produced high yields from an early planting date in previous experiments conducted at NSW DPI, Grafton. In an experiment planted at Grafton on 8 September 2020, Gwydir⁽ᴾ⁾ yielded 5.79 t/ha, which was significantly higher than other industry standard varieties including Richmond (5.01 t/ha) and Moonbi (3.97 t/ha, lsd 0.58).

To further investigate the potential of this variety, a crop of Gwydir⁽ᴾ⁾ was planted by soybean growers Paul and Joe Fleming, Codrington NSW as an initiative of the NSW DPI and GRDC project Soybean expansion in high rainfall zones of northern NSW. The gross margin (GM) was then analysed. In addition to extending new technologies, the project aims to update GM analyses for soybean in various farming systems across north-eastern NSW.

Double cropping summer and winter grain crops on the same paddock is common practice in the high rainfall zones of northern NSW. Identifying soybean varieties suited to an earlier (i.e., spring) planting date, resulting in an earlier harvest date, would benefit double cropping systems by allowing more appropriately timed planting in the winter crop phase.

Site details

Location	Coraki-Casino Road, Codrington, NSW 2471 Latitude 28° 56′ 58.73″ S, Longitude 153° 14′ 23.01″ E
Paddock history	• A heavy clay soil type paddock was selected. • This is a dryland (rainfed) production system in rotation with maize, barley, and soybean. • A minimum tillage (strip-tillage) unit was used that incorporates stubble and forms a bed with furrows at a 1.8 m spacing.

- Two rows of soybean were planted on each bed using a disc opener Kinze planter (90 cm row spacing) and Trimble GPS guidance for planting.

Soil type and nutrition	• Heavy black clay soil. • Table 1 shows the soil analysis for the 0–20 cm depth.
Temperature and rainfall data	A total of 1335 mm of rainfall was received during the growing season, which was 697 mm more than the long-term average of 638 mm for the same period (Figure 1).
Planting date	5 October 2021.
Fertiliser	Sulfate of potash @ 100 kg/ha.
Plant population	Target population 340,000 plants/ha Established population 315,800 plants/ha.
Weed management	• Fallow application of Crucial® @ 3 L/ha (600 g/L glyphosate) + Starane Advanced® @ 300 mL/ha (333 g/L fluroxypyr) + Express® @ 30 g/ha (750 g/kg tribenuron methyl) • Post emergent application of Spinnaker® @ 140 g/ha (700 g/kg imazethapyr) + Verdict® @ 150 mL/ha (520 g/L haloxyfop).
Insect management	• Steward® (150 g/L indoxacarb) @ 300 mL/ha for the control of soybean looper (Thysanoplusia orichalcea) • Shield® (200 g/L clothianidin) @ 200 mL/ha for the control of redbanded shield bug (Peizodorus oceanicus).
Disease management	Folicur 430 SC @ 250 mL/ha (430g/L tebuconazole) was applied to the adjacent Richmond⟑ crop to control soybean leaf rust, yet not to the Gwydir⟑ crop as it is resistant to soybean leaf rust.
Harvest date	23 March 2022. The crop reached physiological maturity (P95 stage on 1 March 2022, however, a flood and continuous wet weather prevented harvest for 3 weeks).

Table 1 Soil chemical analysis, Paul and Joe Fleming, Codrington NSW.

Characteristic / anolyte	Units	Soil depth 0–20 cm
pH (water)	pH units	5.9
Colwell phosphorus	mg/kg	110.0
KCl Extractable nitrate-N	mg/kg	21.0
Exchangeable potassium	cmol(+)/kg	0.48
CEC	cmol(+)/kg	19.4
Aluminium saturation	%	0.9
Exchangeable calcium	%	53.0
Exchangeable magnesium	%	40.0

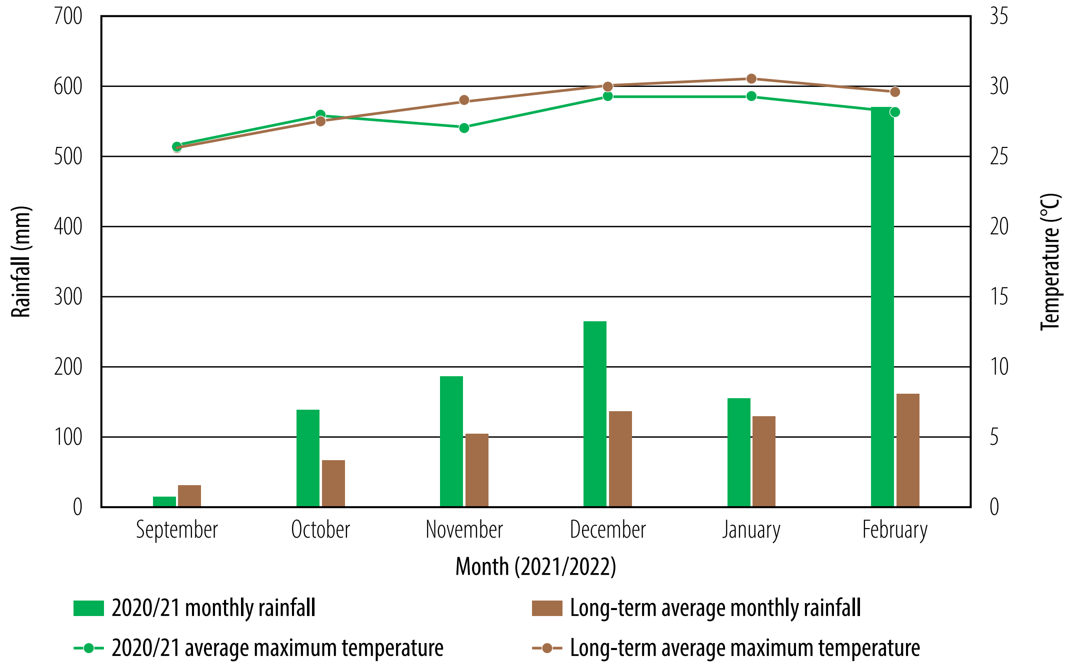

Figure 1 Temperature and rainfall for 2021–22 growing season compared with long-term averages at Casino, NSW.

Results

Yield

The crop yielded 4.60 t/ha (Figure 2).

Figure 2 Crop of Gwydir⁽ᵈ⁾ (left) adjacent to a crop of Richmond⁽ᵈ⁾ (right) at Paul and Joe Fleming's property at Codrington. Note the subtle change in leaf colour of the Gwydir⁽ᵈ⁾, which starts immediately to the left of the people standing in the crop of Richmond⁽ᵈ⁾.

Observed changes in growth

Early planted soybean crops have slower germination and emergence due to colder soil temperatures.

The variety Gwydir⁽ᵈ⁾ had both longer vegetative and reproductive phases compared with long-term data taken by the ASBP for a December planting date. Gwydir⁽ᵈ⁾ took 147 days to reach physiological maturity (P95 stage) when planted on 5 October at Codrington, NSW, compared with a long-term average of 132 days for Gwydir⁽ᵈ⁾ planted in early December at Grafton (ASBP data).

The result at this location suggests that Gwydir⁽ᵈ⁾ takes 15 days longer to reach maturity from a planting date that is 2 months (around 60 days) earlier than traditional early December planting).

The crop grew to 54.6 cm in height, compared with the long-term average of 75.4 cm for Gwydir(b) planted in early December at Grafton, NSW (ASBP data). This could be due to a lack of heat resulting slower growth during the vegetative phase as there were lower than average temperatures in November–December 2021 (Figure 1).

Gross margin analysis

Table 2 shows the full GM analysis for this crop.

Table 2 Gross margin analysis of soybean variety Gwydir(b), Paul and Joe Fleming, Codrington, NSW.

Soybean gross margin analysis – NSW DPI Grafton									
Crop: Soybean variety Gwydir(b)					**Location: Codrington, NSW**			**Date: 2021–22**	
Income/ha:					$600 /tonne		Crushing grade		2,760.00
Grain	4 .60 t/ha @				$750 /tonne		Edible grade		
A. Total income $/ha									**2,760.00**
Variable costs/ha:			**Machinery ex-GST**				**Inputs ex-GST**		**Total Cost $/ha**
Operation	**Date**	**Hrs/ha**	**Cost $/hour**	**Total $/ha**	**Rate /ha**	**Unit**	**Cost $/unit**	**Total $/ha**	
Pre-sowing paddock preparation									
Bed renovation (Cultipak)	24 Jun 2021	1.00	15.00	15.00					**15.00**
Bed renovation (Go-Devil)	28 Jun 2021	2.00	22.00	44.00					**44.00**
Bed renovation (Strip-Tiller)	1 Aug 2021	1.00	25.00	25.00					**25.00**
Bed renovation (Lilliston)	5 Aug 2021	1.00	17.00	17.00					**17.00**
Fallow weed control									
Glyphosate	5 Oct 2021	0.30	20.00	6.00	3.20	L	6.60	21.12	**27.12**
Starane Advance					0.30	L	31.00	8.00	**9.30**
Express					30.00	g	0.24		**7.20**
Sowing									
Gwydir(b) soybean seed	5 Oct 2021	0.35	22.87	7.94	70.00	kg	1.55	108.50	**116.44**
Inoculant	5 Oct 2021				0.18	L	41.60	7.49	**7.49**
Liquid fertiliser	5 Oct 2021				40.00	L	0.58	23.20	**23.20**
Como	5 Oct 2021				0.20	L	20.90	4.18	**4.18**
Fertiliser									
Sulphate of potash	2 Sep 2021			7.00	0.10	T	1,075.00	107.50	**114.50**
Easy N						L	0.79		
In-crop herbicides									
Pre-emergent: Spinnaker	29 Oct 2021	2.00	8.00	16.00	0.14	L	84.00	11.76	**27.76**
Protect Plus	29 Oct 2021				0.50	kg	5.50	2.75	**2.75**
Post-emergent: Verdict	17 Nov 2021	2.00	8.00	16.00	0.15	L	35.50	5.33	**21.33**
Uptake oil	17 Nov 2021				0.50	L	6.20	3.10	**3.10**
Glyphosate 77% band	22 Nov 2021	1.00	16.00	16.00	2.00	L	6.60	13.20	**29.20**
Protect Plus 77% band	22 Nov 2021				0.50	L	5.50	2.75	**2.75**
Broadstar 23% band	22 Nov 2021				0.80	L	33.00	26.40	**26.40**
Blazer 23% band	22 Nov 2021				0.80	L	41.80	33.44	**33.44**
Wetter 1000	22 Nov 2021				0.10	kg	6.70	0.67	**0.67**
Como 50% band	22 Nov 2021				0.60	kg	20.90	12.54	**12.54**

Variable costs/ha:		Machinery ex-GST			Inputs ex-GST				Total Cost $/ha
Operation	Date	Hrs/ha	Cost $/hour	Total $/ha	Rate /ha	Unit	Cost $/unit	Total $/ha	
Zinc Sulphate 50% band	22 Nov 2021				1.00	kg	1.82	1.82	1.82
Boron soluble 50% band	22 Nov 2021				1.00	ha	3.20	3.20	3.20
In-crop insecticides									
Steward	22 Nov 2021				0.30	L	49.00	14.70	14.70
Sheild	10 Jan 2022				0.20	L	90.00	18.00	18.00
Salt	10 Jan 2022				0.50	kg	0.50	0.25	0.25
SOA	10 Jan 2022							0.00	0.00
Vantichor	10 Jan 2022				0.04	L	774.00	30.96	30.96
Duwett	10 Jan 2022				0.25	L	58.00	14.50	14.50
Application	10 Jan 2022				1.00	L	8.00	8.00	8.00
Aerial application	10 Jan 2022							0.00	0.00
Contract harvesting – minimum rate per ha per ha							172.73	per ha	172.73
plus increment for higher yields greater than			0.00	t/ha @			–	per 100 kg	0.00
plus fuel			–	L/ha @			–	per L	0.00
or own plant			–	ha/hr @			–	per hour	0.00
Costs related to income	Your notes								
Levies	http://www.agriculture.gov.au/ag-farm-food/levies/rates#field-crops						1.02%	income/ha	28.15
Insurance								income/ha	0.00
Other								income/ha	0.00
Costs related to yield	Your notes								
Cartage/freight	Cost of transport of grain to receival centre						34.55	/tonne	158.91
Levies							–	/tonne	0.00
B. Total variable costs $/ha:									**1,021.58**
Enterprise Unit: 1 ha									
C. Gross margin (A–B) $/ha:									**1,738.42**
Total gross margin for 1 hectare									**1,738.00**

Grain quality and marketing

Significant weather damage due to the higher-than-average rainfall, including a record flood before harvest, caused the grain to be downgraded from edible ($750/t) to the full fat crushing grade (animal protein market – $600/t) resulting in a GM of $1738/ha.

Conclusions

The variety Gwydir[Ⓓ] has produced a positive GM of $1738/ha after quality downgrade due to weather damaging the grain.

Further investigation of soybean growth and growing degree days is needed to better understand the effects of planting in early spring in coastal NSW. This might influence planting rates and other agronomic advice to further expand soybean planting windows. Determining optimum planting rates to optimise yield and to minimise lodging at October planting dates is also needed.

From a farming system viewpoint, an early harvest could suit soybean growers in the hinterland region of northern NSW. Double cropping soybean with winter cereals is common practice in this region. Combining a soybean variety suited to very early planting could have economic benefits and allow more appropriately timed planting for the winter cereal phase.

Frost is a risk when planting soybean crops in spring in the hinterland regions of north-eastern NSW. Growers must be confident that the frost risk has passed before planting soybean and monitor soil temperatures to ensure the soil temperature is adequate for optimum plant establishment. Soybean requires a minimum soil temperature of 13oC for optimum germination.

Spring is typically the driest month of the year in north-eastern NSW; adequate moisture available at planting for non-irrigated crops is critical to allow establishment and growth until in-crop rainfall occurs. It is recommended that planting should only occur on a full moisture profile (moist soil to 120 cm depth) and to use farming systems with minimal soil disturbance and stubble coverage to conserve moisture.

Soybean crops planted in spring could attract early incursions of pod sucking bugs such as green vegetable bug (*Nezara viridula*) and red-banded shield bug (*Piezodorus oceanicus*), as was observed in this experiment. This presents a challenge for integrated pest management (IPM) programs as no 'soft' options are available for pod-sucking bugs that will conserve beneficial insect populations. Growers are advised to be vigilant with insect monitoring in spring-planted soybean crops.

Future observations are required to understand the weathering risks to soybean crop seed quality planted in spring and harvested in February or early March, compared with the traditional (April and May) harvest period in this region. This spring-planted Gwydir⁽ᵇ⁾ soybean crop matured on 1 March with harvest on 23 March, after the mature crop survived a flooding event in March.

Summer crops

Acknowledgements

Soybean growers Paul and Joe Fleming are gratefully acknowledged for hosting the Gwydir⁽ᵇ⁾ crop and providing information to enable gross margin analysis for the project.

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Gross margin analysis: spring planted soybean variety Gwydir⁽ᴾ⁾, Oakwood 2021–22

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NSW DPI, Grafton

Key findings

- The first commercial scale crop of Gwydir⁽ᴾ⁾ soybean in the northern slopes production region of NSW was planted on 4 November 2021. It took 158 days after planting (DAP) to reach maturity (P95 stage) and was harvested on 23 April 2022.
- The crop yielded 3.1 t/ha with a grain protein concentration of 42.5% dry matter basis.
- Total crop gross margin was $1445/ha.
- Gwydir⁽ᴾ⁾ is well adapted to this region in terms of yield, resistance to leaf diseases and maturity.
- The growers commented favourably on the evenness, ease of harvest, and yield of this variety.
- Based on this result, the growers plan to evaluate Gwydir⁽ᴾ⁾ at an earlier (October) planting date in following seasons.

Keywords Soybean, Oakwood, 2021, 2022, early planting, gross margin

Introduction

Soybean varieties with high yield potential, adapted to early planting dates, and with suitable maturity, are required for grain cropping in the NSW northern tablelands and slopes regions. Slow-maturing soybean varieties (e.g. Hayman⁽ᴾ⁾) are not ideally suited for grain production in this region due to the risk of frost damage to late-maturing crops.

The Australian Soybean Breeding Program (ASBP) bred the variety Gwydir⁽ᴾ⁾. It has shown potential for producing high yields from early planting dates in previous experiments conducted at NSW DPI, Grafton. In an experiment planted at Grafton on 8 September 2020, Gwydir⁽ᴾ⁾ yielded 5.79 t/ha, which was significantly higher than other varieties evaluated including the industry standards Richmond⁽ᴾ⁾ (5.01 t/ha) and Moonbi (3.97 t/ha, lsd 0.58 at p=0.05).

In a replicated on-farm experiment at Brad and Kyeron Schwark's property at Oakwood, NSW in the hot, dry season of 2018–19, Gwydir⁽ᴾ⁾ (then line number T171A-2) produced a yield of 2.15 t/ha, which was comparable with the industry standard Richmond⁽ᴾ⁾ (1.94 t/ha) and higher than industry standard Moonbi⁽ᴾ⁾ (1.73 t/ha, lsd 0.24 at p=0.05) (Ensbey et al., 2019).

To further investigate the potential of this variety, a commercial scale crop of Gwydir⁽ᴾ⁾ was planted by the Schwarks in 2021–22, as an initiative of the NSW DPI and GRDC project 'Soybean expansion in high rainfall zones of northern NSW'. A complete gross margin (GM) analysis was conducted on the crop.

Site details

Location	Narallen, 1306 Dintonvale Road, Oakwood, NSW 2360 Latitude 29° 36' 31.55" S, Longitude 151° 02' 42.96" E
Paddock history	• 2019 fallow (drought). • 2020 barley sown in May.

- 2021 soybean planted in November.

Soil type and nutrition

- Clay soil.
- Soil chemical analysis of the 0–10 cm depth is presented in Table 1.

Temperature and rainfall A total of 628 mm of rain was received during the growing season; 135 mm more than the long-term average (493 mm) for the same period (Figure 1).

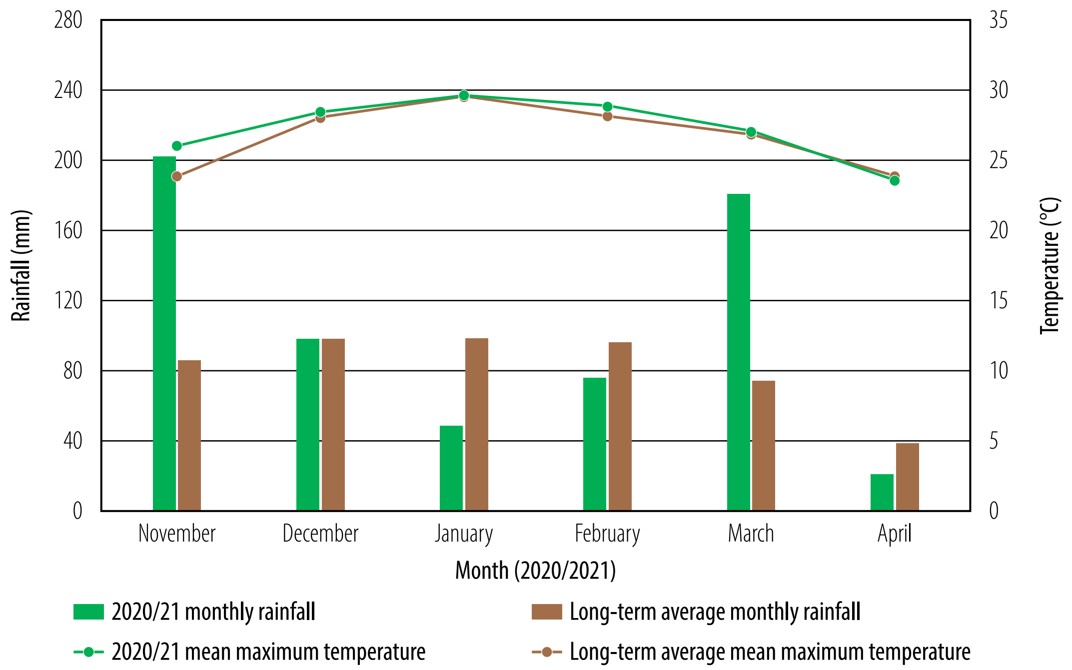

Figure 1 Temperature and rainfall for the 2021–22 growing season compared with long-term averages at Inverell, NSW.

Planting date 4 November 2021.

Fertiliser

- 160 kg/ha sulfate of potash
- 100 kg/ha muriate of potash.

Row spacing and plant population

- Row spacing 75 cm.
- Target population 280,000 plants/ha.
- Established population 210,000 plants/ha.

Weed management

- Pre-emergent: Valor® @ 210 g/ha (500 g/kg flumioxazin) and Gramoxone 250® @ 1.8 L/ha (250 g/L paraquat).
- Post-emergence: Verdict® @ 150 mL/ha (520 g/L haloxyfop).

