HART
premier cropping field site

2023

HART TRIAL RESULTS

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The board of the Hart Field-Site Group would like to acknowledge the significant financial contribution of our committed sponsors, supporters, collaborators and partners.

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Front cover photo by Sandy Kimber.

Thanks also Sandy Kimber, Rebekah Allen, Kaidy Morgan and Gabrielle Hall for other photos used within this publication.

Research supporters

We receive funding from the Australian Government's Future Drought Fund

Collaborators

Hart 2024 calendar

HART FIELD DAY

September 17

Our main Field Day attracts over 500 visitors from all over South Australia and further afield.

Every half hour a block of eight sessions are run simultaneously with highly regarded specialists speaking at each trial. Our comprehensive take-home Field Day Guide is included in your entry fee.

The Hart Field Day is our main event of the year.

Hart AGM

October 2024

Getting The Crop In

March 13

8am – 1:00pm

At this annual seminar, industry guest speakers from across the county cover a wide range of topics, all relevant to broadacre cropping.

Winter Walk

July 16

9am – 12pm

An informal guided walk around the trial site; your first opportunity to inspect the site post-seeding with guest speakers presenting their observations on current trials.

They are on hand to answer questions and will also share their knowledge on all the latest cropping systems and agronomic updates.

Spring Twilight Walk

October 15

5pm followed by BBQ

Another informal opportunity to inspect the trial site, this time just prior to harvest, again with industry researchers & representatives presenting in the field.

This event is followed by drinks and a BBQ in the shed - a great opportunity to network.

Acknowledgements

The success of our research program could not be achieved without the contribution of a large number of people and organisations.

Supporters

We thank the numerous growers and consultants who provide various contributions, from knowledge and experience through to land and equipment for conducting trials.

Pete McEwin
Simon Jaeschke
Shane Reinke
McPharlin family
Paul Jarret
Adam Rowley
Craig Davis
Roger Kimber
Andre Sabeeney
Hill River Pastoral
Larn McMurray
Stuart Sherriff
Andrew Cootes
Stuart Nagel
Kelvin Tiller
Rob & Dennis Dall
Daniel Neill
James Venning
Matt Dare
Sarah Noack
Rob & Glenn Wandel
Trevor Day
Daniel Paterson
Scott Weckert
Colin Edmondson
Anthony Pfitzner
Glen Wilkinson
Justin, Bradley & Dennis Wundke
Michael Jaeschke
Simon Honner
Ben & Kevin Pratt
Chris Preston
Luke Stringer

We would also like to thank various organisations for the provision of seed and/or products that were trialed in the 2023 research program.

ADAMA
FMC
SARDI Clare
Advanta Seeds
Global Grain Genetics
SARDI - vetch breeding program
Agriculture Victoria – field pea breeding program
InterGrain
SARDI Agronomy & Crop Sciences
Agriculture Victoria – lentil breeding program
LongReach Plant Breeders
Seednet
Agspec
Nufarm
Seed Force
Australian Grain Technologies
Nuseed
Sumitomo
Barenbrug
Pioneer Seeds
Syngenta
BASF
Plant Science Consulting
University of Adelaide - bean breeding program
Bayer Crop Science
Pulse Breeding Australia
UPL
Corteva Agriscience
S & W Seeds

Thank you also to the following people who volunteer on Hart's Research Committee.

Rob Dall
Matt Dare
Ash Hentschke
Simon Honner
Simon McCormack
Sarah Noack
Rob Price
Stuart Sherriff
Scott Weckert
Glen Wilkinson
Jana Dixon
Scott Carmichael
Ben McInerney
Nick Longmire

Our guiding principles

OUR PURPOSE

To deliver value to growers and make agriculture better

(in productivity, sustainability & community)

OUR VISION

To be Australia's premier cropping field site, providing independent information and enhancing the skills of the agricultural industry

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OUR VALUES

Independence

in order to provide unbiased results

Relevance

to issues facing farmers

Integrity

in all dealings

Credibility

through providing reliable, quality information

Professionalism

in the management of the site and presentation of trials

Value for money

low cost of information to farmers

Hart management

Hart board

Andre Sabeeney (Clare) .... Chairman
Glen Wilkinson (Snowtown) .... Vice-chairman, sponsorship
Sandy Kimber (Clare) .... Executive officer
Deb Purvis (Wallaroo) .... Finance officer
Matt Dare (Marola) .... Commercial crop manager, sponsorship
Ryan Wood (Clare) .... Sponsorship
Scott Weckert (Blyth) .... Sponsorship, community engagement
Simon Honner (Blyth) .... Board member
Rob Dall (Kybunga) .... Board member
Stuart Sherriff (Clare) .... Board member
Josh Reichstein (Blackwood) .... Board member
James Venning (Barunga Gap) .... Board member