Insect management

- Vantacor® (600 g/L chlorantraniliprole) @ 40 mL/ha to control soybean looper (*Thysanoplusia orichalcea*) and *Helicoverpa* spp.
- Shield® (200 g/L clothianidin) @ 250 mL/ha to control red-banded shield bug (*Piezodorus oceanicus*).
- Kentac 100® (100 g/L alpha-cypermethrin) at rate of 400 mL/ha to control *Helicoverpa* spp.

- Skope® (218 g/L acetamiprid + 32.5 g/L emamectin) at rate of 320 mL/ha to control green vegetable bug (*Nezara viridula*).
- Dimethoate 400® (400 g/L dimethoate) @ 250 mL/ha to control green vegetable bug and mites.
- Vantacor® (600 g/L chlorantraniliprole) @ 40 mL/ha to control soybean looper and *Helicoverpa* spp.

Disease management	Folicur 430 SC (430 g/L tebuconazole) was applied @ 250 mL/ha to the adjacent crop of Richmond$^{\phi}$ to control soybean leaf rust. However, this was not required for the Gwydir$^{\phi}$ crop, which is resistant to soybean leaf rust.
Harvest date	23 April 2022.

Table 1 Soil chemical analysis, Oakwood NSW.

Characteristic/Analyte	Unit	Soil depth 0–10 cm
pH_{Ca}	pH units	5.9
pH (water)	pH units	6.8
Electrical conductivity	dS/m	0.33
Sulfur (KCl40)	mg/kg	7.2
Bray phosphorus (P)	mg/kg	-
Colwell P	mg/kg	40
Phosphorus buffer index		128
Organic carbon (C)	%	2.3
KCl extractable ammonium-N	mg/kg	3.3
KCl extractable nitrate-N	mg/kg	5.2
Total nitrogen (N)	%	-
Chloride	mg/kg	5
Boron	mg/kg	0.6
DTPA Cu	mg/kg	3.4
DTPA Zn	mg/kg	1.3
DTPA Mn	mg/kg	47
DTPA Fe	mg/kg	42
Exchangeable aluminium (Al)	cmol(+)/kg	<0.02
Exchangeable calcium (Ca)	cmol(+)/kg	35.7
Exchangeable potassium (K)	cmol(+)/kg	0.6
Exchangeable magnesium (Mg)	cmol(+)/kg	30.4
Exchangeable sodium (Na)	cmol(+)/kg	0.3
CEC	cmol(+)/kg	67
Ca/Mg	%	1.2
Al saturation	%	0
Exchangeable Ca	%	53.3
Exchangeable K	%	0.9
Exchangeable Mg	%	45.4
Exchangeable Na	%	0.4

Results

Yield and grain protein

The Gwydir⚶ crop (Figure 2) yielded 3.1 t/ha with a grain protein (GP) concentration of 42.5% dry matter (DM) basis.

Figure 2 Soybean growers Kyeron (left) and Brad (right) Schwark in their Gwydir⚶ crop of at Oakwood, NSW.

Observed changes in growth

The ASBP has collected data on variety maturity at Grafton and from on-farm trials across northern NSW for several decades. From traditional planting dates in the first week of December, Gwydir⚶ typically takes around 132 days to reach physiological maturity (P95 stage). From a planting date of 4 November at the Oakwood site, Gwydir⚶ took 158 days to reach physiological maturity (P95). The result at this location suggests that when planted 30 days earlier than a traditional early December date, Gwydir⚶ takes 26 days longer to reach maturity. Seasonal conditions can affect crop maturity, for example, crops can finish more slowly in mild, wet conditions as were experienced in the 2021–22 season.

Gross margin analysis

A full GM analysis for this crop is provided at Table 2.

Table 2 Gross margin analysis of soybean variety Gwydir, Oakwood, NSW.

Soybean gross margin analysis – NSW DPI Grafton				
Crop: Soybean variety Gwydir⚶		**Location: Oakwood, NSW**		**Date: 2021–22**
Income/ha:			Crushing grade	
Grain	3.10 t/ha @	$750 /tonne	Edible grade	2,325.00
A. Total income $/ha				**2,325.00**

Variable costs/ha:		Machinery ex-GST			Inputs ex-GST				Total Cost $/ha
Operation	**Date**	**Hrs/ha**	**Cost $/hour**	**Total $/ha**	**Rate /ha**	**Unit**	**Cost $/unit**	**Total $/ha**	
Sowing									
Gwydir(b) soybean seed	3 Nov 2021	0.35	22.87	7.94	44.78	kg	1.55	69.40	77.35
Inoculant	3 Nov 2021	with above			50.00	g	0.20	10.00	10.00
Fertiliser									
Liquid starter	3 Nov 2021	furrow inject			100.00	L	0.15	15.00	15.00
In-crop plant protection (herbicide, insecticide, fungicide)									
Insecticide: Legion	3 Nov 2021	furrow inject			0.03	L	266.50	8.00	8.00
Pre-emergent: Valor PSPE	4 Nov 2021	0.14	20.17	2.80	0.21	kg	142.50	29.93	32.73
Pre-emergent: Gramoxone	4 Nov 2021				1.80	L	4.45	8.01	8.01
Post- emergent: Verdict	21 Dec 2021	0.14	20.17	2.80	0.15	L	60.00	9.00	11.80
Spray oil	21 Dec 2021				0.30	L	8.00	2.40	2.40
Ammonium sulphate	21 Dec 2021				0.50	kg	1.00	0.50	0.50
Zinc Trac	21 Dec 2021				0.30	L	12.00	3.60	3.60
MOP	28 Dec 2021	0.14	20.17	2.82	100.00	kg	0.88	88.00	90.82
Vantacor	5 Jan 2022	0.14	20.17	2.82	0.04	L	774.95	31.00	33.82
Wetter	5 Jan 2022				0.17	L	7.10	1.21	1.21
Rebuke fungicide	26 Jan 2022	0.14	20.17	2.82	0.17	L	7.10	1.21	4.03
Sulphate of potash	30 Jan 2022	0.14	20.17	2.82	160.00	kg	1.44	23.40	233.22
Shield	1 Feb 2022	0.14	20.17	2.82	0.25	L	84.20	21.05	23.87
Surfactant	1 Feb 2022				0.12	L	16.00	1.92	1.92
Skope	10 Feb 2022	0.14	20.17	2.82	0.32	L	117.00	37.44	40.26
Wetter	10 Feb 2022				0.17	L	7.00	1.19	1.19
Vantachor	4 Mar 2022	0.14	20.17	2.82	0.04	L	774.95		
Wetter	4 Mar 2022				0.17	L	7.10		
Contract harvesting – minimum rate per ha per ha							172.73	per ha	172.73
plus increment for higher yields greater than			0.00	t/ha @			–	per 100 kg	0.00
plus fuel			–	L/ha @			–	per L	0.00
or own plant			–	ha/hr @			–	per hour	0.00
Costs related to income	Your notes								
Levies	http://www.agriculture.gov.au/ag-farm-food/levies/rates#field-crops						1.02%	income/ha	30.05
Insurance								income/ha	0.00
Other								income/ha	0.00
Costs related to yield	Your notes								
Cartage/freight	Cost of transport of grain to receival centre						34.55	/tonne	107.09
Levies							–	/tonne	0.00
B. Total variable costs $/ha:									**879.55**
Enterprise Unit: 1 ha									
C. Gross margin (A–B) $/ha:									**1445.45**
Total gross margin for 1 hectare									**1445.45**

Grain quality and marketing

This Gwydir⁽ᵇ⁾ crop achieved edible standard. The growers commented that seed size was slightly smaller than usually observed with the industry standard variety Richmond⁽ᵇ⁾.

Conclusions

Gwydir⁽ᵇ⁾ yielded 3.1 t/ha and produced a profitable GM of $1445/ha at this site. This was the first commercial-size planting of this new variety in the northern slopes district. On the strength of this result and the availability of Gwydir⁽ᵇ⁾ planting seed, there should be wide adoption of this new variety in the future.

Planting almost a month earlier than the traditional planting time of late November/early December proved to be a profitable strategy in this case, however, several risk factors should be considered when planting soybean in spring.

- Growers are advised to monitor soil temperatures in early spring to ensure that the soil temperature is adequate for optimum plant establishment.
- Soybean seed requires a soil temperature of at least 13 °C and rising for optimum germination.
- Spring is traditionally the driest season of the year in north-eastern NSW, therefore, it is critical to ensure adequate soil moisture at planting for non-irrigated crops.
- It is recommended that planting only occur on a full soil moisture profile and using farming systems with minimal soil disturbance to conserve soil moisture.

By bringing forward the planting date to early November, the growers were concerned that excessive vegetative growth could occur, which could lead to lodging and disease development such as sclerotinia white mould (*Sclerotium sclerotiorum*). However, this was not the case. Gwydir⁽ᵇ⁾ has a low tendency to lodge and lodging did not develop in this crop. The row spacing (75 cm) and plant population (210,000 plants established per hectare) allowed adequate crop aeration and *Sclerotinia* was not observed in this crop despite the wetter than average seasonal conditions. *Sclerotinia* was observed in lodged soybean crops elsewhere in the region.

This Gwydir⁽ᵇ⁾ crop grew to 63.6 cm in height, compared with a long-term average of 75.4 cm for Gwydir⁽ᵇ⁾ planted in early December at Grafton, NSW (ASBP data). Shorter than average plant height was also observed in 2 other spring-planted crops of Gwydir⁽ᵇ⁾ at Nunderi (planted 6 September) and Codrington (planted 8 October) this season, however, this did not negatively affect yield. Shorter plant stature could be due to the milder weather conditions in spring 2021.

Soybean crops planted in spring can attract early incursions of pod sucking bugs such as green vegetable bug (*Nezara viridula*) and red-banded shield bug (*Piezodorus oceanicus*), as was observed this season. This presents a challenge for integrated pest management (IPM) programs as no 'soft' options are available to control pod-sucking bugs that will also conserve beneficial insect populations. Extra vigilance might be required to monitor insects in very early-planted soybean crops.

Spring-planted soybean in this region can present an opportunity to reduce the frost risk by allowing earlier harvesting and avoiding the high frost risk period of late autumn.

This Gwydir⁽ᵇ⁾ crop took 158 DAP to reach physiological maturity. Weather constrained harvest for another 12 days after this. Soybean varieties with faster maturity in this environment (i.e. <150 days) would be advantageous in double-cropping systems.

References

Soybean variety evaluation – Oakwood 2018–19, Nathan Ensbey, Natalie Moore, Sam Blanch and Nguyen Nguyen, Northern NSW Research Results 2019 (https://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/publications/ngrt-results).

Acknowledgements

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Summer crops

NSW DPI and the Grains Research and Development corporation (GRDC) through the project 'Expansion of soybean in high rainfall zones in northern NSW' (GRDC Project Code: DPI2111-019RTX).

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Gross margin analysis: soybean variety Gwydir$^{\phi}$, Delungra 2021–22

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Key findings

- The Gwydir$^{\phi}$ soybean crop was planted on 14 December 2021, approximately one month later than planned. It reached physiological maturity on 5 May 2022. Harvest was delayed by wet weather and was completed on 14 May. The crop yielded 2 t/ha with a grain protein concentration of 42% dry matter (DM) basis.
- The crop gross margin was $822/ha.
- This experiment demonstrated that Gwydir$^{\phi}$ soybean is well adapted to the northern slopes production region of New South Wales (NSW) in terms of yield, resistance to leaf diseases and maturity.
- Despite wet weather delaying harvest, the Gwydir$^{\phi}$ crop achieved the edible standard grade, demonstrating the weathering tolerance of this variety.

Keywords soybean, Delungra, gross margin, 2021, 2022, northern slopes, delayed planting, nitrogen, legume, wet conditions

Introduction

The ASBP has developed soybean varieties with high yield potential, adapted to early planting dates, and with suitable maturity for the NSW northern tablelands and slopes regions. Slow-maturing, long-season soybean varieties (e.g., variety Hayman$^{\phi}$) are not ideally suited for grain production in this region due to the risk of frost damage to late-maturing crops.

The Australian Soybean Breeding Program (ASBP) bred the variety Gwydir$^{\phi}$. It has shown potential for producing high yields and grain protein (GP) concentration in previous experiments conducted at NSW DPI, Grafton. In the hot, dry season of 2018–19, in a replicated, on-farm experiment at a nearby property, Gwydir$^{\phi}$ (then line number T171A-2) produced a yield of 2.15 t/ha, comparable with the industry standard Richmond$^{\phi}$ (1.94 t/ha) and higher than industry standard Moonbi$^{\phi}$ (1.73 t/ha, l.s.d. 0.24 at p=0.05).

The variety Gwydir$^{\phi}$ was planted at Nathan Anderson farm at Baflour's Peak, north of Delungra in NSW as an initiative of the NSW DPI and GRDC project 'Soybean expansion in high rainfall zones of northern NSW'. A complete gross margin (GM) analysis was conducted on the crop.

Site details

Location	The Springs, 2335 Glenesk Road, Balfour's Peak, NSW 2403 Latitude 29° 31′ 29.67″ S, Longitude 150° 45′ 12.64″ E
Paddock history	• Barley winter 2021. • Soybean planted immediately following harvest of the barley crop.
Soil type and nutrition	• Grey clay. • Table 1 details the soil chemical analysis for the 0–15 cm depth.

Temperature and rainfall	A total of 591 mm of rain was received during the growing season; 178 mm more than the long-term average (431 mm) for the same period (Figure 1).
Planting date	14 December 2021.
Fertiliser	GAIN+Z® at 80 kg/ha (10% N, 21.8% P, 4% S, 1% Zn).
Sowing rate and established plant population	• Target population: 280,000 plants/ha. • Established population: 260,000 plants/ha.
Weed management	• Fallow application: Crucial 600® @ 2.5 L/ha (600 g/L glyphosate), Starane Advanced® 450 mL/ha (333 g/L fluroxypyr) and Valor® 30 g/ha (500 g/kg flumioxazin). • Post-emergent application: Spinnaker® @ 140 g/ha (700 g/kg imazethapyr) and Verdict® @ 150 mL/ha (520 g/L haloxyfop).
Insect management	• Skope® (218 g/L acetamiprid + 32.5 g/L emamectin) @ 350 mL/ha to control soybean looper (Thysanoplusia orichalcea) and redbanded shield bug (Piezodorus oceanicus). • Decis Options® (27.5 g/L deltamethrin) @ 500 mL/ha to control soybean looper and redbanded shield bug.
Disease management	Nil required.
Harvest date	Physiological maturity at 5 May 2022; due to wet weather, the harvest was not completed until 14 May 2022.

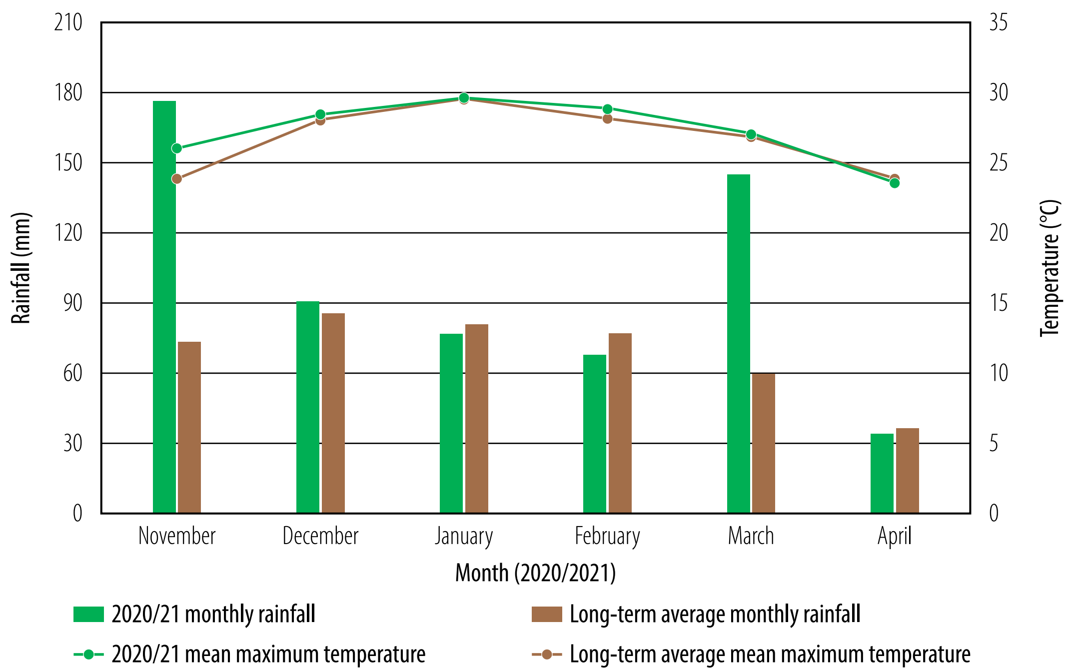

Figure 1 Temperature and rainfall for the 2021–22 growing season compared with long-term averages at Delungra, NSW.

Table 1 Soil chemical analysis of the experiment site at Balfour's Peak, NSW.

Characteristic/analyte	Unit	Soil depth 0–15 cm
pH_{Ca}	pH units	6.8
pH (Water)	pH units	7.5
Electrical conductivity (1:5 water)	dS/m	0.13
Sulfur (S) (KCl40)	mg/kg	2
Colwell phosphorus (P)	mg/kg	16
Phosphorus buffer index		190
Organic carbon (C)	%	1.4
Ammonium nitrogen (N)	mg/kg	2.8
Nitrate nitrogen (N)	mg/kg	4.9
Chloride	mg/kg	<10
Boron	mg/kg	0.6
DTPA copper (Cu)	mg/kg	1.8
DTPA zinc (Zn)	mg/kg	0.38
DTPA manganese (Mn)	mg/kg	13
DTPA iron (Fe)	mg/kg	43
Exchangeable aluminium (Al)	cmol(+)/kg	<0.1
Exchangeable calcium (Ca)	cmol(+)/kg	48
Exchangeable potassium (K)	cmol(+)/kg	0.71
Exchangeable magnesium (Mg)	cmol(+)/kg	26
Exchangeable sodium (Na)	cmol(+)/kg	0.72
CEC	cmol(+)/kg	75
Calcium/magnesium	%	1.8
Aluminium saturation	%	<1

Results

Yield and grain protein

The Gwydir⁽ᵈ⁾ crop (Figure 2) yielded 2 t/ha with a GP concentration of 42% dry matter (DM basis. Because the crop was sown a month later than planned and was slow to establish due to prolonged wet weather, it can be assumed that the yield potential of this crop was reduced.

Observed changes in growth

The ASBP has collected data on the maturity of varieties at Grafton and from on-farm trials across northern NSW for several decades. From traditional planting dates in the first week of December, the variety Gwydir⁽ᵈ⁾ typically takes around 132 days to reach physiological maturity (P95 stage). From a planting date of 14 December at the Balfour's Peak site, Gwydir⁽ᵈ⁾ took 142 days to reach physiological maturity (P95). Seasonal conditions can affect crop maturity, for example, crops can finish more slowly in mild, wet weather as was experienced in the 2021–22 season.

The crop grew to 59.7 cm in height, compared with a long-term average of 75.4 cm for Gwydir⁽ᵈ⁾ planted in early December at Grafton, NSW (ASBP data). The wet weather that caused the later planting time probably accounts for the slow establishment and shorter than average plant height. The crop also had competition from weeds during the vegetative phase.

Summer crops

Gross margin analysis

Table 2 details the GM analysis for this crop, which was $822/ha for edible grade soybean ($722/t).

Table 2 Gross margin analysis of soybean variety Gwydir, Nathan Anderson, Balfour's Peak, NSW.

Soybean gross margin analysis – NSW DPI Grafton									
Crop: Soybean variety Gwydir[PBR]				**Location: Balfour's Peak, NSW**				**Date: 2021–22**	
Income/ha:						Crushing grade			
Grain	2.00 t/ha @			$720 /tonne		Edible grade			1440.00
A. Total income $/ha									**1,440.00**
Variable costs/ha:		**Machinery ex-GST**				**Inputs ex-GST**			**Total Cost $/ha**
Operation	**Date**	**Hrs/ha**	**Cost $/hour**	**Total $/ha**	**Rate /ha**	**Unit**	**Cost $/unit**	**Total $/ha**	
Sowing									
Gwydir[PBR] soybean seed		0.35	22.87	7.94	37.50	kg	1.75	65.63	73.57
Inoculant		with above				g			
Fertiliser									
GAIN+Z		0.14	20.17	2.80	0.80	t	104.00	83.20	86.00
Stoller COMO		0.14	20.17	2.80				32.00	89.66
In-crop plant protection (herbicide, insecticide, fungicide)									
Knockdown: glyphosate		0.14	20.17	2.80	3.20	L	6.60	21.12	23.92
Knockdown: Starane					0.30	L	31.00	8.00	9.30
Pre-emergent: Valor PSPE		0.14	20.17	2.80	0.21	kg	142.50	29.93	32.73
Post-ermergent: Spinnaker 700WG								0.00	0.00
Post-emergent: Verdict		0.14	20.17	2.80				0.00	2.80
Insecticide: Skope		0.14	20.17	2.82	0.32	L	117.00	37.44	40.26
Insecticide: Decis		0.14	20.17	2.80	0.50	L	12.50	6.25	9.05
Insecticide: Decis		0.14	20.17	2.80	0.50	L	12.50	6.25	9.05
Contract harvesting – minimum rate per ha per ha							172.73	per ha	172.73
plus increment for higher yields greater than			0.00	t/ha @			–	per 100 kg	0.00
plus fuel			–	L/ha @			–	per L	0.00
or own plant			–	ha/hr @			–	per hour	0.00
Costs related to income	Your notes								
Levies	http://www.agriculture.gov.au/ag-farm-food/levies/rates#field-crops						1.02%	income/ha	0.00
Insurance								income/ha	0.00
Other								income/ha	0.00
Costs related to yield	Your notes								
Cartage/freight	Cost of transport of grain to receival centre						34.55	/tonne	69.09
Levies							–	/tonne	0.00
B. Total variable costs $/ha:									**618.13**
Enterprise Unit: 1 ha									
C. Gross margin (A–B) $/ha:									**821.87**
Total gross margin for 1 hectare									**1445.45**

Grain quality and marketing

Despite wet weather delaying harvest, the Gwydir⁽ᶦ⁾ crop achieved the edible standard grade, demonstrating this variety's weathering tolerance. Grain protein concentration was 42% DM basis, which is above the edible standard specification of 40% DM.

Figure 2 Nathan Anderson's crop of Gwydir⁽ᶦ⁾ at Balfour's Peak, NSW.

Conclusions

Gwydir⁽ᶦ⁾ yielded 2 t/ha at this site with a gross margin of $822/ha. A higher yield potential would have been expected if wet weather had not delayed harvest of the preceding barley crop and delaying the soybean crop planting by a month. Provided soil moisture is not limiting, the traditional planting time for dryland soybean crops in this region is early to mid November.

Synthetic N fertiliser prices reached record highs during the 2021–22 season. The grower highlighted the benefit of N fixed by the soybean crop and the N-rich crop residues to his double cropping system with a winter cereal. This grower estimates the value of the residual N from the soybean crop at around $140/ha, which he includes in the GM analysis of the following barley crop.

More work is required to benchmark residual N from soybean crops in this region to allow growers to better estimate the economic benefit to their farming system. Future work is also required to define the value of other soil benefits provided by soybean crops, such as increased soil biological activity.

Frost is a risk to soybean crops on the northern slopes and tablelands of NSW. This late-planted crop was harvested on 14 May 2022, which is in the frost-risk period for this region. Variety selection and rotation choices should aim for soybean crops to reach physiological maturity as early in autumn as possible to minimise the risk of frost damage before harvest.

As spring is usually the driest season of the year in north-eastern NSW, having adequate moisture available at planting in non-irrigated crops is critical. It is recommended that planting only occurs on a full moisture profile using farming systems with minimal soil disturbance. In the northern slopes region of NSW, soybean should be considered in summers where wetter than average conditions are predicted (e.g., La Niña cycles).

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Soybean grower Nathan Anderson is gratefully acknowledged for hosting the crop and providing information for gross margin analysis. McGregor Gourlay agronomist John Frazier is gratefully acknowledged for his valued input. This work is supported by NSW DPI and Grains Research and Development Corporation (GRDC) through the project 'Expansion of soybean in high rainfall zones in northern NSW' (GRDC Project Code: DPI2111-019RTX).

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Using imidazolinone to alter sorghum row configuration post sowing, Mungindi 2021–2022

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Key findings

- Establishing a target population yielded significantly more than establishing double the population and then spraying 50% of the plants out at 7 leaf stage. For example, sowing a population of 30,000 plants/ha and then reducing the population to 15,000 plants/ha yielded about 30% less than establishing 15,000 plants/ha initially.
- Biomass production and grains per unit area were strong indicators of yield.
- In years of above average rainfall and good starting soil moisture, reducing the population and changing the row configuration post emergence with an imidazolinone herbicide is not suggested due to the yield penalty incurred.
- Using an in-crop imi herbicide was effective in reducing plant population and altering row configuration.

Introduction

The release of imidazolinone (imi) tolerant lines of sorghum has opened a new avenue for weed control in sorghum crops. This same tolerance could be used to change plant population and row configuration post sowing to help mitigate yield penalties if a season is drier than expected.

It is difficult to predict long term weather and as such it is hard to know what population and row configuration to sow, especially in marginal production environments. However, alternate rows of an imi tolerant and a conventional line of similar maturity can be planted at the ideal population and row spacing for higher yielding years. Then, if the season forecast changes to be drier than expected, the crop can be sprayed with an imi herbicide effectively halving the plant population and creating a double skip row configuration by killing/stunting the conventional line of sorghum and also achieving in-crop weed control. This could be particularly useful in the northern cropping region where water is often a limiting factor.

Treatments examined in this experiment

- Can plant population be reduced and row configuration manipulated post sowing to increase yield and quality in a drier year?
- Can imi tolerant and conventional hybrids be used to manipulate population and row configuration without reducing yield?

The results of this paper are based on one experiment at Mungindi, grown in dryland conditions in the 2021–22 growing season.

Site details

Location	Morialta South, Mungindi, 29°17′1″S, 149°07′11″E
Co-operator	Tom and Melissa Greentree
Soil type and nutrition	The site was cored for starting levels (Table 1) and recorded 266 kg/ha of nitrogen (N). This was most likely due to residual N from the previous crop plus mineralisation.

Table 1 Site soil chemical characteristics.

Characteristic	Depth (cm)				
	0–10	10–30	30–60	60–90	90–120
pHCa	6.6	7.7	7.8	7.9	7.9
Nitrate N (mg/kg)	20	18	17	16	11
Sulfur (mg/kg)	3.3	2.6	3.6	9.3	33.7
Phosphorus (Colwell) (mg/kg)	37	8	8	13	16
Organic carbon (OC) (%)	0.95	0.52	0.37	0.32	0.30

Starting soil water and rainfall

The site was soil cored at planting to measure starting plant available water (121 mm) to 1.2 m deep.

A total of 291 mm of in-crop rainfall was recorded at the site between mid September 2021 and mid February 2022 (Table 2); 24 mm more than the long-term average rainfall for Mungindi. Excellent rainfall was received during November and December and overland flow flooded the site in mid–late December.

Seasonal conditions

The site started with a reasonably good soil moisture profile following a flood the previous summer. This was supplemented by above average in-crop rainfall.

There was very little rain in the 2 weeks before planting so leading tynes were used on the planting rig to break the soil surface and allowed good placement of the seed into moisture.

Fifteen days post planting, 50 mm of rain was recorded at the site on 30 September, which helped to ensure seedbed moisture was not limiting during germination and establishment.

Experiment design

- Fully randomised design, 3 replicates.
- Plots were 8 m wide by 10 m long.
- The 3 different populations sown were 74,074, 37,037 and 18,519 seeds/ha, with the target of establishing 60,000, 30,000 and 15,000 plants/ha respectively.
- Plots were sown on 100 cm solid plant rows using a Monosem precision planter.

Table 2 In-crop rainfall at Morialta in 2021–22 and long-term Mungindi average rainfall.

Month	September	October	November	December	January	February	Total
2021–22 rainfall (mm)	52.8	13.8	102.8	57.2	23.6	40.8	291.0
Mungindi long-term average (mm)	13.8	38.1	46.5	51.3	70.2	47.5	267.4

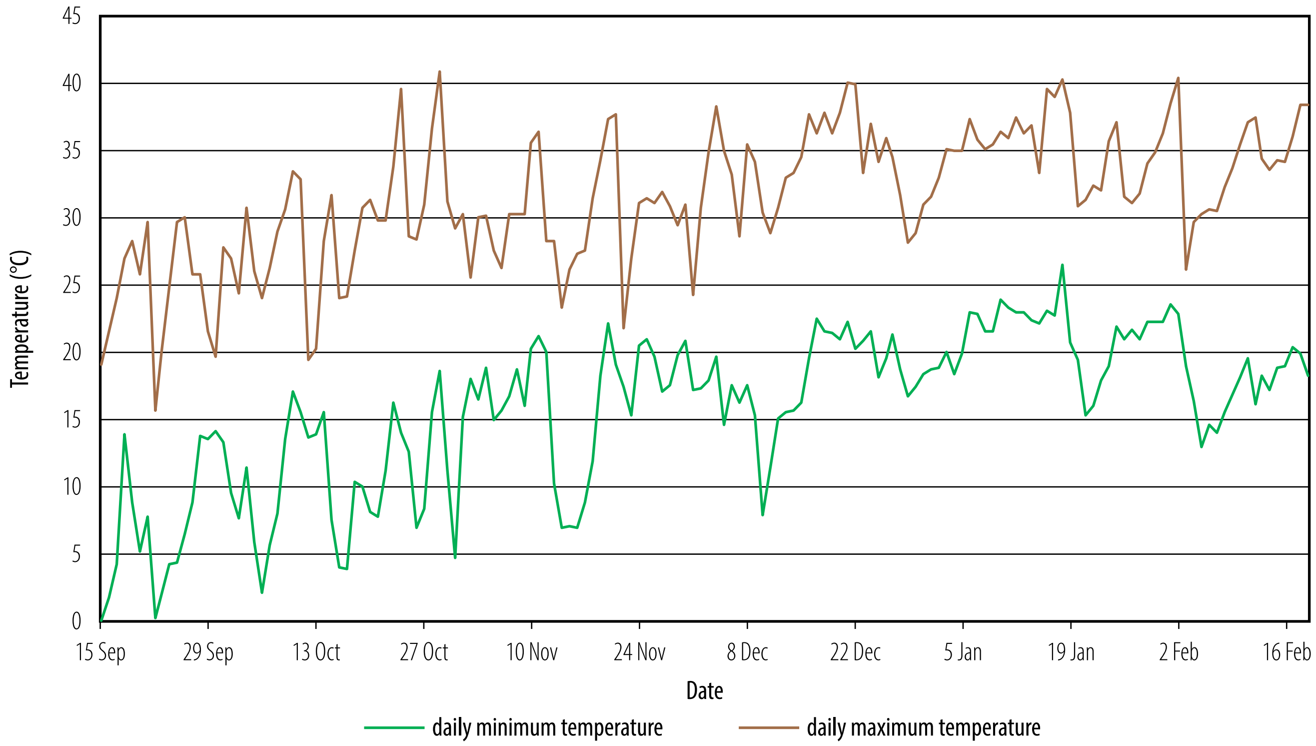

Figure 1 Maximum and minimum temperatures at Morialta.

Treatments

Target populations

- 60,000 plants/ha.
- 30,000 plants/ha.
- 15,000 plants/ha.

Hybrids

- Sentinel IG (imi tolerant).
- MR Buster (conventional).

Population and row configuration manipulation post sowing

- Treatments 1–3 were Sentinel IG only plots with 1 m row spacing, at varying populations of 15,000 plants/ha, 30,000 plants/ha or 60,000 plants/ha.
- Treatment 4 was MR Buster on 1 m row spacing sown at 60,000 plants/ha.
- Treatments 5–8 were sown with alternating rows of Sentinel IG and MR Buster i.e., a row of an imi tolerant hybrid and then a row of a conventional hybrid planted at either 30,000 plants/ha or 60,000 plants/ha.
- Treatment 5 and 7 had Intervix® applied at 7 leaf stage.
- Treatment 6 and 8 were unsprayed and planted at 30,000 plants/ha or 60,000 plants/ha respectively.

Table 3 Treatment list.

Treatment number	Hybrids	Target plant density (plants/ha)	Herbicide application	Treatment
1	Sentinel IG	15,000	Nil	Sentinel IG + 15
2	Sentinel IG	30,000	Nil	Sentinel IG + 30
3	Sentinel IG	60,000	Nil	Sentinel IG + 60
4	MR Buster	60,000	Nil	MR Buster + 60
5	Sentinel IG + MR Buster alternating	30,000	Intervix at 7 leaf	Sentinel IG + MR Buster + 30 + herbicide
6	Sentinel IG + MR Buster alternating	30,000	Nil	Sentinel IG + MR Buster + 30
7	Sentinel IG + MR Buster alternating	60,000	Intervix at 7 leaf	Sentinel IG + MR Buster + 60 + herbicide
8	Sentinel IG + MR Buster alternating	60,000	Nil	Sentinel IG + MR Buster + 60

Results

Application of Intervix® to treatments 5 and 7 halved the population from 30,000 plants/ha to 15,000 plants/ha and 60,000 plants/ha to 30,000 plants/ha respectively (Table 4).

The variability in the final plant density of treatment 2 was not statistically different from the 30,000 plants/ha or 15,000 plants/ha treatments.

Table 4 Target, established and final plant densities

Treatment number	Treatment	Target plant density post herbicide application (plants/ha)	Plant density at 6 leaf stage (plants/ha)	Final plant density at physiological maturity* (plants/ha)
1	Sentinel IG	15,000	17,500	18,333[c]
2	Sentinel IG	30,000	33,333	25,000[bc]
3	Sentinel IG	60,000	63,333	56,667[a]
4	MR Buster	60,000	52,500	50,000[a]
5	Sentinel IG + MR Buster + herbicide	15,000	27,500	14,167[c]
6	Sentinel IG + MR Buster	30,000	25,000	33,333[b]
7	Sentinel IG + MR Buster + herbicide	30,000	58,333	30,833[b]
8	Sentinel IG + MR Buster	60,000	59,167	60,000[a]
			l.s.d	11,920

*Note: treatment cells which contain the same letters are not significantly different at $P=0.05$

Days to 50% flowering

There were very small, but significant differences in the number of days to flowering ranging from 88 days to 89.7 days. Where Sentinel IG and MR Buster were sown in a plot together, there was at most a one-day difference in flowering date. This shows that maturity is similar between hybrids up to the point of flowering.

Tiller production

The number of tillers/plant generally increased with lower plant populations. The imi herbicide-applied treatments (treatments 5 and 7) were significantly lower ($P<0.05$) for tillers/ha than most treatments, except for treatment 1. There was a moderate correlation between tillers/ha and yield ($R^2 = 0.58$) (data not shown).

Head production

The number of heads/ha for the 2 imi herbicide treatments (5 and 7) was lower compared with the other treatments, except for treatments 1 and 2. This is because the final populations of these 2 treatments were lower than all other treatments. The differing row configuration did not affect head production/ha for a given final plant population. Different results might be seen in dryer environments.

Biomass production

The imi applied treatments produced 27% less biomass than the other treatments. This is likely to be a result of increased plant competition within the plant rows. There were no biomass differences between the other treatments.

Yield

No yield differences were detected between variety or population in this experiment. There was no difference between treatments with alternating hybrid rows that were not treated with imi herbicide and comparable populations of individual varieties.

There were differences between treatments where imi herbicide was applied and treatments of comparable plant population.

Spraying out treatments 5 and 7 halved the population to around 15,000 plants/ha and 30,000 plants/ha, making them comparable with treatments 1 and 2 in terms of plant population. However, the yields from treatments 5 and 7 were about 30% lower than treatments 1 and 2. This indicates that either the change in row configuration, imi herbicide application or a combination of both caused the yield reduction.

Treatments 5 and 7 and treatments one and 2 cannot be separated from the results of this experiment. Future experiments could decouple the 2 treatments by applying imi herbicide to plots of a straight imi tolerant variety and sow plots of skip row configuration without imi herbicide application. Furthermore, row configuration such as skip row are beneficial in drier seasons, therefore, an experiment in a drier environment/season would probably produce a different result.

Despite no differences being found in this experiment between hybrid and plant population, different environmental conditions might produce a different response. Therefore, future experiments could determine the effect of population reduction without altering yield by sowing mixed imi tolerant/conventional seed, which would result in a reduced population but not affect row configuration.

Not only was yield affected, but biomass and grains/m^2 in the imi herbicide-applied treatments were also significantly reduced, by 30% (Table 5 and Figure 2). This infers that yield is positively linked to biomass production/ha and number of seeds/ha, which is also suggested by the high correlation (biomass/ha $R^2 = 0.94$, grains/ha $R^2 = 0.92$) (Figure 2). This suggests that maximising biomass and seed set in high yielding years is important to maximise yields. All 3 populations of Sentinel IG yielded statistically the same, suggesting that in high yielding seasons reduced planting rates do not reduce yield (Table 5). Future experiments could investigate management practices to maximise biomass/ha and seed number/ha and/or key growth stages where these are affected.

Table 5 Grain yield adjusted to receival standard of 13.5% moisture.

Treatment number	Treatment	Grain yield (t/ha) at 13.5% moisture content *	Biomass (t/ha) *
1	Sentinel IG	7.85[a]	14.89[a]
2	Sentinel IG	7.52[a]	14.77[a]
3	Sentinel IG	6.90[ab]	15.40[a]
4	MR Buster	6.95[ab]	14.76[a]
5	Sentinel IG + MR Buster + herbicide	5.30[c]	11.15[b]
6	Sentinel IG + MR Buster	8.07[a]	17.24[a]
7	Sentinel IG + MR Buster + herbicide	5.52[bc]	11.17[b]
8	Sentinel IG + MR Buster	6.87[ab]	14.91[a]
	l.s.d	1.502	3.534

*Note: treatment cells which contain the same letters are not significantly different at *P*=0.05

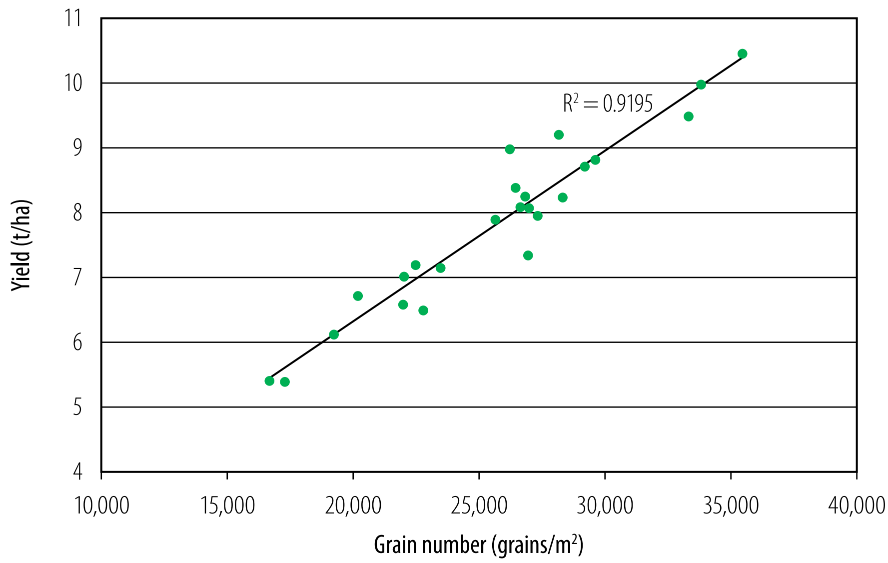

Figure 2 Relationship between number of grains per square metre and yield per hectare. Note, the x and y axes do not start at zero.

Grain quality

There were small differences between treatments in grain protein (GP) of about 1% between the lowest and highest values, but there was no correlation with yield. (Table 6).

In treatments 6 and 8, MR Buster had significantly higher GP than Sentinel IG (MR Buster 10.7–10.77%, Sentinel IG 9.73–9.8%).

The 1000 grain weight showed small differences 28.08–31.72 g between the lowest and highest levels (Table 6). All the MR Buster 1000 grain weights (including alternating row plots that were separated and tested separately) were lower than Sentinel IG, but this was not always significant.

There was a moderate negative correlation between GP and 1000 grain weight (R^2=0.33).

There were no differences for screenings and test weight (Table 6).

Table 6 Grain quality: GP, screenings, test weight and 1000 grain weight.

Treatment number	Treatment	Grain protein (%)*	Screenings (%)	Test weight (kg/hL)	1000 grain weight (g)*
1	Sentinel IG + 15	9.51[bc]	3.10	77.10	30.60[abc]
2	Sentinel IG + 30	9.39[c]	3.24	77.67	29.35[cd]
3	Sentinel IG + 60	9.69[bc]	2.83	76.07	30.60[abc]
4	MR Buster + 60	10.26[a]	3.50	78.00	28.08[d]
5	Sentinel IG + MR Buster + 30 + herbicide	9.63[bc]	3.03	79.07	31.72[a]
6	Sentinel IG + MR Buster + 30	9.91[ab]	3.45	77.03	29.80[bc]
7	Sentinel IG + MR Buster + 60 + herbicide	9.53[bc]	3.03	78.63	31.13[ab]
8	Sentinel IG + MR Buster + 60	9.61[bc]	2.83	77.30	29.75[bc]
	LSD	0.428	ns	ns	1.486

*note: treatment cells which contain the same letters are not significantly different at *P*=0.05

Harvest index

Harvest index is the ratio of grain weight to the weight of total above-ground biomass. The site mean for harvest index was 52.92% and there were no differences between treatments. In plots of alternating rows (treatments 6 and 8) there was no difference between Sentinel IG and MR Buster for harvest index. This is consistent with biomass being correlated to yield

Growing imi tolerant and conventional sorghum in alternating rows (treatments 6 and 8)

For treatments 6 and 8, Sentinel IG and MR Buster were grown in alternating rows without an imi herbicide application resulting in both varieties growing through to maturity. Separate data was able to be collected on the 2 hybrids because separate measurements were taken when processing the biomass samples. There was no difference in screening or test weight between the 2 hybrids (Table 6). However, Sentinel IG at both populations had a higher 1000 grain weight and contributed a higher proportion to the total yield compared with MR Buster. MR Buster recorded a higher GP compared with Sentinel IG (Table 6). This suggests that Sentinel IG had access to more moisture than MR Buster allowing for larger seeds and thus slightly diluting the GP. There was no difference in yield between treatments 3, 4 and 6, which were the only Sentinel IG with the same target population (Table 4), Sentinel IG could be out competing MR Buster in some way. This could be caused by shading from Sentinel IG being a taller variety, differences in root morphology or above/below ground growth rate. Further research could be conducted to determine the reason for the difference in yield, but the total combined yield was not less than any other treatment and thus is of little concern (Table 4).