Hart staff

Rebekah Allen .... Research & extension manager
Kaidy Morgan .... Regional intern
Sandy Kimber .... Executive officer
Simone Lawry .... Admin support
Gabrielle Hall .... Media
Hannah Pridham .... Finance support

Site Management

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Rebekah Allen, Kaidy Morgan, Laura Purvis

<u>SARDI, Agronomy Clare:</u>
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Or find out more about us…

The Hart site

The Hart field site (40 ha owned by the group) is managed as four quarters that are rotated each year.

In 2023, Quarter 1 hosted our trials.

Quarter 2 was sown with Kingbale oats and was cut for hay to tidy the site in preparation for 2024 trials.

Quarters 3 and 4 were also sown with oaten hay as part of our commercial crop rotation and weed management program.

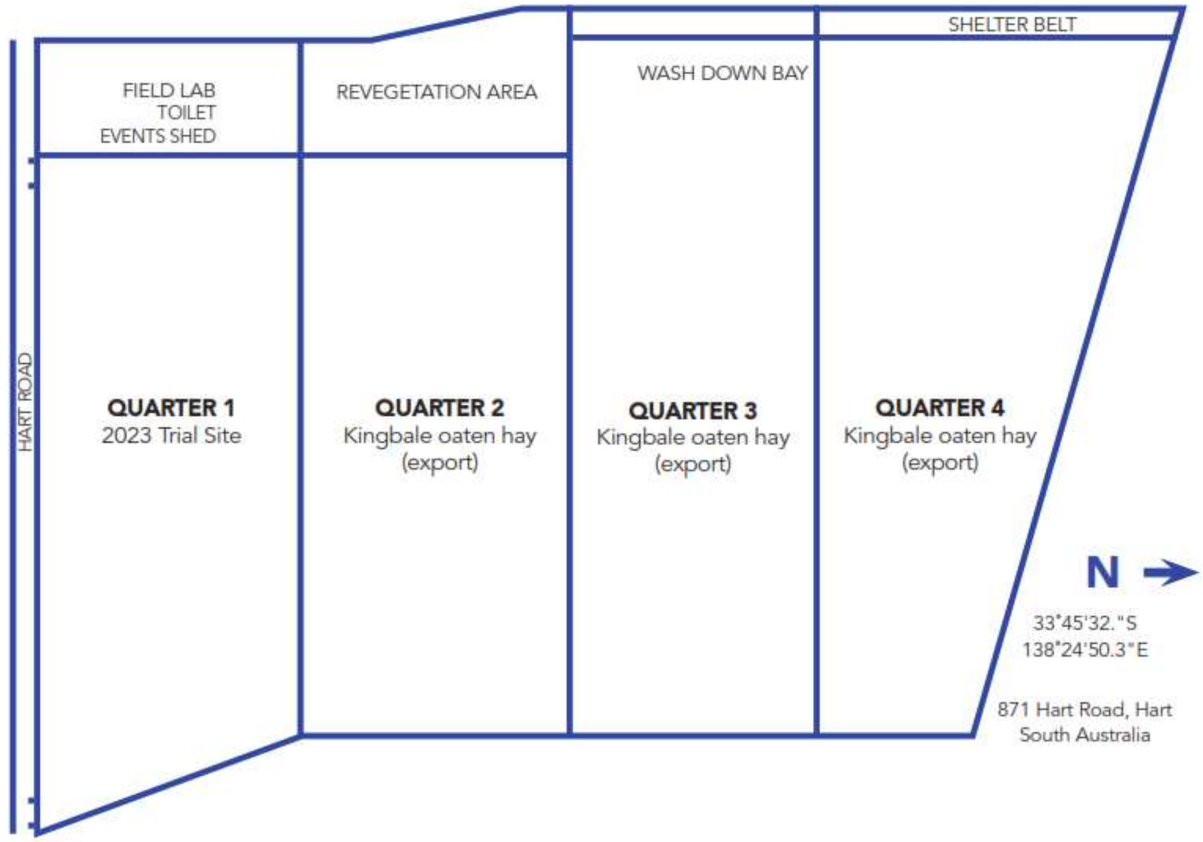

Photo. Students from St Joseph's School, Clare, visited the Hart field site on a 'Cultivating Futures' tour in October 2023.

Hart commercial crop report

Matt Dare

Commercial Crop Manager, Hart Field-Site Group

The Hart commercial crop was sown to export hay (Kingbale oats) in Quarters 2, 3 & 4, a total of 28 ha, at a rate of 110 kg/ha with 100 kg/ha of 24:16 fertiliser on June 1.

Thank you to the McPharlin family for kindly donating the seed.

A knockdown herbicide mix of 1.6 L/ha Glyphosate 540 and 30 g/ha Terrad'or was applied prior to sowing.

Moisture at sowing was good following rainfall the previous week totalling 23 mm.

Thanks to Michael Jaeschke and Rob Wandel who prickle chained and rolled the oats post-sowing.

Also, thanks to Pete McEwin for donating and spreading 50 kg/ha of urea on June 22.

This crop was sprayed for broadleaf weeds on July 20 with 25 g/ha Paradigm, 350 ml/ha MCPA LVE570, 80 ml/ha Dicamba500 and 0.5% uptake oil/ha applied.

Cutting took place on October 9 and was later than ideal due to some small weather events and availability of contacting.

Raking and baling was completed 11 days later on October 20.

Hart's 2023 commercial crop was contracted and sold to Balco Australia.

Thanks to Maitland Foods for their contracting services from cutting through to delivering the hay to Balco.

With final deliveries pending at the time of writing, hay yield is estimated as ~4.0t/ha and was graded as G4A.

Photo: Hart's commercial crop 2023.

The 2023 season at Hart

Kaidy Morgan and Rebekah Allen
Hart Field-Site Group

The Mid-North region had a dry start leading into the 2023 growing season. Below average rainfall across summer months (Figure 1) meant that stored soil moisture was low at Hart and surrounding regions (Figure 2).

Significant rainfall towards the end of April saw the start of seeding for many growers with 20 mm of rainfall received over a four-day period. Seeding at Hart commenced with canola and long coleoptile wheat trials sown on April 21.

Follow up rainfall was marginal until late May, in some cases resulting in delayed and patchy emergence of many early sown crops. As a result, most of Hart's trial program was dry sown or delayed.

Above average rainfall (68 mm) was received in June causing logistical difficulty towards the end of sowing, however all trials were sown by June 20. By this time, Hart had received 100 mm of growing season rainfall (GSR), and early sown crops were developing rapidly.

During the 2023 growing season we were met with below average rainfall for all months other than June. Despite an early break, a dry finish to the season reduced the yield potential of late sown crops and harvest commenced early across the region. Harvest commenced on October 23 with Barley and concluded with our off-site trials on November 22.

Hart received 236 mm of growing season rainfall (GSR average 300 mm), equivalent to a Decile 4 (40^{th} percentile). Annual rainfall totalled 355 mm, below Hart's 400 mm average.

Across the site, observations showed that the early, dry sown crops outperformed later sown crops despite establishing on marginal moisture. An extended season length and access to growing season rainfall early in the year played a critical role in yield potential, with later sown crops affected by limited rainfall in the second half of the growing season.

Photo: The Hart field site just prior to the Hart Field Day (September, 2023).