Table 7 Comparison between MR Buster and Sentinel IG for grain quality traits including grain protein, screenings (%), test weight, 1000 grain weight and varietal contribution to yield.

Treatment		Grain protein (%)*	Screenings (%)	Test weight (kg/hL)	1000 grain weight (g)*	Contribution to yield (%)*
6	Sentinel IG	9.80[b]	2.62	235.4	28.96[b]	56.47[a]
6	MR Buster	10.77[a]	3.18	229.3	27.52[c]	43.53[b]
8	Sentinel IG	9.73[b]	2.67	237.2	30.60[a]	55.72[a]
8	MR Buster	9.70[a]	3.57	237.2	27.73[c]	44.28[b]
	LSD	0.33	ns	ns	1.14	2.06

*Note: treatment cells which contain the same letters are not significantly different at *P*=0.05

Conclusions

In seasons with a high potential for sorghum yields, halving the population by spraying out every second row with an imi herbicide significantly reduces yields. Using an imi herbicide was very effective in reducing plant populations and manipulating row configuration. This could be a useful in-crop management tool in years where a producer is unsure if a season will become unfavourable for higher plant populations and solid row configuration. Further evaluation in lower rainfall years is required to determine if this management strategy can improve yield and reduce risk.

In a high yield potential season such as in this experiment, it was found that biomass/ha and number of grains/ha were highly positively correlated to yield. This suggests methods to maximise biomass and seed production should be investigated as they could increase potential yield.

There was no difference in yield between Sentinel IG and MR Buster when grown individually, however, when grown together, Sentinel IG contributes a high proportion to yield. It should be noted that this did not reduce yield compared with treatments of similar populations.

Future research could attempt to determine the individual effects of row configuration and imi herbicide. Furthermore, to better understand the interaction between population and row configuration treatments of mixed seed could be used where population is reduced but row configuration is not.

Acknowledgements

This experiment was jointly funded by University of Queensland (UQ), Grains Research and Development Corporation (GRDC) and NSW DPI under project UOQ 1808-001RTX – 'Optimising sorghum yield through agronomic management'. Technical assistance provided by William Tydd and Lucy Loveridge (NSW DPI) is gratefully acknowledged.

Summer crops

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The effect of temporal nitrogen and water on wheat infected with fusarium crown rot, Tamworth 2021

Mitch Buster[1,2], Richard Flavel[2], Steven Simpfendorfer[1], Christopher Guppy[2], Mike Sissons[1]

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[2] University of New England, Armidale

Key findings

- Deep banded nitrogen (N) can have a significant effect on grain protein when in-crop rainfall is low.
- Soil N availability appears to be a driver of fusarium crown rot (FCR) severity.
- Fusarium crown rot had no significant effect on grain protein (GP) levels.
- In a wet season, the durum variety DBA Lillaroi[⊕], had a significant yield penalty (25%) with the additional FCR inoculum, and a 36% yield loss in a dry finish.
- LongReach Lancer[⊕] had improved FCR tolerance with an 8% yield loss in a wet finish and 9% loss in a dry finish and could be considered an option in moderate-risk paddocks to limit disease effects.

Keywords Fusarium, FCR, Tamworth, 2021, nitrogen

Introduction

Fusarium crown rot, caused by the stubble-borne fungus *Fusarium pseudograminearum* (Fp), produces significant yield penalties in wheat and barley across much of northern NSW and southern Qld. Historically, N interactions with the FCR fungus have not been well studied or understood. This controlled environment study explored interactions between spatially (vertical) available soil N, FCR and available soil moisture during flowering and grain filling in high protein bread and durum wheat varieties.

Site details

Location	Polyhouse, Tamworth Agriculture Institute 31° 08′ 52.3′ S, 150° 58′ 55.0′ E.
Pot design	PVC tube 150 mm diameter × 1200 mm heigh growth tubes to replicate field soil profile. (Figure 1).
Soil type and nutrition	• Grey dermosol. • Very low background of Fp (no history of cereal production). • Starting N of 36.4 mg nitrate N/kg and 3.8 mg ammonium N/kg soil.
Watering	• Soil tubes were individually weighed and watered to field capacity each week until flowering. Post flowering, the dry finish treatment was managed to 40% of field capacity (–100 kPa matric potential), whilst the wet finish treatment maintained the original field capacity watering regime. • Water was administered through a 25 mm PVC pipe located in the soil column, which had three watering points vertically throughout the profile at 35 cm, 55 cm and 75 cm below the soil surface.

- This method sought to mimic dryland growing conditions in northern NSW with minimal in-crop rainfall during grain filling with crops growing predominantly on stored soil moisture.

Experiment design	• Randomised complete block design. • Spatial location as primary block and N placement, water regime and variety as secondary blocks. • Four replications.
Sowing date	6 May 2021.
Fertiliser	• Soil tubes were treated with potassium nitrate (KNO_3), equivalent to 50 kg K/ha at planting, which was evenly mixed in the top 350 mm of soil to rectify K deficiency. • The banded treatment received urea in solution equivalent to 80 kg N/ha 350 mm below the surface. • The surface treatment received the same solution at 50 mm below the surface.
Established plant population	Four plants/per tube.
Insect/disease management	Seed was treated with Vibrance® and Emerge® at rates of 360 mL/100 kg and 240 mL/100 kg, respectively.
Harvest date	30 November 2016.

Treatments

Varieties (2)

- Bread wheat: LongReach Lancer⏀
- Durum wheat: DBA Lillaroi⏀.

Infection (Fusarium Crown Rot) (2)

- Background
- Background + inoculation

Nitrogen (2)

- Banded (35 cm)
- Surface Applied

Results

Infection response

- The background FCR severity scores early in season at GS31 were negligible. They were higher at harvest, especially in DBA Lillaroi⏀.
- At GS31m deep-banded N (35 cm depth) in the background and the + inoculation treatment reduced the FCR score compared with surface-applied N in LongReach Lancer⏀, but not in DBA Lillaroi⏀. (Figure 2).
- At harvest, higher FCR scores were obtained in background and the + inoculation treatment. However, deep banding N increased FCR severity scores in the background treatment in both cultivars, but gave similar results to surface N in the inoculation treatment (Figure 2).
- These results demonstrate that FCR severity potentially has a relationship with the relative availability of N to the crop.

Winter crops

Figure 1 PVC tube design for controlled environment study exploring interactions between spatially (vertical) available soil N, FCR and available soil moisture during flowering.

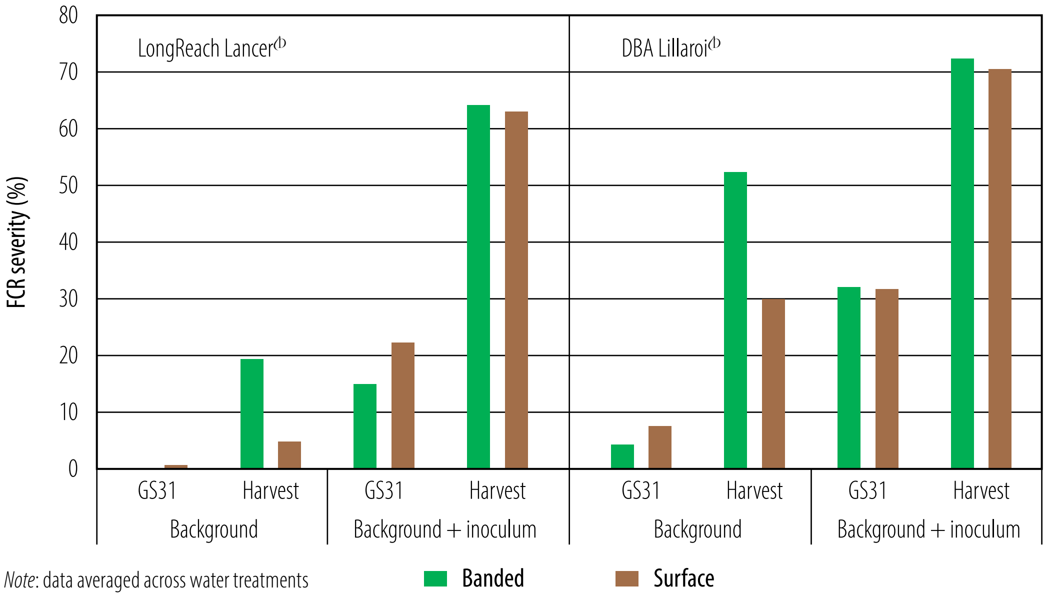
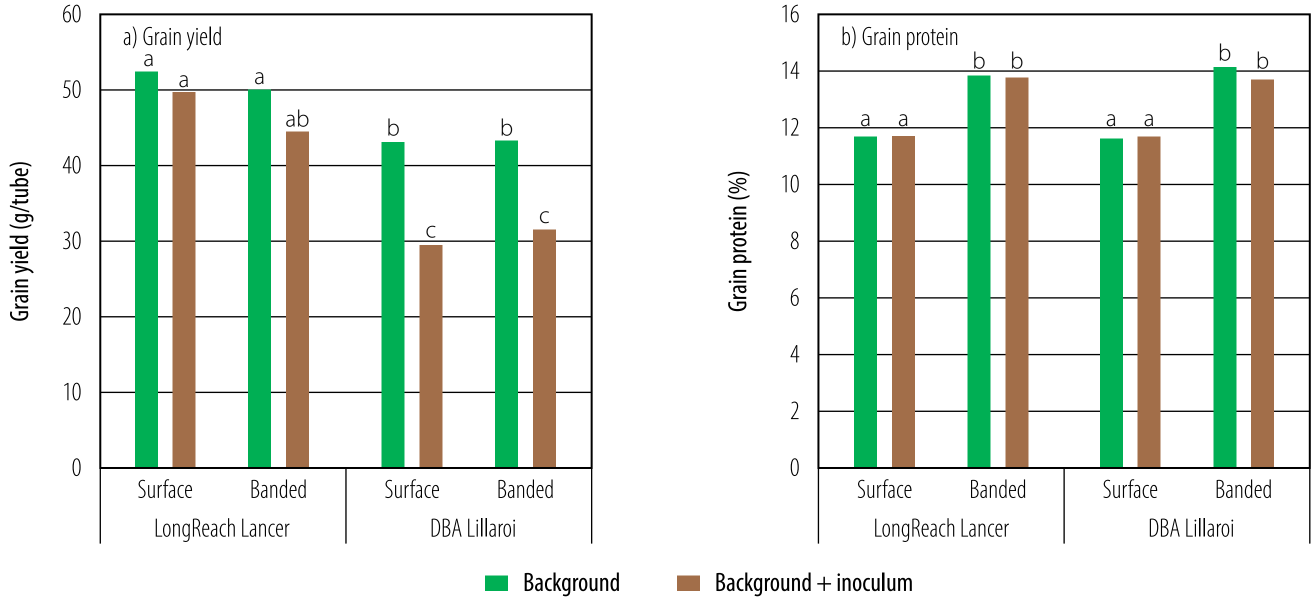


Figure 2 Effect of banded (35 cm) and surface (5 cm) nitrogen application on FCR severity (FCR index 0–100) conducted at GS31 and harvest of LongReach Lancer⊕ (left) and DBA Lillaroi⊕ (right) in the presence of background or background plus inoculation infection by Fp.

Effect of N banding on yield and protein

- Inoculation had no significant effect on grain yield for LongReach Lancer$^{\phi}$, but reduced yield in DBA LillaroiA.
- Nitrogen placement had no significant effect on yield (Figure 3, left).
- The deep banded N resulted in a significant increase in GP compared with surface-applied N in both durum and bread wheat (Figure 3, right).
- Inoculation had no significant effect on GP content (Figure 3) and tiller count (data not shown).



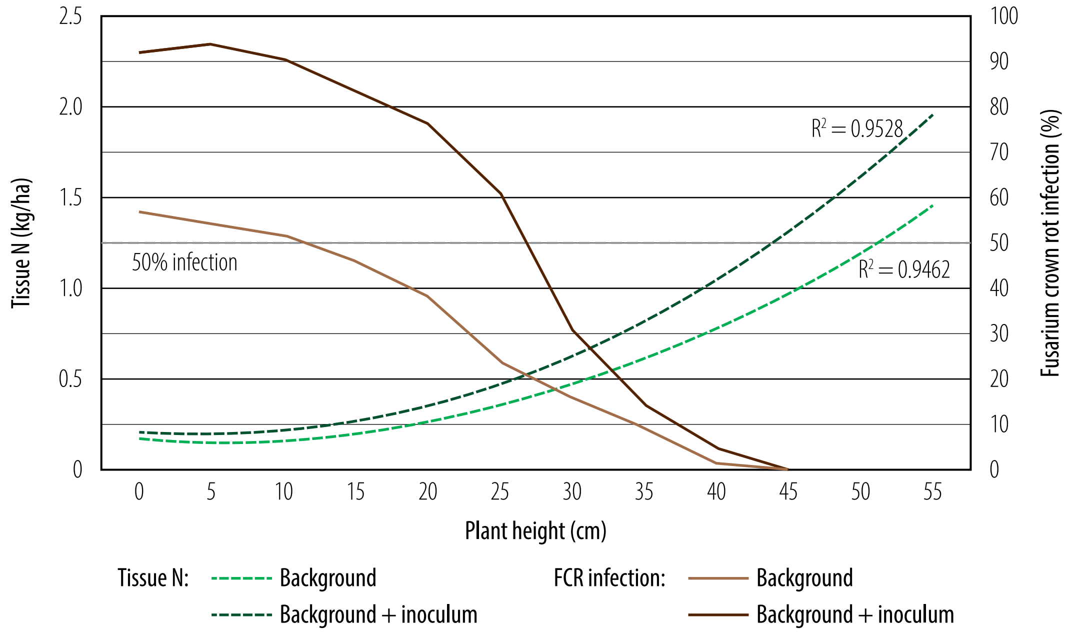
Note: Significance letters indicate 95% confidence at l.s.d. (*P*>0.05)

Figure 3 Average yield (a) and protein responses (b) of LongReach Lancer$^{\phi}$ and DBA Lillaroi$^{\phi}$ under N (banded and surface application) with background and background + inoculation FCR treatments.

Fusarium infection levels, recovered from laboratory plating, demonstrated a significant increase in main stem vertical colonisation in both cultivars in the background + inoculum treatment compared with background only (figures 4 and 5). The vertical height intercept where 50% of tillers were colonised by Fp for LongReach Lancer$^{\phi}$ was 27.5 cm in the background + inoculation treatment, but was at 10 cm in the background only treatment (Figure 4). For DBA Lillaroi$^{\phi}$, the 50% vertical colonisation height was 33 cm in background + inoculation and 27 cm in background (Figure 5).

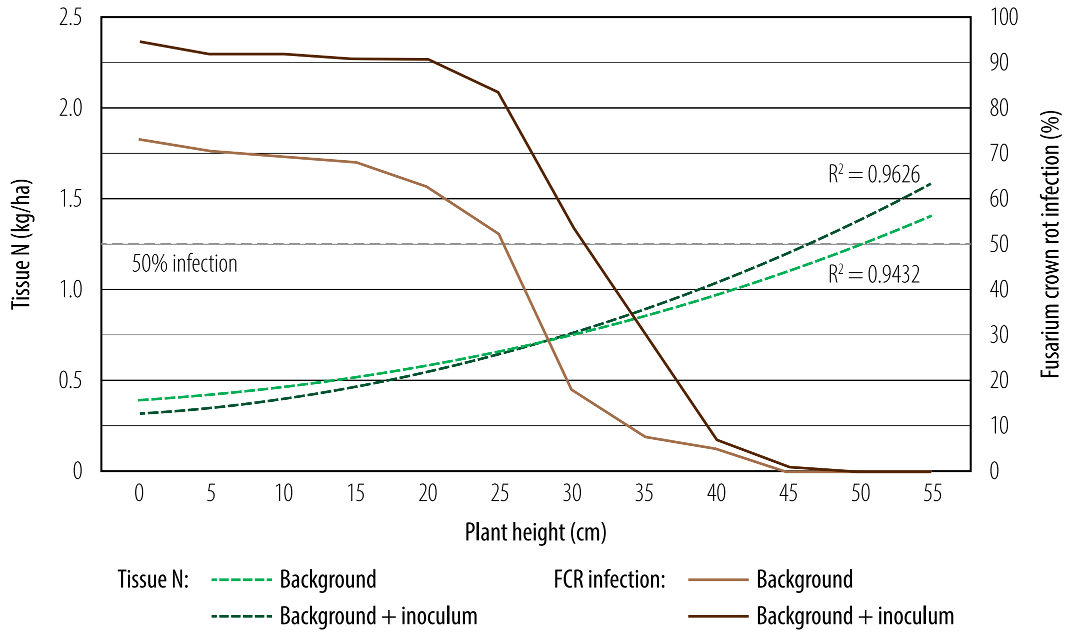
Recovered tissue N post harvest was significantly higher in the background + inoculation FCR treatment compared with background alone for LPRB LancerA (Figure 4), but was not significantly different for DBA Lillaroi$^{\phi}$ (Figure 5). This is likely to be due to the increased susceptibility of DBA Lillaroi$^{\phi}$ to FCR resulting in a smaller separation between FCR treatments, which limited the ability to detect differences in N tissue recovery.

The increase in tissue N, relative to FCR severity, indicates that fungus is increasing the plant's demand for N (figures 4 and 5) but not transferring into protein (Figure 3), suggesting a decrease in nitrogen use efficiency (NUE).



Note: data averaged across N and water treatments

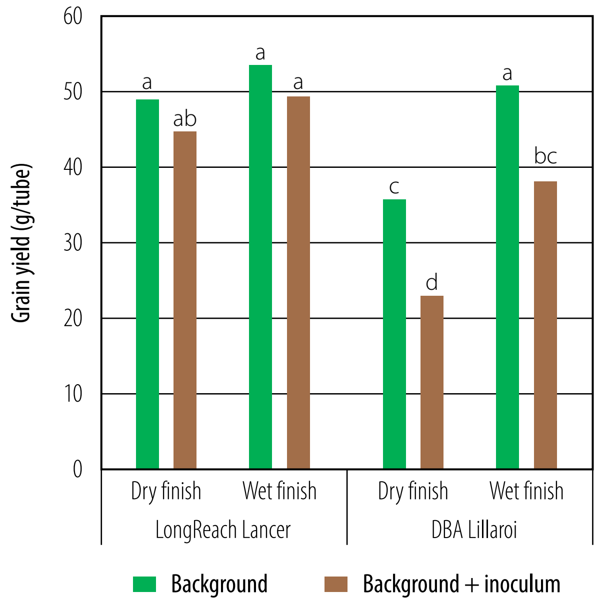
Figure 4 Tissue N (kg/ha) and percentage of FCR infection as sampled vertically up the main stem of LongReach Lancer⁽ᵈ⁾.



Note: data averaged across N and water treatments

Figure 5 Tissue N (Kg/ha) and percentage of FCR infection as sampled vertically up the main stem of DBA Lillaroi⁽ᵈ⁾.

Increased levels of FCR infection (inoculated treatment) decreased yield in DBA Lillaroi⁽ᵈ⁾ by 25% under wet finish conditions and 36% under dry finish conditions, relative to the background levels of inoculum (Figure 6). There was a trend towards LongReach Lancer⁽ᵈ⁾ being 8% lower yielding under wet finish conditions and 9% lower under dry finish conditions due to increased FCR infection, but these differences were only significant at the 90% level as opposed to the 95% level shown in Figure 6 below. Hence the durum varieties continue to display a significantly higher susceptibility than the bread wheats.



Note: Significance letters indicate 95% confidence at l.s.d. (*P*>0.05)

Figure 6 Average yield response of LongReach Lancer⁽ᵈ⁾ and DBA Lillaroi⁽ᵈ⁾ under dry and wet finishes to the growing period post flowering with varying levels of FCR infection.

Summary

Nitrogen availability was a likely driver for FCR severity in-crop with surface N applications resulting in a FCR increase (compared with banded N) under certain treatments at the early GS31 assessment. However, as the season progressed under low simulated in-crop rainfall, the topsoil dried and hence crop access to surface applied N decreased.

At harvest, banded N treatments resulted in the highest severity of FCR, but produced higher grain protein levels compared with surface N applications and with no effect on grain yield. Logistically, banding fertiliser at 35 cm is not easily achieved, however, practices such as applying N early in the fallow and allowing it to move down the profile with rain might achieve a similar N location.