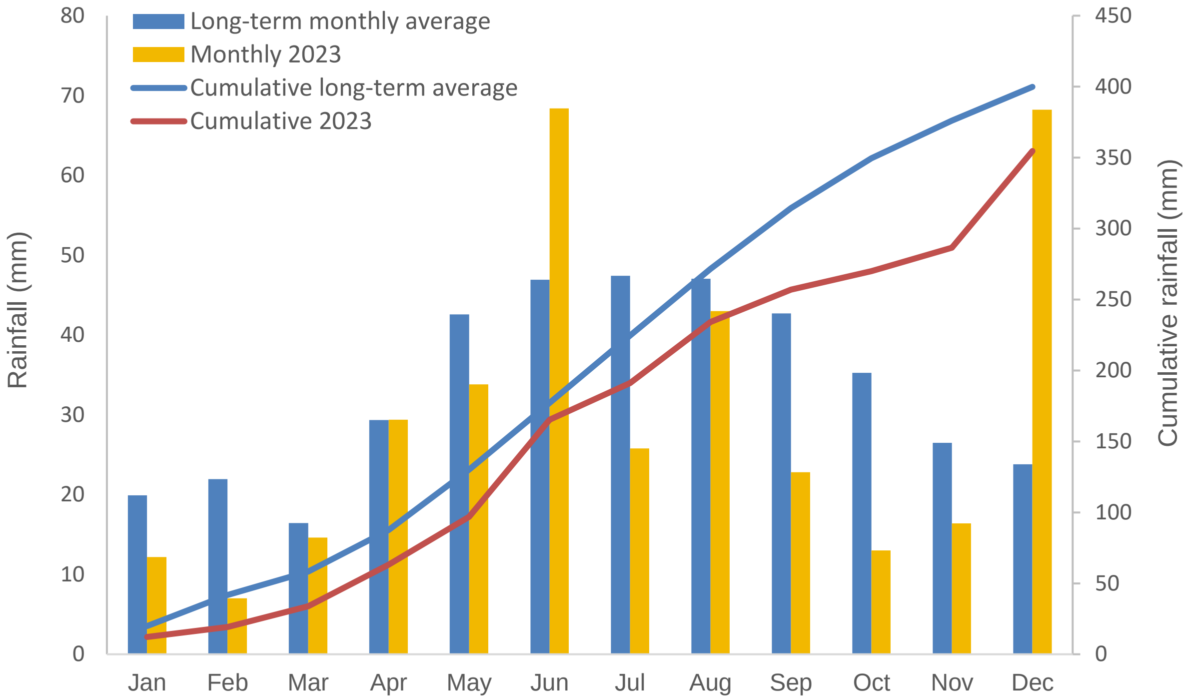

Figure 1. Hart rainfall graph for the 2023 season and long-term average. Lines are displayed to present cumulative rainfall for long-term average (blue) and 2023 (orange).

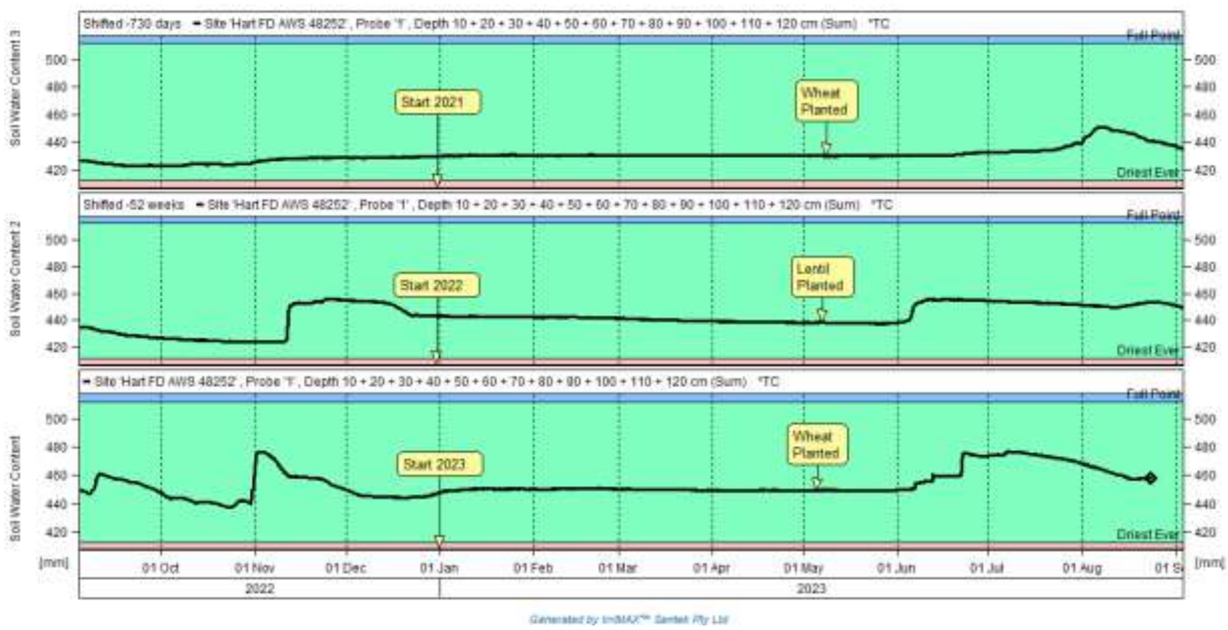

Figure 2. Soil moisture probe summed comparison (80 cm) for 2021 (top), 2022 (middle) and 2023 (bottom) at the Hart field site. Hart soil moisture data is free to view thanks to [Agbyte](https://www.hartfieldsite.org.au/pages/live-weather/soil-moisture-probe.php).
https://www.hartfieldsite.org.au/pages/live-weather/soil-moisture-probe.php

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Interpretation of statistical data

The results of replicated trials are presented as the average (mean) for each of the replicates within a treatment.

Authors generally use ANOVA, in which the means of more than one treatment are compared to each other. The least significant difference (LSD $P \leq 0.05$), seen at the bottom of data tables gives an indication of the treatment difference that could occur by chance. NS (not significant) indicates that there is no difference between the treatments. The size of the LSD can be used to compare treatment results and values must differ by more than this value for the difference to be statistically significant.

So, it is more likely (95%) that the differences are due to the treatments, and not by chance (5%). Of course, we may be prepared to accept a lower probability (80%) or chance that two treatments are different, and so in some cases a non-significant result may still be useful.

Interpretation of replicated results: an example

Here we use an example of a replicated wheat variety trial containing yield and grain quality data (Table 1). Statistically significant differences were found between varieties for both grain yield and protein. The LSD for grain yield of 0.40 means there must be more than 0.40 t/ha difference between yields before that variety's performance is significantly different to another. In this example Trojan is significantly different to all other varieties as it is the only variety followed by a superscript (^{a}). Scout, Mace and Cosmick are not significantly different from each other and are all followed by a superscript (^{b}) as they all yielded within 0.4 t/ha of each other.

Similarly, for grain protein a varieties performance was significant from another if there was more than 0.9% difference in protein. In the example, Arrow contained a higher protein level compared to all other varieties which were not different to one another.

Where there are no significant differences between treatments, NS (not significant) will be displayed as seen in the screenings column (Table 1).

Table 1. Wheat variety grain yield, protein and screenings from a hypothetical example to illustrate interpretation of LSD.

Variety	Grain yield (t/ha)	Protein (%)	Screenings (%)
Arrow	3.50^{c}	10.3^{a}	0.2
Cosmick	3.98^{b}	8.4^{b}	1.0
Mace	3.75^{bc}	9.1^{b}	0.5
Scout	4.05^{b}	8.9^{b}	0.9
Trojan	4.77^{a}	8.4^{b}	0.4
LSD ($P \leq 0.05$)	**0.40**	**0.9**	**NS**

Disclaimer

While all due care has been taken in compiling the information within this manual the Hart Field-Site Group Inc or researchers involved take no liability resulting from the interpretation or use of these results.

We do not endorse or recommend the products of any manufacturers referred to. Other products may perform as well or better than those specifically referred to.

Any research with un-registered products and rates in the manual does not constitute a recommendation for that particular use by the researchers or the Hart Field-Site Group Inc.

Comparison of wheat varieties

Rebekah Allen and Kaidy Morgan
Hart Field-Site Group

Key findings

- The average grain yield was 3.75 t/ha for all wheat varieties at Hart in 2023, with individual yields ranging from 3.35 – 4.26 t/ha.
- APH variety Sunblade CL Plus performed well, yielding 4.26 t/ha alongside AH varieties Ballista, Calibre, Kingston, Scepter, Vixen and APW varieties Denison and LRPB Trojan.
- Grain quality for most varieties tested low for screenings (%) and protein (%) and high for test weight (> 76 kg/hL).
- Despite below average annual rainfall at Hart in 2023, reasonable grain yields were achieved, with several varieties exceeding > 4 t/ha in a Decile 4 (40th percentile) season for both growing season rainfall (GSR) and annual rainfall.
- Although not highest yielding, the only variety to meet maximum receival standards within its grain classification was APW variety Chief CL Plus.

Aim

To compare the performance of new wheat varieties alongside current commercial standards.

Methodology

A trial was implemented at Hart, SA to evaluate wheat variety performance (Table 1). The trial was a randomised block design with three replicates and 29 wheat varieties comprising of both bread and durum wheat. New lines trialed at Hart in 2023 were Soaker (LRPB19-6184) LRPB Matador**,** LRPB Dual, Genie (IGW6754), Dozer CL Plus (IGW6783) and Mowhawk. This trial was managed with the application of pesticides to ensure a weed, insect and disease-free canopy. All plots were assessed for grain yield (t/ha), protein (%), test weight (kg/hL) and screenings (%). All data was analysed using a REML spatial model (Regular Grid) in Genstat 23rd edition.

Table 1. Trial details for 2023 wheat variety comparison at Hart, SA.

Plot size	1.75 m x 10.0 m	**Soil N**	105 kg N/ha
Seeding date	May 12, 2023	**Fertiliser**	Seeding: DAP (18:20) Zn 1% + Impact @ 80 kg/ha
Location	Hart, SA		
Harvest date	November 3, 2023		July 21: 74 kg N/ha (applied as urea @ 160 kg/ha)
Previous crop	Oaten hay		
Growing season rainfall	Decile 4 (236 mm)		

Pre-seeding available nitrogen (N) (0 – 90 cm) at Hart was 105 kg N/ha following an oaten hay crop in 2022. In-season nitrogen (N) decisions considered existing soil organic N, Yield Prophet® (based on Scepter wheat), Bureau of Meteorology (BoM) climate outlooks and simple economics.
At the time of N application, the site was highly responsive to N (Figure 1) and given the BoM forecast, it was clear that even a Decile 5 season would require significant N input to achieve water-limited yield potential (PYw). The BoM forecast a week prior to N application showed a 70% chance of El Niño developing, with the three-month outlook (August – October) showing a 47% chance of falling into a Decile 1 or 2 rainfall category at Hart and a 27% chance of Decile 3 – 4. Combined, this information showed us that the likelihood of receiving above average rainfall from August - October was low (22%).