Residual tissue N concentrations within stems at harvest increased with greater severity of FCR infection. This N was not translocated to the grain, and it is suspected that an increased demand for N is placed on the plant by the fungus, potentially mining more N out of the soil profile and decreasing NUE.

At the time of writing, soil N analysis was not complete, but these results will confirm the fate of N in the presence of varying levels of FCR infection. Even so, N availability in wheat stems did not appear to drive FCR colonisationdrive.

Fusarium crown rot did not influence grain protein, however, yield penalties were significant in the durum variety. This was not a result of decreased tiller number, but a combination of reduced grain size and whitehead expression (data not presented). Yield penalties in the durum were exacerbated by a dry finish, which frequently occurs in northern NSW and southern QLD cropping systems. Fusarium crown rot prevalence in these regions, combined with historically dry/hot seasonal finishes, has made durum production inherently a higher risk crop than growing bread wheat varieties, such as LongReach Lancer⁽ᵈ⁾, which has improved tolerance to this disease. To manage this risk, growers should consider PREDICTA®B or NSW DPI stubble testing of paddocks planned for durum production in 2022 before sowing.

Acknowledgements

The research undertaken as part of this project is made possible by the significant contributions of growers through both experiment cooperation and the support of the Grains Research and Development Corporation (GRDC) and NSW DPI. This work was undertaken as part of project DAN00213: 'Grains Agronomy & Pathology Partnership' (GAPP) – a strategic partnership between GRDC and NSW DPI. The PhD study is enrolled through the University of New England with the support of supervisors Dr. Richard Flavel (UNE), Dr. Steven Simpfendorfer (NSW DPI), Dr. Christopher Guppy (UNE) and Dr. Mike Sissons (NSW DPI). The author thanks them for their continued support.

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Faba bean seed source trial, Liverpool Plains Field Station, Breeza 2021

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NSW DPI, Tamworth Agricultural Institute

Key findings

- Large differences in yield potential were found among farmer-grown faba bean seedlots.
- The *Bean yellow mosaic virus* epidemic in northern faba bean crops during 2020 did not result in significant levels of virus seed transmission, but seed harvested from severely infected paddocks showed generally less growth vigour, resulting in lower yields.
- Early season normalized difference vegetation index readings correlated significantly with plant emergence and yield.

Key words 2021, *Bean yellow mosaic virus*, Breeza, establishment, faba bean, NDVI, seed, seedling, vigour, yield

Introduction

Most seed for sowing faba bean and other pulses in NSW is grown on-farm. Seed is regularly tested for germination and the presence of seed-borne diseases, but rarely for other traits such as seedling vigour. Seedling vigour can have a major effect on crop establishment and can be critical to yield, particularly in stressful plant growing environments.

After 2 years of severe drought, seed for the 2020 season was in short supply and often of a lower quality, resulting in a low or irregular plant emergence. A severe virus epidemic occurred in 2020, mainly *Bean yellow mosaic virus* (BYMV), which caused high crop losses throughout northern NSW. The virus appeared to be particularly damaging in paddocks with a poor plant emergence.

The devastating virus epidemic concerned growers about the potential of virus seed transmission in seed harvested from virus-affected paddocks. NSW DPI provided free seed testing for BYMV transmission. Over 50 faba bean seedlots were submitted to NSW DPI Tamworth. Of the PBA Warda[Φ] seedlots submitted, 18 lots had enough seed for a replicated yield test to investigate whether virus-infected plants can affect quality and yield potential of the harvested seed.

Winter crops

Site details

Location	Liverpool Plains Field Station, Field 2: 1° 1826′ S, 150° 4256′ E.
Paddock history	2020 fallow
Soil type and nutrition	• Grey/brown vertosol • pHCa 7.6–8.0.
Rainfall	• Total rainfall 1011 mm (Figure 1), of which 336 mm was recorded during the growing season (May–October).
	• No pre-sowing or in-season irrigation was applied.

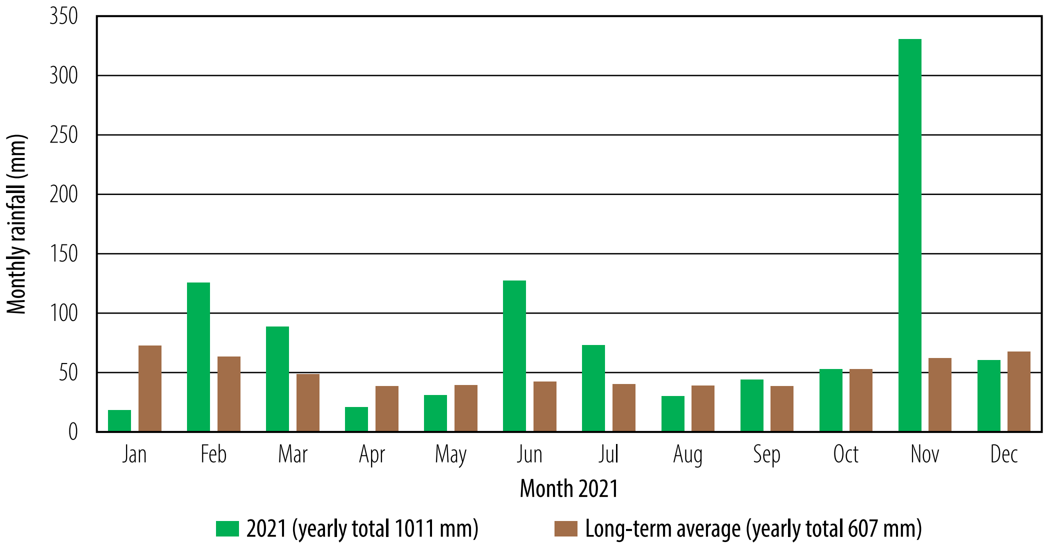

Figure 1 Monthly rainfall for the Liverpool Plains Field Station for 2021 and long-term average.

Experiment design

- Sown on 2 m wide irrigation beds using a randomised complete block design.
- three replications
- three rows: 7.5 m length with 0.45 m row spacing within plots and 1.10 m between plots.

Sowing date

12 May 2021.

Fertiliser

No fertiliser applied.

Sowing rate and established plant population

All seed lots used were graded by hand and small and discoloured seeds were discarded. Sowing rate of 300 seed/plot was used for a target population of 30 plants/m^2.

Weed management

Terbyne® @ 1 kg/ha (750 g/kg terbuthylazine) + glyphosate (450 g/L) @ 1.5 L/ha applied on 12 May before sowing.

Disease management

Two preventative fungicide applications were made before predicted rain:

1. Aviator® Xpro® @ 0.6 L/ha (150 g/L prothioconazole and 75 g/L bixafen) applied on 8 July.
2. Veritas® @ 1.0 L/ha (200 g/L tebuconazole and 120 g/L azoxystrobin) applied on 28 July.

Insect management

Steward® EC 0.3 L/ha (150 g/L indoxacarb) applied on 4 October 2021 for *Helicoverpa* spp control.

Emergence counts and NDVI readings

Plant emergence counts

Taken on 23 June by counting emerged plants in the centre row of each plot. On 20 July, images of the trial were taken by a Parrot Sequoia + multispectral sensor mounted on a DJI Phantom 4 drone. normalized difference vegetation index (NDVI) plot readings were extracted from the images using QGIS and PIX4D software.

Harvest date	9 November 2021.

Treatments

Seedlots (23)

- Eighteen farmer grown seedlots
- Two commercial seedlots
- Three seedlots harvested from 2020 LPFS trial plots with contrasting levels of BYMV infection.

For 10 farmer grown seedlots, the BYMV infection levels during the 2020 season were: 4 low, 2 moderate and 4 severe.

Results

Plant emergence and NDVI readings

The seedlot plant emergence varied between an average of 64 plants/row for seed originating from a severely BYMV infected 2020 LPFS plot and 110 plants/row from a farmer's seedlot that had a low BYMV infection level in 2020.

NDVI plot readings ranged from an average of 0.485 for a farmer's seedlot that showed a very high level of BYMV in 2020 to 0.671 from a farmer's seedlot with an unspecified level of BYMV infection in 2020.

Plot readings for plant emergence and NDVI were significantly correlated (Figure 2).

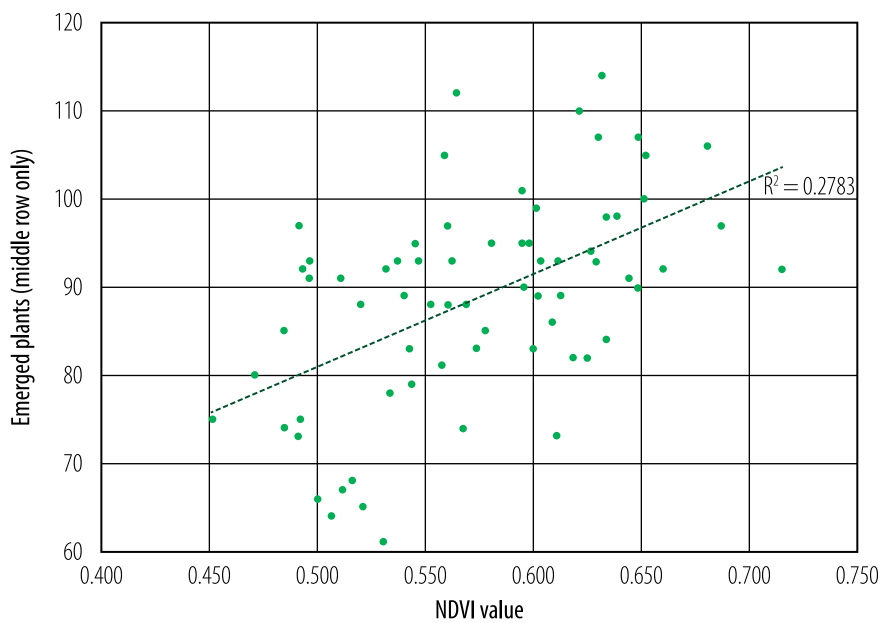

Figure 2 Relation between 69 PBA Warda[Φ] plot readings for plant emergence and NDVI, Liverpool Plains Field Station 2021.

Grain yield

Grain yields varied from 3.47 t/ha for a farmer's seedlot harvested from a paddock with a severe level of BYMV in 2020 to 4.33 t/ha from a seedlot harvested from a plot in the 2020 LPFS trial with a low level of BYMV.

Average grain yield was positively correlated with the NDVI readings (Figure 3, r =0.452), but not with the emerged plant count (r =0.274). There was no clear relationship with the level of virus infection and yield (Figure 3), but the lowest yielding seedlots originated from paddocks with severe or moderate BYMV levels.

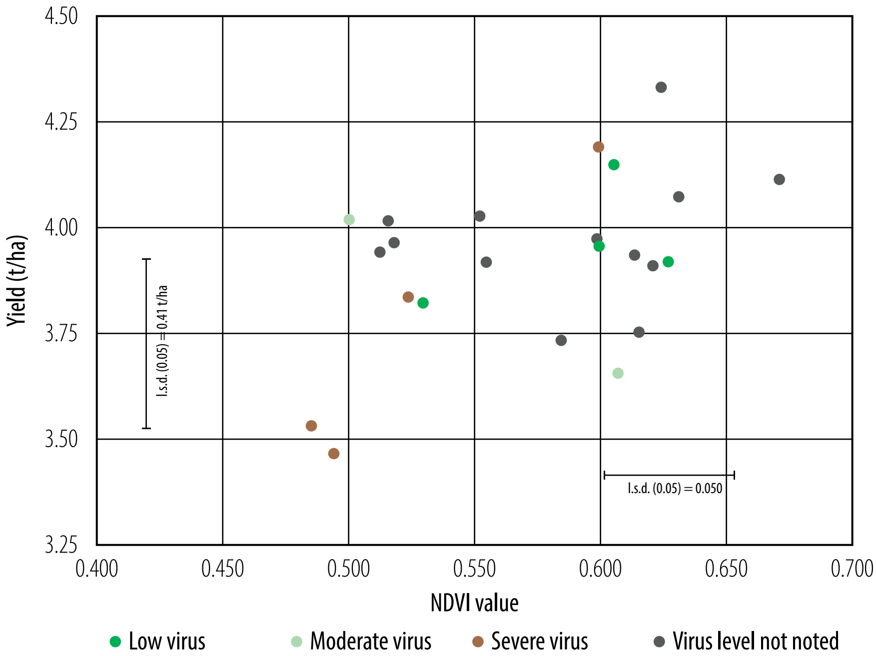

Figure 3 Relation between NDVI and yield (averages over 3 replicates) for 23 PBA Warda(b) seedlots, Liverpool Plains Field Station 2021

Conclusions

The large yield differences in vigour and yield potential among the PBA WardaA seedlots harvested in 2020 confirmed preliminary findings in earlier years of a 20%yield penalty for the poorest seedlot compared with the best performing lot. No clear relationship between the level of virus infection in the crop and the yield potential of the harvested grain was found, but growers' ratings were likely subjective and were only provided for a limited number of seedlots. Using actual yields of the 2020 crops as a variable to relate to the 2021 results might have been more descriptive, but unfortunately, we did not have this information for farmers' submitted seedlots.

NDVI readings related well to early growth vigour and yield. More frequent early NDVI measurement could help to measure differences in seedling vigour among seedlots.

Testing BYMV infection of over 7000 seedlings grown from 54 seedlots harvested in 2020 from BYMV infected paddocks only yielded a single BYMV positive plant. BYMV seed infection of faba bean is therefore not considered to be of epidemiological significance. Nevertheless, growers were advised to avoid using seed from severely infected paddocks as poorly growing crops are likely to yield seed with lower seedling vigour and yield potential.

Acknowledgements

This experiment was part of the 'Pulse integrated disease management – northern NSW/QLD' project, a co-investment by the Grains Research and Development Corporation (GRDC) and NSW DPI through the Grains Agronomy Pathology Partnership (GAPP).

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How important are arbuscular mycorrhizal fungi to chickpea yield? Tamworth 2021

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Key findings

- Increasing soil arbuscular mycorrhizal fungi (AMF) levels increased the yield of chickpea by 13%.
- Sowing chickpea with starter fertiliser containing P increased yield by 14%.
- Increasing soil AMF levels can increase yield to levels comparable to those obtained when applying fertiliser.
- The application of starter fertiliser plus AMF inoculation did not have a cumulative yield effect.

Introduction

Chickpea production continues to rapidly expand in the northern grains region (NGR) with chickpea now being the dominant break crop for cereal production in northern NSW and southern QLD. Chickpea is highly dependent on AMF for its nutritional needs. Arbuscular mycorrhizal fungi are symbiotic fungi that colonise the roots of a wide variety of plants, including a number of key crops grown in the NGR. AMF can benefit plants in several ways including:

- Increasing plant tolerance to abiotic stress, such as drought and salinity
- Increasing disease resistance
- Increasing water uptake and improving soil conditions.

Arbuscular mycorrhizal fungi mainly benefit plants through improved nutrient acquisition, primarily phosphorus (P) and zinc (Zn) (Smith and Read 2008).

Long fallow disorder is a risk facing growers following periods of dry weather. The term 'long fallow disorder' has long been associated with low soil levels of AMF, often in paddocks that have been fallow for 8–12 months. AMF levels can be reduced due to a lack of plant roots, which act as a host for the fungus. If AMF-dependent crops such as chickpea are subsequently grown in these paddocks, their growth can be poor. It is likely that low soil AMF levels are a symptom of long fallow disorder, rather than the only cause. There are a number of other non-mycorrhizal organisms that can significantly contribute to long fallow disorder by influencing soil organic matter and nutrients following periods of drought.

A survey of 264 wheat and barley paddocks across the NGR during the winter of 2019 showed a large number of paddocks with below adequate AMF levels (Simpfendorfer et al. 2020). Paddocks were assessed using the PREDICTA®B platform, a DNA-based soil-testing service that primarily helps producers identify soil-borne pathogens (Cay 2017). The service can test for select species of AMF that have been associated with long fallow disorder in the region (Thompson et al. 2017). PREDICTA®B reports the combined result of 2 tests:

- Test A detects the genus *Funneliformis*.
- Test B detects the genus *Claroideoglomus*.

Of the 264 paddocks tested, only 4% had adequate soil AMF levels. In north-eastern NSW, 83% of the paddocks surveyed had levels of AMF below detection. Similar results were recorded in a survey of the region conducted in 2018. It should be noted that both 2018 and 2019 were dry years.

It is estimated that yield losses of 60–80% can occur in highly AMF-dependant crops such as chickpea where AMF levels are below detection and in soils with low P (Thompson et al. 2017). The low soil AMF levels recorded across the region in 2018 and 2019 therefore represented potentially significant future losses to chickpea growers.

To date, there have been limited experiments to test chickpea yield losses when grown in low AMF soils. The main objective of this experiment was to gather preliminary data over the 2021 winter-cropping season to study whether low soil AMF levels limit chickpea yield.

Site details

Location

Tamworth Agricultural Institute, Tamworth, NSW, 2340.
31° 15′ 24. 1″ S; 150° 98′ 37.5″ E.

Paddock history

- 2019: Durum wheat.
- 2020: Canola.

Soil type

Brown-grey vertosol.

Soil characteristics

Details see Table 1.

Table 1 Soil characteristics at Tamworth in 2021 (0–30 cm depth).

Characteristic	Depth (0–10 cm)	Depth (10–30 cm)
AMF Test A (kDNA/g soil)	4	
AMF Test B (kDNA/g soil)	3	
Ammonium nitrogen (N) (mg/kg)	6	5
Nitrate N (mg/kg)	14	7
Colwell P (mg/kg)	20	3
BSES P (mg/kg)	26.27	1.14
PBI	130.5	174.9
Organic carbon (%)	1.63	1.05

Starting soil moisture

135.8 mm, plant available water (PAWC) (0–120 cm).

Rainfall

- Tamworth 2021 rainfall: 980 mm (long-term average 630 mm).
- In crop rainfall: 565 mm.

Experiment design

- Randomised complete block design.
- Four replicates of each treatment, 12 m plots.
  Five plant rows at 33 cm spacings.

Sowing date

2 June 2021.

Crop management

- **Fungicide**. Chlorothalonil 720 (720 g/L chlorothalonil) at 2 L/ha, applied on 27 July, 3 September, 20 September, 8 October, 10 November and 24 November 2021. Applications before major rain events.
- **Insecticide**. Altacor® (350 g/kg chlorantraniliprole) at 70 g/ha. Applied on 10 November 2021 for *Helicoverpa* larvae.
- **Herbicide**. Roundup Ultra®MAX (glyphosate 570 g/L) at 2 L/ha + Sharpen® (700 g/kg saflufenacil) at 3 g/ha applied on 7 December 2021.

Harvest date	16 December 2021.

Treatments and assessment

- The soil chosen was a vertosol with low AMF levels
- The soil had a starting AMF A+B level of 7 kDNA/g. (Based on PREDICTA®B testing). AMF:
  - levels <0.01 are considered below detection.
  - levels between 0.1 and 10 are considered low.
  - levels between 10 and 20 are considered medium.
  - levels >20 are considered high.
- The variety PBA Seamer⫽ was grown with 6 treatments (Table 2).
- PBA Seamer⫽ is an NGR desi chickpea that is moderately resistant to ascochyta blight and phytophthora root rot. PBA Seamer⫽ is broadly adapted from central NSW to central Queensland
- All chickpea seed was inoculated at the recommended rate with the *Mesorhizobium ciceri* strain CC1192, the commercial Group N legume inoculant (NoduleN™ – New Edge Microbials).
- For the +AMF treatments, chickpea was inoculated with a commercially available AMF inoculum (EndoFuse® – Sumitomo Chemical Australia) at the recommended rate of 15 mL/ha.
- The commercial AMF product was used a research tool to alter soil AMF levels in specific treatments. The experiment did not intend to simply validate the effectiveness of the product.
- Planting rate was 89 kg/ha.
- For +fertiliser treatments, 60 kg/ha Granulock®Z (Incitec Pivot Fertilisers) was banded below the seed (6.6 kg N/ha, 13.08 kg P/ha, 2.4 kg S/ha, 0.6 kg Zn/ha).
- Treatments not requiring fertiliser were balanced for N and S using urea and gypsum respectively.

Table 2 Treatments established at Tamworth, 2021.

Treatment number	Treatment name	Treatment description
1	nil	Control: chickpea seed, nil fertiliser, nil AMF as seed treatment, nil AMF in-furrow
2	+fertiliser	Chickpea seed + fertiliser
3	+AMF seed	Chickpea seed + AMF as seed treatment
4	+AMF furrow	Chickpea seed + AMF inoculum in-furrow
5	+fertiliser +AMF seed	Chickpea seed + fertiliser + AMF as seed treatment
6	+fertiliser +AMF furrow	Chickpea seed + fertiliser + AMF in-furrow

Measurements taken

Roots from each treatment were scored for nodulation 16 days post sowing. Nodulation scores measured the number, size, location and activity of nodules (Howieson and Dilworth 2016). Plants were given scores of between zero (absent) and 8 (extremely abundant). A score of 4 is considered adequate. The roots of 15 plants per plot were scored. Root nodulation was used as a health indicator for the association between chickpea and rhizobia.