Based on Figure 1 (Graph A) there was no significant benefit to applying further N if Decile 2 occurred, however from Decile 3 and above, there was potential for significant yield to be left in the paddock due to insufficient N. The difference between YPw and nitrogen limited yield (YP_N) at Decile 5 was approximately 0.9 t/ha. Based on the rule of thumb of 40 kg N/ha per tonne of grain, this gap could be covered by adding an additional 36 kg of N/ha (HART BEAT, 2023).

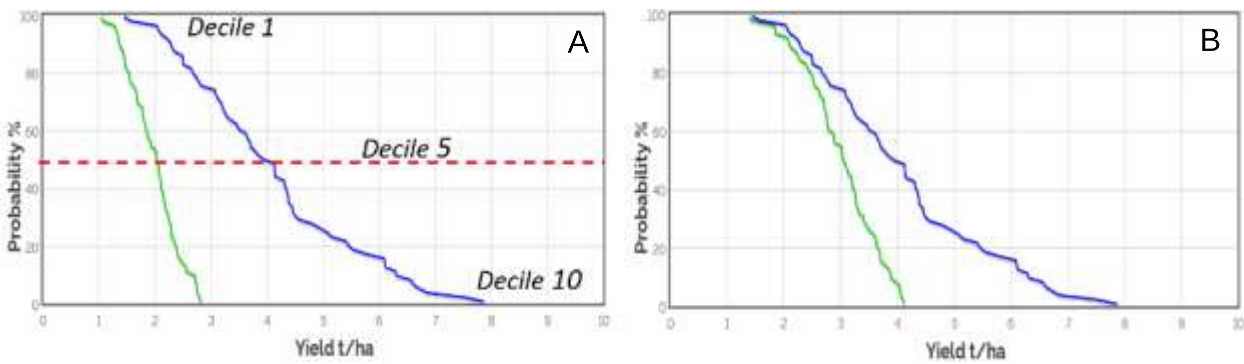

Figure 1. Yield Prophet® Output 1 (Graph A) for the Hart field site on July 14, 2023 for Scepter wheat with no in-crop N applied. This graph shows N responsiveness across all decile outcomes with PYw ranging from 1.5 – 8 t/ha. This output accounts for starting soil N (105 kg N/ha) and seeding N (14.4 kg N/ha). Graph B shows predicted yields after an application of 44 kg N/ha was added.

When a forecasted 22% chance of exceeding average rainfall was considered, the chance of drier deciles increased. The worst-case and best-case scenarios didn't change (-$67 to +$283), but the average income ($/ha) across deciles reduced from $180/ha to $113/ha and the chance of a negative partial budget was 18%.

Taking the information above into account, the variety trial received an additional 30 kg N/ha, totalling 74 kg N in nitrogen inputs. In a scenario where more N would be applied, the forecast of 22% chance of below average rainfall reduced profits to only 20% of the time with high downside risk (carry over N not accounted for) (HART BEAT, 2023).

Results and Discussion

Grain yield

Below average spring rainfall was received at Hart in 2023 reducing yield potential, however early moisture received in April and above average rainfall across June (68.4 mm) was favourable to early crop growth. The average grain yield was 3.75 t/ha for all wheat varieties at Hart in 2023, with individual yields ranging from 3.35 – 4.26 t/ha. A number of Australian Premium Hard (APH), Australian Hard (AH) and Australian Premium White (APW) varieties yielded well at Hart, ranging from 3.94 – 4.26 t/ha. This is in contrast to the 2022 season, where durum wheat varieties Bitalli, DBA-Aurora and Patron yielded highest, ranging from 4.61 – 5.14 t/ha in a Decile 8 growing season.

APH variety Sunblade CL Plus performed well, yielding 4.26 t/ha alongside AH varieties Ballista, Calibre, Kingston, Scepter, Vixen and APW varieties Denison and LRPB Trojan. Long-term yield data at Hart shows that Scepter continues to perform well across multiple seasons, yielding similarly or above the annual trial average (Table 3). Newer varieties Sunblade CL Plus, Calibre and Brumby have also performed well across three seasons at Hart. All durum varieties and Australian Standard White (ASW) variety Razor CL Plus perfomed similarly with yields ranging from 3.63 – 3.68 t/ha. Long-term yield data for Bitalli and DBA-Aurora from 2019 – 2023 at Hart shows these two varieties have performed well across all years trialed (not all data shown).

Grain quality

Wheat grain protein was low at Hart in 2023 with a trial average of 10.5% (Table 2). No varieties met Australian Premium Durum (ADR) or AH receival standards of ≥ 13% (DR1 receival ranges is 13 – 13.5%). Durum varieties Bitalli and DBA-Aurora were the best performing for protein, ranging from 11.5 – 11.8%. Test weights were high, with all varieties achieving > 76 kg/hL. Highest test weights came from AH varieties Kingston, Reilly, Scepter and APW varieties Soaker (LRPB19-6184) and LRPB Trojan achieving 86.2 – 87.1 kg/hL. Screenings were low across the trial with ADR variety Bitalli and AH variety Grenade CL Plus achieving the lowest screenings of 1.6 and 2.4%, respectively, while new APW variety Soaker (LRPB19-6184), in addition to Genie (IGW6754), LRPB Matador, RockStar and Scepter exceeded 5% and did not meet H1 or APW 1 receival standards.

Summary

Despite below average rainfall at Hart in 2023, reasonable grain yields were achieved, with several varieties achieving > 4 t/ha in a Decile 4 (40^{th} percentile) season for both GSR and annual rainfall. In general screenings and protein were low, however test weight was high with all varieties exceeding 76 kg/hL. The only variety meeting maximum receival standards was APW classified variety Chief CL Plus (APW1).

Photo: Hart's 2023 wheat variety trial.

Table 2. Wheat grain yield (t/ha) and quality results at Hart in 2023. Values shaded indicate the best performing varieties in each column.

Quality	Variety	Grain yield (t/ha)	% of site average	Protein %	% of site average	Test weight (kg/hL)	% of site average	Screenings (%)	% of site average
APH	Sunblade CL Plus	4.26^{i}	114	10.2^{bcd}	96	85.3^{d-l}	100	6.6^{n}	165
AH	LRPB Anvil CL Plus	3.26^{a}	87	11.0^{jkl}	104	86.1^{lmn}	101	3.9^{hij}	99
	Ballista	3.99^{f-i}	106	9.8^{a}	93	85.9^{j-m}	101	4.4^{jk}	110
	Calibre	4.04^{g-i}	108	10.1^{bcd}	96	85.1^{c-i}	100	3.5^{c-j}	89
	Catapult	3.79^{c-h}	101	10.2^{b-e}	97	85.2^{d-k}	100	3.4^{c-i}	84
	LRPB Dual	3.72^{c-h}	99	11.1^{lm}	105	85.9^{j-m}	101	3.7^{g-j}	93
	Grenade CL Plus	3.59^{a-e}	96	10.7^{f-k}	102	83.5^{a}	98	2.4^{ab}	60
	Hammer CL Plus	3.51^{abc}	94	10.7^{f-j}	101	86.1^{lmn}	101	4.2^{j}	106
	Kingston	3.95^{f-i}	106	10.5^{e-i}	100	87.0^{o}	102	2.6^{bcd}	66
	LRPB Scout	3.67^{b-f}	98	10.0^{ab}	95	84.2^{ab}	99	4.2^{j}	106
	Reilly	3.83^{c-h}	102	10.9^{jkl}	103	87.1^{o}	102	2.7^{bcd}	67
	Genie (IGW6754)	3.56^{a-d}	95	10.7^{g-j}	102	85.8^{h-m}	100	9.0^{o}	225
	LRPB Matador	3.89^{d-h}	104	10.3^{b-e}	98	84.3^{abc}	99	6.0^{mn}	150
	RockStar	3.57^{a-d}	95	10.0^{ab}	95	84.2^{abc}	99	5.1^{kl}	128
	Scepter	4.06^{hi}	108	10.1^{abc}	96	86.8^{no}	102	5.1^{kl}	127
	Valiant CL Plus	3.55^{a-d}	95	10.9^{jkl}	104	85.0^{b-h}	100	2.6^{bc}	66
	Vixen	3.94^{e-i}	105	10.4^{d-h}	99	84.8^{b-g}	99	4.0^{ij}	102
	H1 receival standard			≥ 13		≥ 76		≤ 5	
APW	Brumby	3.89^{d-h}	104	10.2^{bcd}	97	84.7^{b-f}	99	3.6^{f-j}	90
	Chief CL Plus	3.55^{a-d}	95	10.8^{i-l}	102	84.6^{bcd}	99	3.1^{b-h}	79
	Dozer CL Plus (IGW6783)	3.67^{b-f}	98	10.4^{c-g}	99	83.7^{a}	98	4.2^{j}	106
	Soaker (LRPB19-6184)	3.70^{b-g}	99	10.3^{b-e}	98	87.1^{o}	102	5.3^{lm}	133
	Denison	3.94^{e-i}	105	10.2^{b-e}	97	85.5^{e-m}	100	3.6^{f-j}	90
	LRPB Trojan	3.95^{f-i}	106	10.1^{a-d}	96	86.2^{mno}	101	2.8^{b-f}	70
	Sheriff CL Plus	3.35^{ab}	89	10.3^{b-f}	98	85.2^{d-j}	100	3.0^{b-g}	76
	Mowhawk	3.76^{c-h}	100	11.1^{k-m}	105	85.8^{i-m}	101	2.7^{b-e}	67
	APW1 receival standard			≥ 10.5		≥ 76		≤ 5	
ASW	Razor CL Plus	3.68^{b-f}	98	10.1^{abc}	96	86.1^{lmn}	101	4.1^{ij}	102
	ASW1 receival standard			NA		≥ 76		≤ 5	
ADR	DBA-Aurora	3.67^{b-f}	98	11.5^{no}	109	84.7^{b-f}	99	3.6^{f-j}	91
	Bitalli	3.63^{b-f}	97	11.8^{o}	112	86.0^{k-n}	101	1.6^{a}	40
	Patron	3.66^{b-f}	98	11.3^{mn}	107	84.7^{b-e}	99	3.1^{b-h}	78
	DR1 receival standard			≥13		≥ 76		≤ 5	
	Site average	3.75	100	10.5	100	85.4	100	4.0	100