Roots from each treatment were also assessed for AMF root colonisation 16 weeks post sowing. Roots were cleared, stained and assessed microscopically. Colonisation percentages were determined using the magnified-intersection method (McGonigle et al. 1990).

Grain yield for each plot was measured with a plot harvester 30 weeks after sowing.

Data was analysed using analysis of variance (ANOVA) with Genstat for Windows, 19th edition (Genstat 2018). Treatment means were compared using least significant difference (l.s.d.) with significant differences accepted at $P<0.05$.

Figure 1 Chickpea growing on a vertosol soil with a series of treatments to determine the potential effects of low soil AMF levels on yield at Tamworth, 2021.

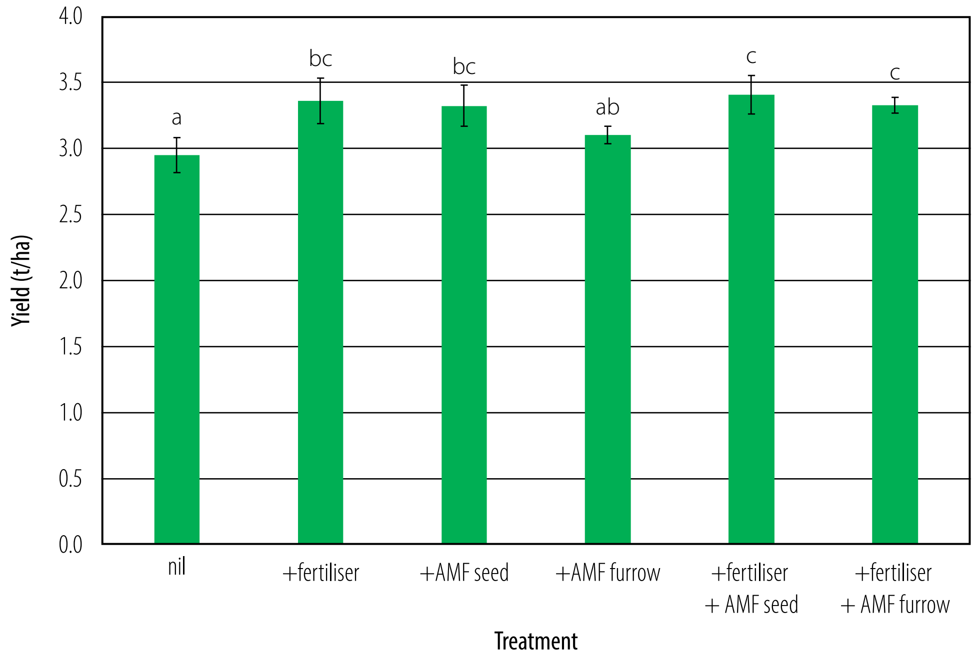
Results

Grain yield

- The average grain yield across all treatments was 3.24 t/ha (Figure 2).
- A significant yield increase was recorded from all treatments excluding the +AMF furrow treatment compared with the control (2.95 t/ha).
- The +fertiliser treatment resulted in a significant yield increase of 410 kg/ha (3.36 t/ha yield) compared with the control.
- Inoculation with AMF as a seed coat (+AMF seed) resulted in a significant yield increase of 373 kg/ha (3.32 t/ha yield) compared with the control.
- A non-significant yield increase of 150 kg/ha (3.1 t/ha yield) was recorded from the +AMF furrow treatment compared with the control.

Root nodulation

- The number of nodules on the roots of plants from the nil, +AMF seed and +AMF furrow treatments did not significantly differ 16 weeks post-sowing (Table 3).
- A significant increase in root nodulation occurred where plants were fertilised, either with starter fertiliser or when combined with AMF (Table 3).
- Across all treatments, plant roots had a nodulation score of 4 that is considered at least adequate.



Letters indicate significant differences between treatments (*P*<0.05, l.s.d. = 0.32 t/ha). Vertical bars represent standard error.

Figure 2 Average chickpea grain yield at Tamworth, 2021.

Table 3 Number of root nodules on plants at Tamworth, 2021.

Treatment number	Treatment name	Number of nodules* (nodules/plant)	Nodulation score#
1	nil	24.1[a] (13)	4
2	+fertiliser	43.6[b] (21)	4.5
3	+AMF seed	25.08[a] (13)	4
4	+AMF furrow	25.67[a] (13)	4
5	+fertiliser +AMF seed	44.15[b] (22)	4.5
6	+fertiliser +AMF furrow	46.33[b] (10)	4.5

* Letters indicate significant differences between treatments (*P*<0.05, l.s.d. = 8.3). Number in bracket represents standard error.

\# Scores range from zero (absent) and 8 (extremely abundant). A score of 4 is considered adequate

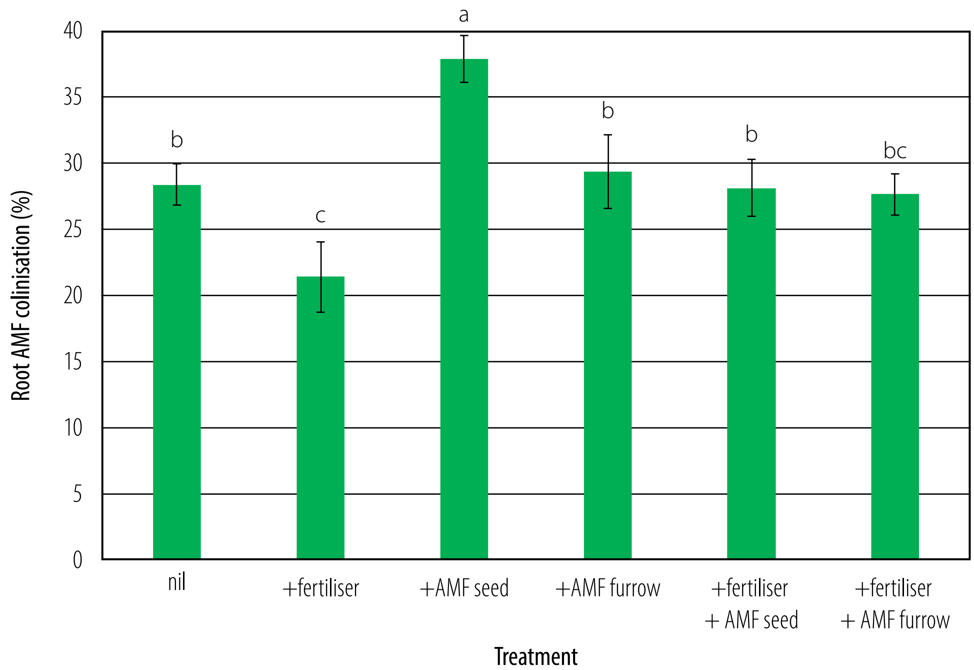
Root AMF colonisation

- The average colonisation rate of plant roots across all treatments was 29% (Figure 3).
- The highest colonisation rate (38%) was where AMF was used as a seed coat (+AMF seed). Root colonisation in this treatment was significantly higher than for any other treatment.
- The lowest root colonisation (22%) was for the +fertiliser treatment.

Conclusions and future work

Chickpea yield was limited by low starting soil AMF levels. Increasing soil AMF levels using a commercial inoculum as a seed coat (+AMF seed) resulted in a significant 13% yield increase compared with the nil (control) treatment (Figure 2).

The +fertiliser treatment yield was also significantly higher compared with the nil treatment (14% higher). Enhancing soil AMF levels in-furrow (+AMF furrow) did not significantly increase yield compared with the nil treatment (a 5% increase).



Letters indicate significant differences between treatments (*P*<0.05, l.s.d. = 6.53%). Vertical bars represent standard error.

Figure 3 Root AMF colonisation of plants at Tamworth, 2021.

The results of this experiment demonstrate that the current practice of starter fertiliser application can reduce effects from low starting soil AMF levels on chickpea yield, even in soils with moderate levels of P. But the experiment also demonstrated that potential yield limitations can be overcome by increasing soil AMF levels. In this experiment, this was achieved through AMF inoculation as a seed coat (+AMF seed). The yield from the +fertiliser treatment was not significantly higher than the yield from the +AMF seed treatment. A combination of fertiliser and AMF (seed coat or in-furrow) did not have a cumulative benefit greater than that that of either fertilisation or AMF inoculation (seed coat or in-furrow) alone.

Grain yields across all treatments were relatively high (Figure 2) and probably reflected the significant rainfall that the crop received in 2021 (565 mm in-crop) compared with long-term annual averages (603 mm) for Tamworth.

AMF inoculation did not increase root nodulation in this experiment. The root nodule numbers from the nil treatment were not significantly different from plants that were inoculated with AMF as either a seed coat or in-furrow (Table 3). Plants from the fertilised treatments had significantly higher nodule numbers than plants from the non-fertilised treatments (Table 3). Applying starter fertiliser would have promoted early vigorous root growth that would have influenced nodule formation, growth and number. Crop N-fixation was not measured in this experiment.

A significant increase in AMF root colonisation was recorded from the +AMF seed treatment compared with the nil treatment (Figure 3). Inoculating seed with the AMF inoculum resulted in increased root colonisation along with significantly increased grain yield. The lowest root colonisation recorded was from the +fertiliser treatment. Fertiliser application can result in reduced levels of AMF colonisation as crops are able to preference readily available nutrients (e.g., fertiliser) over forming associations with AMF (Venegas et al. 2021). The latter association costs the plant energy, but is more beneficial long-term.

Soil PREDICTA®B testing throughout the season showed that levels of select AMF were highest in the soil at flowering (data not shown). Plant roots would have had plenty of biomass at this growth stage and would have still been actively growing, increasing AMF activity in soil. Soil AMF levels were also higher in the autumn of 2022 than at the start of the trial in June 2021, including in the nil treatment.

The experiment showed that soil AMF levels can be significantly increased over a season, even by growing an AMF-dependant crop such as chickpea without applying AMF inoculum or starter fertiliser.

The conclusions made in this report are drawn from one pilot experiment conducted over a single season. Yield losses of 13% and 14% respectively were recorded where chickpea was not inoculated with AMF or fertilised. This was in soils where the starting levels of P were moderate, rather than low. The potential yield losses of 20–60% described by Thompson et al. (2017) would have been mitigated in this experiment due to the amount of rainfall the crop received. Further studies investigating the influence of low soil AMF levels on chickpea yield need to be done in drier seasons in soils with lower P levels. This would increase our understanding of the role that AMF play in chickpea P acquisition. Future work will investigate the potential to reduce fertiliser input where soil AMF levels are adequate as well as a more detailed analysis of soil and crop nutrient levels.

Growers are advised to monitor soil AMF levels, especially following periods of drought, prolonged fallow or after the growth of a non-mycorrhizal crop. PREDICTA®B testing can enable growers to easily measure soil AMF levels. If growers identify low soil AMF levels, crops with low AMF dependency (e.g. wheat/barley) should be considered. These crops will not be significantly affected by low soil AMF levels, but will increase AMF populations. Growers should be looking to maintain soil AMF levels over multiple seasons by applying management strategies such as avoiding growing non-AMF crops and reducing tillage. This experiment demonstrated that growers could record yield increases of 13% by having increased soil AMF levels, compared with applying fertiliser.

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Investigating the growth of imidazolinone-tolerant chickpea

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Key points

- This study assessed the growth of an imidazolonine (imi)-tolerant chickpea line being developed by Chickpea Breeding Australia (CBA) under controlled conditions at Tamworth in 2020.
- Growth and root nodulation of imi-tolerant chickpea was similar to that of PBA Seamer⁽ᵈ⁾ in control soil.
- PBA Seamer⁽ᵈ⁾ growth was significantly reduced in the presence of imazapic, whereas imi-tolerant chickpea growth was only significantly reduced where plants were grown in soil where imazapic was applied at the high rate of 72 g/ha.
- Results from this experiment suggested that the imi-tolerant chickpea line was tolerant of imazapic when the herbicide was applied at the recommended rate of 36 g/ha.

Introduction

Chickpea is a key break/rotational crop in the cereal-dominated northern grains region (NGR) of northern NSW and southern/central QLD (Aslam et al. 2003). The decision to grow a break crop is based on a number of factors including the profitability of the crop, cereal disease pressure and herbicide resistance, with chickpea capable of providing a number of benefits in crop rotation (Herridge 2009). In recent years, the demand for chickpea from the sub-continent has seen an increasing number of growers in the NGR sow chickpea (mainly desi type). Chickpea production has steadily risen, with a record production year in 2016. Chickpea production fell between 2017 and 2019, due to drought conditions.

Group 2 herbicides inhibit the acetolactate synthase (ALS) enzyme, which depletes the key branched-chain amino acids required for plant growth (Cobb and Reade 2010).

Group 2 herbicides are classed into 4 groups:

1. imidazolinones
2. sulfonylureas
3. pyrimidinylthiobenzoates
4. triazolopyrimidines.

Group 2 herbicide use is increasing across the NGR to manage problem grasses and broadleaf weeds. For example, applying Group 2 herbicides such as Flame®, an imi herbicide, in fallows is now common practice to help control annual summer grass weeds such as feathertop Rhodes grass and awnless barnyard grass. The plant-back period for Flame® is approximately 4 months for chickpea, with recent research suggesting this could be closer to 8 months.

Plantback periods can be lengthened or shortened by:

- soil type (e.g. clay or sand, acid or alkaline)
- environmental factors (e.g. moisture and temperature)
- microbial activity.

Soil type is a key driver of herbicide persistence, with imidazolinone herbicides generally more persistent in acidic soils. Growers must pay close attention to these soil parameters as Group 2 herbicide residues can be extremely damaging to sensitive crops, including chickpea.

The South Australian Research and Development Institute (SARDI) conducted initial evaluations of chickpea lines with desirable herbicide-tolerant traits. Following the identification of these traits, CBA is currently developing imi-tolerant desi chickpea lines. This 2020 pilot study contributed towards early studies that assessed the growth of select (derived) material – CBA2061 (Croser et al. 2021). The aim of this experiment was to assess the growth of this material line in the presence of imazapic compared with the commercial variety PBA Seamer⌽. The results from this work were to ideally generate proof of concept data that would contribute to commercialising the imi-tolerant material. The key characteristics assessed included root nodulation and plant biomass when plants were grown in soil where imazapic was applied at a number of rates. The chickpea plants were grown for 15 weeks under controlled conditions.

Methodology

Pot experiment set up and treatments

Imi-tolerant chickpea seed was obtained from CBA, Tamworth, NSW.

All seed was inoculated with *Mezorhizobium ciceri* (CC1192), the commercial Group N rhizobial strain.

The imidazaolinone herbicide Flame®, 240 g/L imazapic, was used.

PBA Seamer⌽ and the imi-tolerant chickpea material had 4 different treatments applied:

1. control, no herbicide applied to the soil
2. imazapic applied to the soil at 36 g/ha, added at the start of the experiment
3. imazapic applied to the soil at 72 g/ha, added at the start of the experiment
4. no herbicide applied to the soil at the start of the experiment, imazapic applied to the soil at 36 g/ha 5 weeks post-planting (Table 1).

Treatment 4 was an unconventional application method for imazapic and was used as an experimental treatment to test how tolerant the imi-tolerant chickpea material was to an over the top (OTT) spray treatment. Imazapic is not registered for use in this manner.

Table 1 Treatments established at Tamworth.

Treatment	Product (Flame®) application rate, (mL/ha)	Concentration of active (imazapic) applied (g/ha)	Chickpea
1	0	0	PBA Seamer
			Imi-tolerant CBA2061
2	150 commercially recommended rate	36	PBA Seamer
			Imi-tolerant CBA2061
3	300	72	PBA Seamer
			Imi-tolerant CBA2061
4	150	36 OTT, over the top	PBA Seamer
			Imi-tolerant CBA2061

- Plants were grown in 175 mm squat plant pots of approximately 2.1 L in volume.
- One plant per pot, four replicates of each treatment.
- Pots were maintained for 15 weeks within a glasshouse facility at the Tamworth Agricultural Institute (31° 15′ 00.38″ S, 150° 96′ 61.47″ E), Tamworth NSW 2340, with a maximum temperature of 25 °C.
- For treatment 2 and treatment 3, herbicide was applied once at the start of the experiment. Pots were watered to capacity with a volume of imazapic that the equivalent area of soil would receive in the paddock to obtain the targeted application rate.
- For treatment 4, imazapic was applied at 5 weeks post-planting using a boom spray over the plants. Plants were at the 5–6 node growth stage.
- All pots were hand-watered weekly to maintain growth.

Soil type and nutrition

Dark earth (vertosol).

The soil used in the pots was collected from the NSW DPI Liverpool Plains Field Station at Breeza. The soil represented a 'typical' cropping soil from the district and consisted predominantly of surface soil (0–10 cm). The collected soil was passed through a 2 mm sieve and analysed for starting nutrition (Table 2).

Table 2 Characteristics of soil used in pot experiment.

Soil characteristic	Value
Ammonium nitrogen (mg/kg)	8
Nitrate nitrogen (mg/kg)	54
Phosphorus, Colwell (mg/kg)	40
Organic carbon (%)	1.24
Potassium, Colwell (mg/kg)	509
pH_{Ca}	7.5

Assessment

Root nodulation

- Eight weeks post-planting, plant roots were evaluated for nodulation using scores of between 0 (no nodulation) and 8 (extremely abundant nodulation).
- Scores measured nodule number, size, location and activity (Howieson and Dilworth 2016). Scores were used as an indicator of the interaction between the chickpea plants and rhizobia.
- Additional pots were established at the start of the experiment that were destructively harvested for root nodulation.

Plant biomass

- Fifteen weeks post-planting, individual plants were removed from each pot and excess soil washed off the roots. Plant material was then dried at 40 °C for 72 hours and weighed to establish plant biomass, which was used as an indicator of plant health.

Herbicide levels in soil

- Triple quadrapole mass spectrometry was used to analyse herbicide levels in the soil.
- A day (24 hours) after pots were established, a 5 g soil sample was taken from each pot and immediately stored at –20 °C before analysis.
- Samples were taken using a mini soil corer 100 mm long.
- Soil samples taken from pots of the same treatment were combined into a single sample for analysis.
- Herbicide levels from the treatment 4 soil were also further analysed a day after the OTT herbicide application. Here, all samples (from both PBA Seamer[(b)] and imi-tolerant pots) were combined into a single sample for analysis.

Analysis

- Plant biomass was analysed via analysis of variance (ANOVA) using Genstat for Windows (Genstat 2018).
- Treatment means were compared using least significant difference (l.s.d.) with significant differences accepted at *P*<0.05.

Results

Imazapic levels in soils

- The imazapic concentration in soil increased with increasing herbicide rates (Table 3).
- Imazapic was not detected in the control soil.

- An average concentration of 57.5 ng/g imazapic was recorded where herbicide was applied at the recommended commercial rate of 150 mL/ha at the start of the experiment (treatment 2).
- The OTT imazapic application (treatment 4) resulted in the highest level of herbicide from any treatment. This type of imazapic application most likely resulted in the herbicide not being evenly distributed throughout the soil, compared with the application method used in treatments 2 and 3.

Table 3 Imazapic concentration in soils from different treatments.

Treatment	Imazapic application rate (g/ha)	Chickpea	Imazapic concentration in soil (ng/g)
1	0	PBA Seamer	0.0
		Imi-tolerant CBA2061	0.0
2	36	PBA Seamer	56.0
		Imi-tolerant CBA2061	58.9
3	72	PBA Seamer	194.0
		Imi-tolerant CBA2061	175.7
4	36, OTT	PBA Seamer	0.0 (Herbicide level tested before the OTT application)
		Imi-tolerant CBA2061	0.6 (Herbicide level tested before OTT application)
		PBA Seamer Imi-tolerant CBA2061	291.0 (Herbicide level tested after OTT application)

Root nodulation

- Root nodules were recorded on all plants except for the PBA Seamer$^{\Phi}$ plants grown in soil treated with imazapic at 36 g/ha and 72 g/ha (Table 4).
- The highest nodulation score recorded was 3.
- Root nodulation of the imi-tolerant plants was equal to or higher than PBA Seamer$^{\Phi}$ root nodulation plants in every treatment.

Table 4 Chickpea root nodulation for each treatment.

Treatment	Imazapic application rate (g/ha)	Chickpea	Nodulation score
1	0	PBA Seamer	3
		Imi-tolerant CBA2061	3
2	36	PBA Seamer	0
		Imi-tolerant CBA2061	3
3	72	PBA Seamer	0
		Imi-tolerant CBA2061	2
4	36, OTT	PBA Seamer	2
		Imi-tolerant CBA2061	3

A score of 0 represents no nodulation and a score of 4 represents adequate nodulation.

Plant growth

- Visual differences in plant shoot biomass were obvious between treatments in early plant growth, particularly with PBA Seamer⁽ᵇ⁾.
- Eight weeks post-planting, there was a clear biomass reduction in PBA Seamer⁽ᵇ⁾ plants grown in soil treated with imazapic (treatments 2 and 3) compared with the control plants (Figure 1).
- Differences in biomass were not obvious 8 weeks post-planting when comparing imi-tolerant plants grown across all treatments (Figure 2).
- Fifteen weeks post-planting, the average biomass of PBA Seamer⁽ᵇ⁾ and imi-tolerant plants grown in the control soil (treatment 1) was not significantly different (Figure 3).
- A significant reduction in biomass was recorded when PBA Seamer⁽ᵇ⁾ plants were grown in soil where imazapic was applied at any rate and at any stage (treatments 2, 3 and 4).
- A significant reduction in imi-tolerant plant biomass was only recorded in Treatment 3 where imazapic was applied to the soil at 72 g/ha (Figure 3).

Figure 1 Eight-week-old PBA Seamer⁽ᵇ⁾ plants grown in soil treated with 0 g/ha (A), 36 g/ha (B) and 72 g/ha (C) of imazapic. Also pictured (D) is a plant grown in unamended soil for 5 weeks before an OTT imazapic at 36 g/ha application.

Figure 2 Eight-week-old imi-tolerant plants grown in soil treated with 0 g/ha (A), 36 g/ha (B) and 72 g/ha (C) of imazapic. Also pictured (D) is a plant grown in unamended soil for 5 weeks before an OTT imazapic at 36 g/ha application.

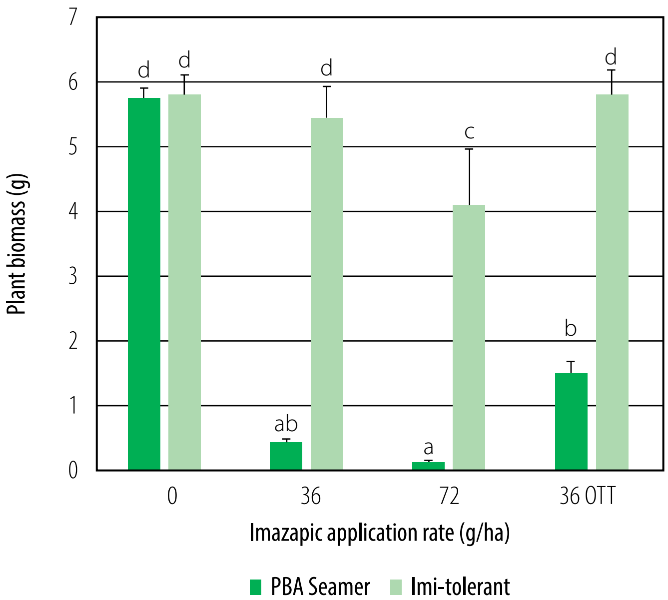

Figure 3 Average plant weight of PBA Seamer⁽ᵇ⁾ and imi-tolerant chickpea after 15 weeks of growth.

Conclusions and future work

The aim of this pot experiment was to investigate the growth of imi-tolerant chickpea material being developed by CBA. The experiment analysed the imi-tolerant material growth compared with PBA Seamer$^{\Phi}$, as well as imi-tolerant material growth in the presence of imazapic at specific rates. Plant biomass was the main measurement used to determine plant growth. The experiment was conducted under controlled conditions.

After 15 weeks of growth, the imi-tolerant plants produced biomass similar to that of PBA Seamer$^{\Phi}$ (Figure 3). Significant plant biomass reductions were measured where PBA Seamer$^{\Phi}$ was grown in soil where imazapic was applied, either at the start of the experiment or with an OTT application after plant emergence. Imazapic impeded PBA Seamer$^{\Phi}$ growth; imazapic inhibits key amino acid production, which is necessary for protein synthesis and growth. There was a significant growth reduction in the imi-tolerant material where plants were grown in soil where imazapic was applied at double the commercially recommended rate (72 g/ha, treatment 3).

The experiment showed that there is no negative growth effect on plants containing the imi-tolerant trait when compared with conventional PBA Seamer$^{\Phi}$ growth, under the controlled conditions used in this experiment. The results from this pot experiment suggests that the imi-tolerant material tolerated imazapic up to the commercially recommended rate of 36 g/ha, equivalent to 150 mL/ha Flame®.

The root nodulation analysis also indicated that the imi-tolerant trait has no effect on the symbiotic relationship that roots form with rhizobia. Imi-tolerant and PBA Seamer$^{\Phi}$ root nodulation were similar. Nodulations scores in the control soil were slightly below average for PBA Seamer$^{\Phi}$ and imi-tolerant chickpea, but the soil used in this study did have relatively high starting nitrate levels.

Root nodulation was reduced in the presence of imazapic, particularly in PBA Seamer$^{\Phi}$. This reduction in nodulation corresponded to the reduced below-ground biomass where plants were grown in imazapic-treated soil (data not shown). The herbicide itself could have potentially reduced rhizobial numbers in the soil as well.

This experiment was conducted under controlled conditions over a limited period. Though valuable data was collected as part of the initial imi-tolerant material studies, future studies should include a suitably measured imi-tolerant material growth under field conditions over an entire cropping season. The potential tolerance to other Group 2 herbicides should also be tested.

CBA is continuing to study the imi-tolerant material. Such material has the potential to be integrated into farming systems in the NGR and could provide growers with increased chickpea sowing options, particularly around using Group 2 herbicides that provide growers with an important tool to help control problem weeds such as feathertop Rhodes grass.

Acknowledgments

This project was part of the Grains Agronomy and Pathology Partnership (GAPP) between NSW DPI and the Grains Research and Development Corporation (GRDC). Project BLG113, 'Pilot – Investigating the growth of Imidazolinine and Sulfonylurea tolerant chickpea'. Assistance provided by the technical and farm staff at the Tamworth Agricultural Institute is gratefully acknowledged. We would especially like to acknowledge Bruce Haigh for his help with experiment design and analysis. We would like to thank Kristy Hobson and CBA for allowing us access to the imi-tolerant material and for general advice. We would like to acknowledge SARDI for playing a role in the development of the imi-tolerant material. We would also like to acknowledge Mick Rose (NSW DPI Wollongbar) for his help in analysing herbicide levels in soils. The authors are thankful to Penny Heuston and Carey Martin for the constructive suggestions and comments in the development of this report.

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Safflower agronomy research in NSW

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Key findings

- In the 2021/22 growing season, the performance of super high oleic safflower (SHOS) crops in NSW was mixed. Benchmarking highlighted varying agronomic practices. Crop establishment, in-crop management practices and crop yields were inconsistent.
- Overall confidence of growers and agronomists in their agronomic knowledge of safflower is low.
- There is an incomplete understanding of safflower's role in different farming systems. Robust information surrounding safflower's legacy effects on pathogens, weed species dynamics, soil nutrient use, soil water and soil structural changes is required. The reasons for the responses in subsequent crops are often simplistic and frequently rely on anecdotal evidence.
- Safflower has the capacity for growth compensation to adjust to variable growing conditions. Better knowledge of safflower physiology and adapting crop management practices to suit regional environments will maximise water use efficiency (WUE) and yield potential.
- Care is required to ensure crop performance expectations of this new industry are realistic with current crop genetics.
- Ongoing research, development and extension will be crucial to ensure SHOS achieves its potential and becomes a reliable and profitable component of farming systems.

Key words Safflower, research, establishment, super high oleic

Background

Safflower has been grown in Australia since the late 1950s. Production areas have fluctuated widely due to factors that include variable prices, disease, poor seasons and alternative oilseed crops with different market options. National production peaked at 74,688 ha in 1979.

The industry was initially based on the American variety Gila, which is highly susceptible to alternaria (*Alternaria carthami*). In 1987, the first Australian safflower varieties Sironaria and Sirothora were released from the CSIRO safflower breeding program based in Griffith, NSW. Sironaria is resistant to alternaria and Sirothora has improved phytophthora (*Phytophthora cryptogea*) resistance.

Two main types of conventional safflower were grown: low oleic (LO) and high oleic (HO) oil varieties. Originally grown to supply oil markets for industrial uses, the market development and expansion of vegetable oils in the food industry dominated after several decades. The domestic birdseed and small animal-feed market remains small and volatile, based on white-coloured seed varieties.

Safflower research in NSW has largely been focused on northern NSW, where it was regarded as being best suited to vertosols with high water-holding capacity. Consistently referenced as a drought- and heat-tolerant crop, safflower's traditional fit in farming systems has been as a late sowing option in winter crop seasons, sown between June and August. It has also been grown in cotton farming systems, principally in the role as a soil ameliorant to break up compacted soil layers and dry down soil profiles.

Figure 1 High quality commercially harvested safflower seed.

Super high oleic safflower (SHOS) was developed after 11 years of investment and research in the Crop Biofactories Initiative, a partnership between GRDC and CSIRO. The partnership emerged as the increasing global demand for sustainable, renewable, and biodegradable industrial products was recognised. Specialised oilseed crops could provide an alternative to palm and crude oils.

In late 2015, GO Resources Pty Ltd became the commercial partner to develop and commercialise the new industrial oil industry. Commercial production of SHOS in south-eastern Australia began in 2019 after the required regulatory approvals were granted. Delta Agribusiness Pty Ltd has the distribution and marketing rights for SHOS crops grown in south-eastern Queensland, NSW, and Victoria.

Grown in a closed loop marketing system under contract, 1,700 ha of the first-generation variety E40-R was sown in NSW during 2019 for a $650/t 'farm gate' contract price.

Past research – conventional safflower

Safflower research in Australia has evolved to include collaborative relationships between federal and state government departments, universities, grower organisations, and the GRDC. Investigations have often been focused on adapting foundational agronomic safflower practices (e.g. time of sowing, population, nitrogen (N) response, etc.) in regional grain growing areas. The incidence of unfavourable seasons, coinciding with short-term projects, has often resulted in limited data.

NSW DPI has mainly conducted research in northern NSW. From 2004, a 3-year NSW DPI project, 'SIP08. Northern Grains Region - Combating subsoil constraints', investigated the response of winter crops, including safflower, to subsoil constraints such as salinity and/or sodicity (topsoil was unconstrained). Two linoleic varieties were grown: Saffola 555 and Gila. The overall yield loss measured in safflower, barley, canola, and mustard was 17%, compared with 15% in wheat, 24% in faba bean and 36% in field pea.

In 2015, the NSW DPI–GRDC jointly funded the 3-year project 'Tactical agronomy of minor crops (safflower, linseed, sunflower)'. Safflower experiments involving the conventional varieties Sironaria and S317 focused on optimising sowing date, populations, and row configurations in northern NSW. Some of the findings were that a wide range of plant populations and row spacings could maintain yield potential, that yield declined with later sowing dates, and other detailed regional crop phenology.

Figure 2 Commercial crops of safflower showing adequate plant stands.

Super high oleic safflower (SHOS) research

GRDC/CSIRO/NSW DPI

The 'Northern NSW safflower evaluation and seed increase project, 2011–2015' (DAN00153), evaluated genotypes from Mexico and the USA for the GRDC/CSIRO Crop Biofactories Initiative. Six potential lines and 105 single plant selections from 12 segregating lines were evaluated to provide a genetic base for future crop development.

In 2013/14, further evaluation of selected lines took place at Rowena, Narrabri and Tamworth, in northern NSW.

The first field trials of SHOS tested the varietal line Event 26 (E26). E26 was sown with conventional safflower varieties, including S317. The 3 trials were located at Bellata (northern NSW), Kalkee, and Kaniva (both western Victoria) during the 2015/16 growing season.

GO Resources Pty Ltd

In late 2015, GO Resources Pty Ltd became the commercial partner to develop and commercialise SHOS. Since then, GO Resources has invested approximately $10 M into targeted research on developing crop management packages at locations throughout NSW, Queensland, Victoria, South Australia (SA), and Western Australia (WA). This research is ongoing.

Research has included, but is not limited to:

- SHOS breeding program
- SHOS variety evaluation
- sowing date × SHOS variety/line
- herbicide tolerance screening
- crop nutrition
- saline/sodic soil tolerance
- seed treatments
- farming systems – crop response after safflower
- glass house – SHOS variety tolerance to sodic and saline soils.

Delta Agribusiness

Delta Agribusiness has investigated a wide range of agronomic issues. Some examples include individual and comparative winter crop performance (yield, soil water use, WUE, $/ha/mm, kg/ha/mm, $/ha), populations, row spacing configurations, sowing dates, herbicide screening and crop nutrition. Targeted research is ongoing.

Other

Independent regional grower solutions groups such as the Northern Grower Alliance (NGA) and the Birchip Cropping Group (BCG) and others have also conducted regionally specific SHOS research.

GRDC

In 2022, GRDC has funded SHOS crop nutrition research in WA, SA, Victoria, and NSW.

NSW DPI/GRDC

The 'Safflower agronomy' project was initiated and developed in 2021 under the NSW DPI/GRDC Grains Agronomy and Pathology Partnership (GAPP). One of the project outcomes was identifying what was learned from current agronomic management practices and industry knowledge. A large component of this was a state-wide safflower production benchmarking project during the 2021/22 growing season.

The research objectives of this part of the project included:

1. benchmarking the current crop performance

2. identifying current safflower management practices and comparing key agronomic indicators between crops
3. quantifying crop growth and development responses across diverse growing environments and farming systems.

Some of these findings are presented in this paper.

Bilateral GAPP safflower agronomy project

Crop locations

All 2021 NSW-registered SHOS growers with Delta Agribusiness participated in the crop benchmarking. Twenty-seven crops were benchmarked, totalling 2,038 ha, equivalent to two-thirds of the NSW SHOS crop area. All crops were sown with the first-generation variety E40-R, released in 2019. Crop locations are shown in Figure 3.

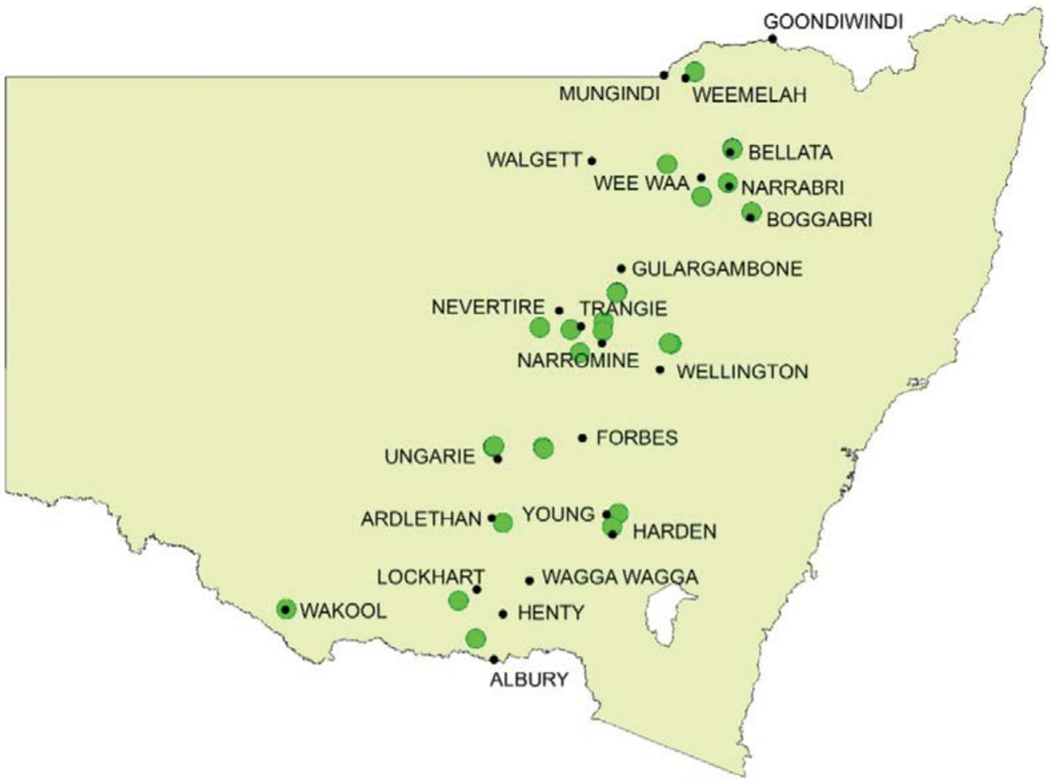

Figure 3 Benchmarked SHOS crops in NSW in 2021/22.

Findings

Industry knowledge and perceptions of SHOS

At the start of the project, growers and advisors from the 2020/21 and 2021/22 growing seasons were asked specific questions to compile their knowledge, understanding, and expectations of SHOS. Some examples follow.

Why did you grow SHOS?

The main reason growers grew SHOS was because it was a 'late crop option'; offered 'crop diversity'; or as a 'soil ameliorant'.

A range of other responses included annual ryegrass management; 'an experiment' (4 growers); income; rotation benefits; sodicity tolerance; logistics and 'sowed it on a whim' (2 growers).

Further comments:

- 'I think it's an exciting crop to sow'
- 'Market is excited about it, so interested to see what it has to offer'
- 'Useful tool to dry out the soil to manage salt issues'
- 'Hope it puts N [nitrogen] back in'
- 'Told it would yield $2.5 t/ha, money okay, sounded attractive'
- 'Flexibility of sowing time'
- 'Taproot to break up the soil'.

How would you rate your knowledge of safflower agronomy?

Individuals were asked to rate their personal level of safflower agronomy knowledge out of 5, where 5 rated 'excellent' and one equalled 'poor'. Answers are shown in Figure 4. The average response was 2 out of 5.

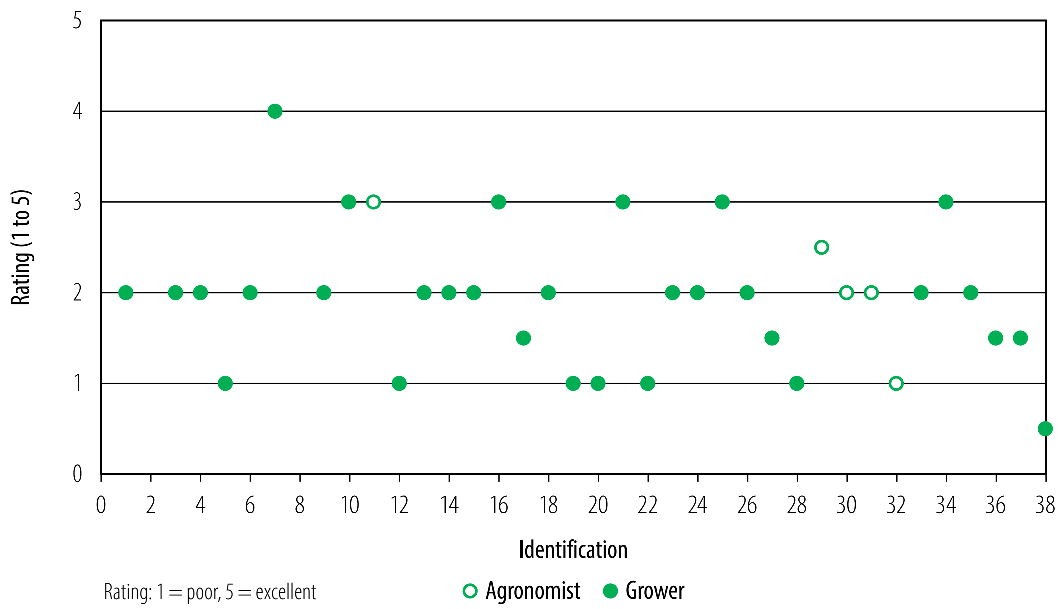

Figure 4 Self-rating of agronomic knowledge by growers and advisors.

Crop benchmarking

Role of SHOS in the farming system

Most safflower crops were sown after 2020 winter crops, predominantly wheat, but also one chickpea crop. Three were sown as a late option after failed 2021 barley and lupin crops, and 3 directly after pasture phases. One crop was sown into a 2020/21 cotton field.

Growers were asked what specific role/s they saw for SHOS in a farming system context. The leading four benefits of safflower in a farming systems context were:

1. reduced soil-borne pathogens such as crown rot and take-all
2. An opportunity for non-selective weed control with later sowing dates
3. annual ryegrass resistance management
4. increased crop diversity and reduced economic risk.

Safflower's role as a soil ameliorant and its tolerance to sodic soils was mentioned as a benefit, but most crops in 2020/21 were sown into paddocks where soil characteristics were considered to be unconstrained. As one grower said, 'it's one of my better paddocks'.

Seeding rate and crop establishment

A common finding across most NSW crops was the wide variation in crop establishment of 5–47 plants/m^2. Seeding rates varied between 12 kg/ha and 25 kg/ha, with most crops sown at rates between 15 kg/ha and 20 kg/ha.

During discussions with growers about choosing seeding rates, no apparent adjustment was made for the sowing date. Selected sowing rates were based on:

- general recommendations of 18–20 kg/ha
- personal thoughts regarding a suitable rate
- quantity of seed on-hand and paddock size
- adjusting calibrations during sowing
- the cost of seed.

Figure 5 shows the relationship between seeding rate and crop establishment.

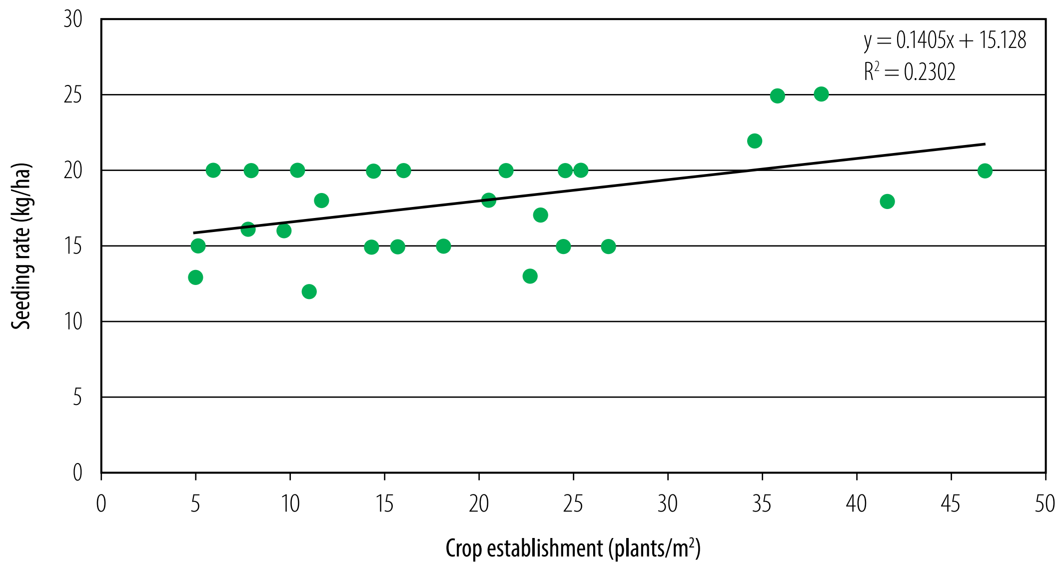

Figure 5 Relationship between seeding rate and population in SHOS crops in 2021/22.

Crop establishment and seeding depth

Seeding depth was measured for crops in the rosette growth stage at the first crop inspection. Results are shown in Figure 6. Average seeding depths varied between 15 mm and 44 mm. The low correlation with, and high level of, variation with plants established, strongly suggest other factors are affecting crop establishment in these crops.

GO Resources implements processes ensuring the supply of high-quality seed. This includes, but is not limited to: seed purity, harvest timing, storage standards, minimum germination thresholds and applying seed dressing e.g. thiram.

Many factors contribute to variable crop establishment including:

- environmental (e.g., temperature, moisture, soil chemical and physical characteristics)
- seed quality (e.g., germination, vigour)
- pests and diseases
- genetics (e.g. dormancy, hard seed)
- or a combination of the above.

There was no relationship between crop establishment and sowing date (data not shown). A summary of examples of other parameters investigated in relation to crop establishment are shown in Table 1. Results were inconsistent (detailed data not shown).

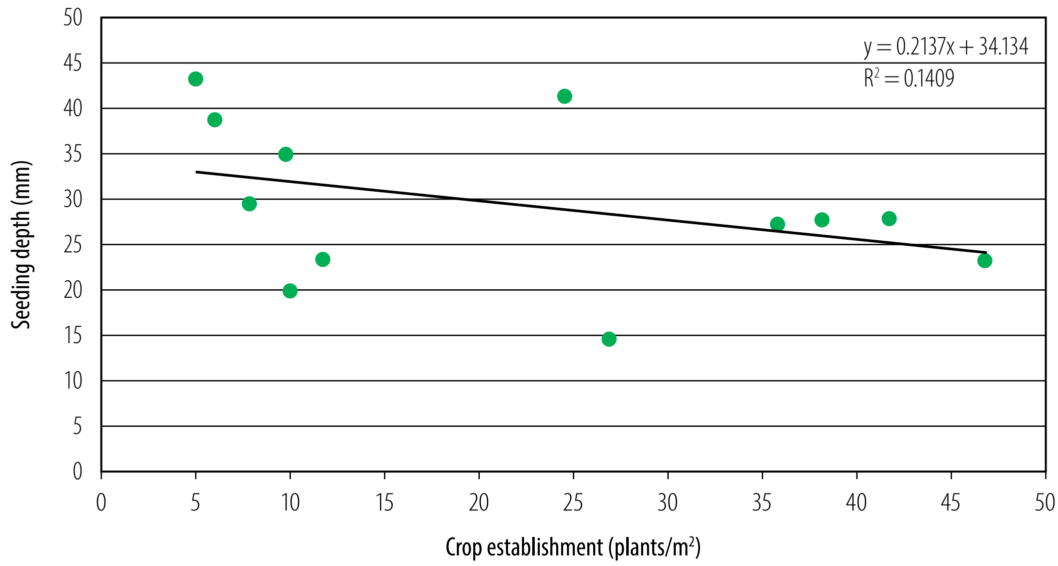

Figure 6 Relationship between seeding depth and crop establishment in SHOS crops in 2021/22.

Table 1 Sowing and seedbed characteristics of SHOS crops in 2021/22.

	Sowing speed (km/hr)	Seeding depth (mm)	Ground cover (%)	N with seed (kg/ha)	Phosphorus with seed (kg/ha)	Soil stability score	Ex. Sodium (%)	Salinity (ds/m)	pH_{Ca}	Seeds sown (no./m^2)	Seed est. (%)
Min.	6	15	0	0	0	0	0.1	0.04	4	32	11
Max.	11	44	57	13	23	13	12.6	0.43	8	56	91
Mean	9	29	18	6	11	8	3.3	0.11	6	43	41

Sowing date

Current recommendations are to sow E40-R in May, with some suggestions to move to as early as late April. Specific sowing windows for various growing regions are not specified. In 2021, sowing dates in NSW began on 20 May with the last crop sown on 8 October in 2021. Figure 7 shows the crop cycle of each benchmarked crop in 2021/22, extending from sowing date to harvest date. All crops were the variety E40-R.

In summary:

- Crop cycle length: 128–273 days
- sowing date: 22 May–8 October 2021
- flowering (F50): 28 October–26 December
- days to flowering: 80–219 days
- harvest: 16 October 202120 February 2022.

A knowledge gap frequently nominated by survey participants was identifying the best sowing time for their area. Participants also questioned how the sowing date would affect the timing of critical growth periods, soil water use patterns and harvest logistics.

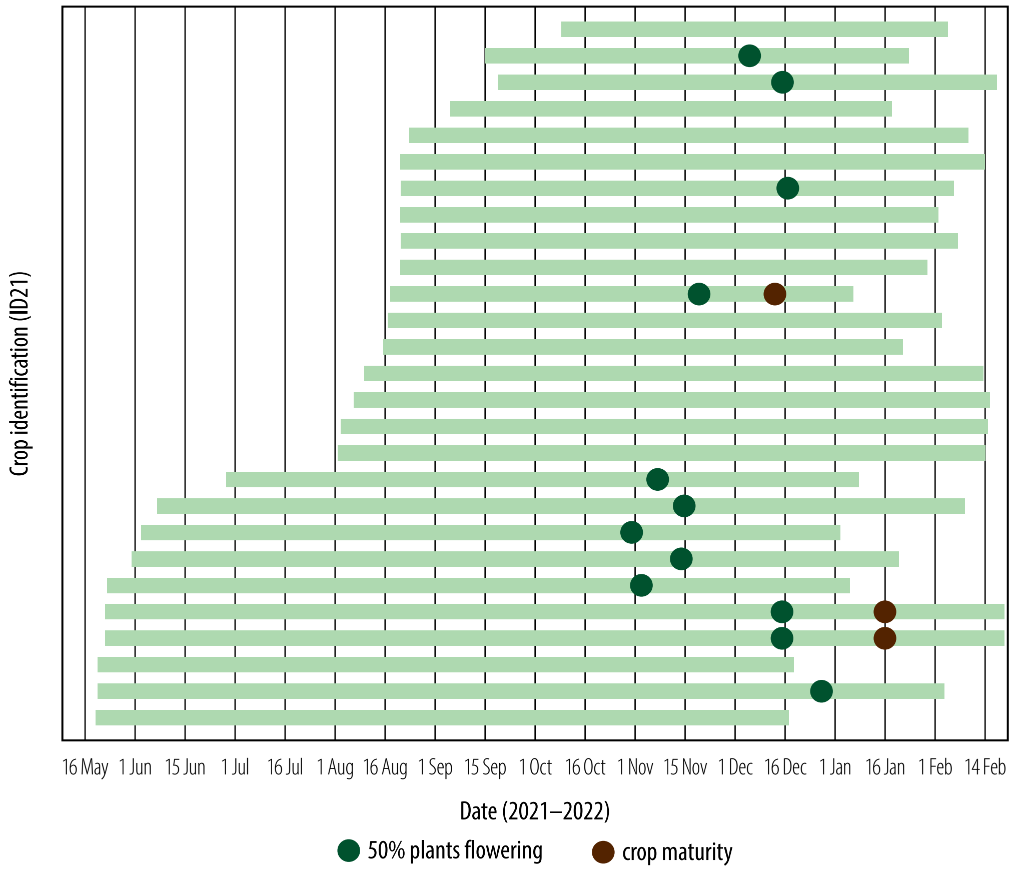

Figure 7 Crop cycles of SHOS crops in 2021/22.

Weed management

The approach to weed management was inconsistent. Most crops relied solely on herbicides for fallow weed management. Six crops were sprayed either with pre-emergent or post-sowing pre-emergent herbicides. In-crop herbicides were applied to approximately two-thirds of crops, including both registered products and those listed in current minor crop permits.

Knowledge of herbicide registrations and the limited arsenal available in safflower was well known to some growers, but other growers appeared to have minimal awareness of the lack of registered options. Agronomists were generally well informed about current registrations and permits, but some expressed the need for a comprehensive information package.

Nutrition

Soil nutrient status

Of the 27 safflower paddocks, soil tests were conducted in 4 paddocks before sowing. In most paddocks, it was several years since the last soil test was taken.

At the initial visit to each crop, soil was sampled from the centre of crop rows to avoid fertiliser placed with seed. The sampled depths were 0–10 cm and 10–30 cm. A selection of test results is shown in Table 2.

Table 2 SHOS paddock soil test results in 2021/22.

Soil depth	Ammonium N (mg/kg)	Nitrate N (mg/kg)	P– Colwell (mg/kg)	Potassium (K) – Colwell (mg/kg)	Sulfur (mg/kg)	Organic carbon (%)
0–10 cm						
Mean	4	19	45	439	7	1
Range	1–12	3–123	18–95	231–878	1.7–33.6	0.56–2.06
10–30 cm						
Mean	3	10	33	371	5	1
Range	2–9	2–41	14–87	191–726	1.9–13.6	0.52–1.59

*Note. These figures do not include results from paddocks where fertiliser was broadcast before sampling.

Crop nutrition

The nutritional requirements for safflower appear to be a major knowledge gap. When questioned about how fertiliser requirements were determined, at best 'similar to wheat' was the answer, with no follow-up detail given. Overall, there was no consistency in the approach to crop nutrition.

There was little evidence of growers or advisors estimating crop requirements, considering previous crop removal rates, or conducting soil nutrient budgets. Some crops received several fertiliser inputs during the crop cycle, while others received nil. Figure 8 shows the total amount of N applied to each crop. Rates varied between 0 kg N/ha and 72 kg N/ha.

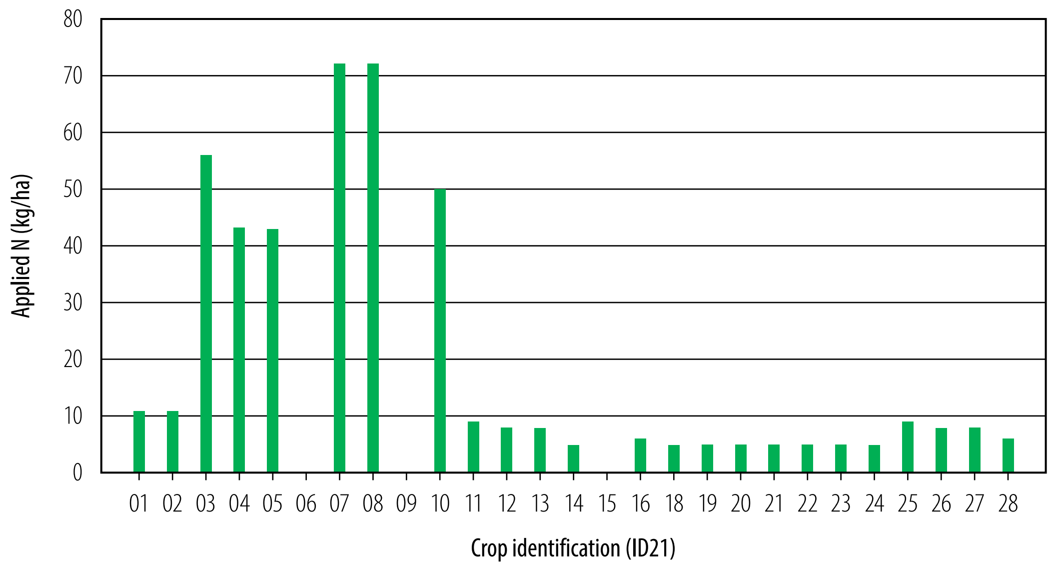

Figure 8 Applied N to SHOS crops in 2021/22.

Crop performance

Yield

Growers were asked what their crop yield expectations were at the beginning of the season. Many were unsure what to expect and relied on information from advisors and GO Resources. Estimated yield expectations varied between 1 t/ha and 3 t/ha (Figure 9). Some growers expressed similar yield expectations of 2.5 t/ha for sowing dates as early as mid May, through to early October There was no consistent relationship between yield expectations and sowing date (data not shown).

In 2021/22, yields of harvested crops in NSW varied between 0.28 t/ha and 2.28 t/ha. Approximately 400 ha of benchmarked crops were not harvested. Three crops were abandoned before harvest and harvest was discontinued in another due the low yield of ~0.5 t/ha.

The overall average yield of NSW crops was 1.0 t/ha.

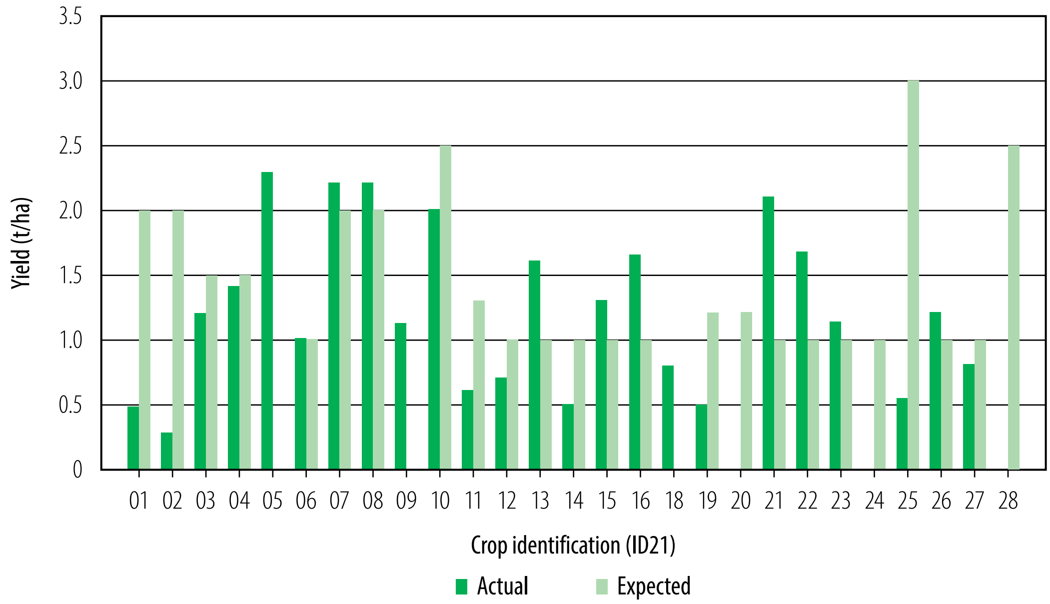

Figure 9 Actual and expected yield of SHOS crops in 2021/22.

Seed quality

Seed was sampled from each crop immediately before harvest. Total oil content varied between 23.5% and 37.7%, averaging 32.6% (Figure 10).

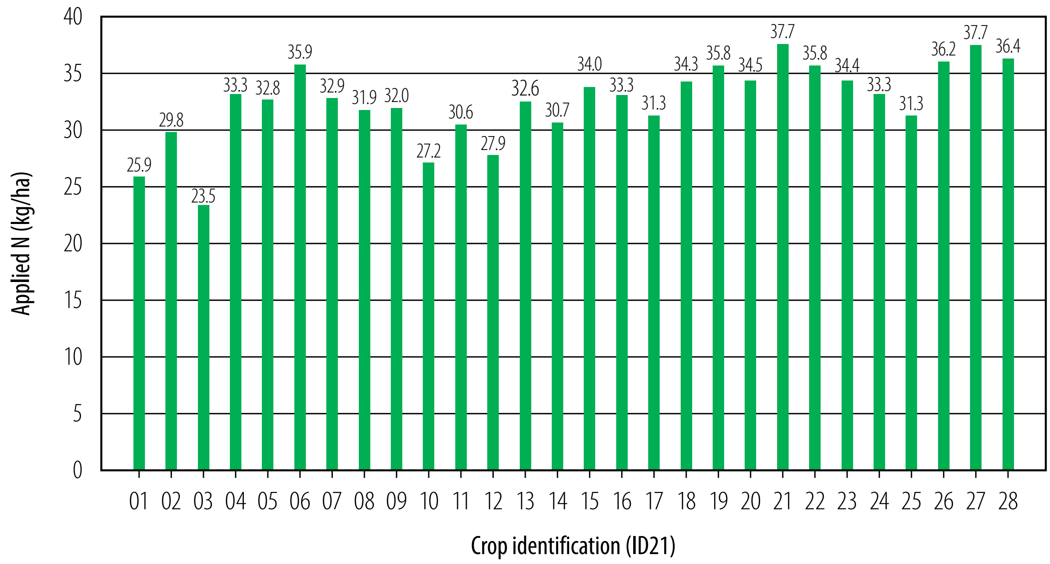

Figure 10 Total oil content of SHOS crops in 2021/22.

The seed fatty acid composition was analysed; oleic acid content varied between 89.1% and 91.8%, averaging 90.9%.

Seed N content

Seed was analysed to determine the export of nutrients out of the paddock. Based on the seed N content, crop yield and applied N fertiliser only, Figure 11 shows the N balance after harvest. Balances varied between +27 kg/N ha and 51 kg N/ha.

NOTE: This does not include N in the soil at sowing, N cycling or the N contained in remaining crop residues.

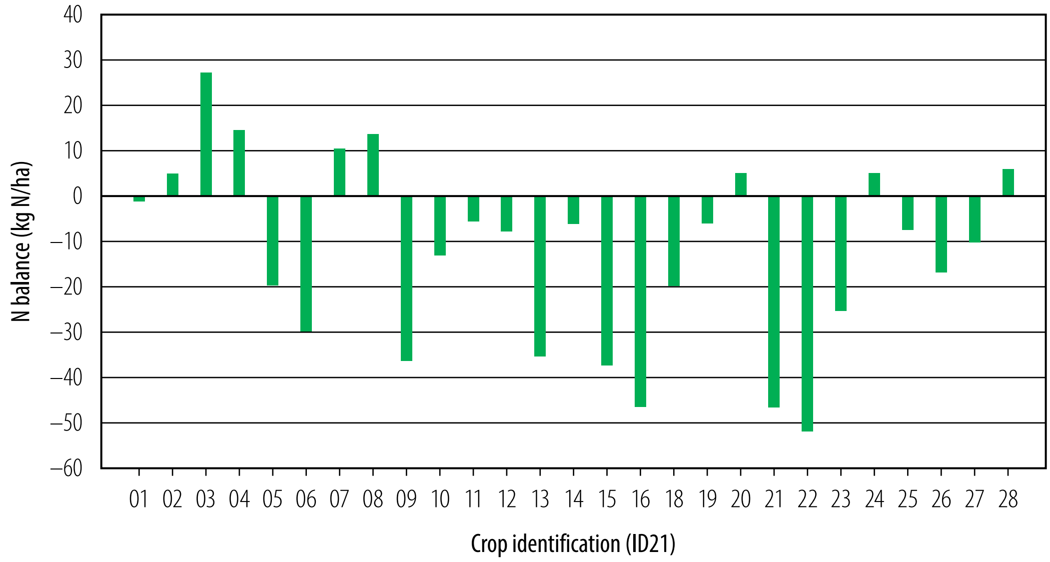

Figure 11 Modified N balance after grain removal of SHOS crops in 2021/22.

Summary

The specialised oil industry derived from SHOS production is in its early stages of commercial production in Australia. To date, it is based on a single, first-generation variety. There is keen interest from growers and advisors alike, mostly for whom, safflower is an unfamiliar crop.

Integrating the knowledge derived from past and current research (Australian and overseas), and findings from present-day regional crop management systems is essential. This information will support the development of SHOS as a reliable and economic crop option and potential major industry for Australian growers.

Acknowledgements

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