Table 3. Long-term wheat variety performance at Hart for 2019 – 2023 seasons (expressed as a % of trial average).

		% Trial average					Grain yield (t/ha)
Quality	**Variety**	**2019**	**2020**	**2021**	**2022**	**2023**	**2023**
APH	Sunblade CL Plus			105	111	114	4.26
AH	LRPB Anvil CL Plus			105	81	87	3.26
	Ballista		95	100	108	106	3.99
	Calibre			112	99	108	4.04
	Catapult	97	107	96	105	101	3.79
	LRPB Dual					99	3.72
	Grenade CL Plus	93	93	93	97	96	3.59
	Hammer CL Plus		106	108	89	94	3.51
	Kingston			101	95	106	3.95
	LRPB Scout	107	106	86	101	98	3.67
	Reilly				102	102	3.83
	Genie (IGW6754)					95	3.56
	LRPB Matador					104	3.89
	RockStar	104	108	80	107	95	3.57
	Scepter	106	101	113	100	108	4.06
	Valiant CL Plus			93	100	95	3.55
	Vixen	111	109	130	96	105	3.94
APW	Brumby			115	104	104	3.89
	Chief CL Plus	85	113	102	85	95	3.55
	Dozer CL Plus (IGW6783)					98	3.67
	Soaker (LRPB19-6184)					99	3.70
	Denison			86	110	105	3.94
	LRPB Trojan	102	94	93	105	106	3.95
	Sheriff CL Plus	96	100	107	96	89	3.35
	Mowhawk					100	3.76
ASW	Razor CL Plus	109	98	111	94	98	3.68
ADR	DBA-Aurora				109	98	3.67
	Bitalli				106	97	3.63
	Patron				124	98	3.66
	Trial average yield t/ha	**1.50**	**2.50**	**2.03**	**4.40**	**3.75**	
	Sowing date	May 15	May 6	May 3	May 5	May 12	
	Apr-Oct rain (mm)	162	336	232	355	236	
	Annual rain (mm)	189	503	401	519	355	

Acknowledgements

The Hart Field-Site Group would like to acknowledge the generous support of our sponsors who provide funding that allows us to conduct this trial. Proceeds from Hart's ongoing commercial crop also support Hart's research and extension program.

This trial is funded by HART

We would also like to thank InterGrain, AGT, LongReach and Seednet for providing seed to conduct this trial.

References

HART BEAT (2023). Available online.

Comparison of barley varieties

Kaidy Morgan and Rebekah Allen
Hart Field-Site Group

Key findings

- The average barley yield was 4.66 t/ha at Hart in 2023.
- Combat, Neo, Minotaur and Beast were the highest yielding barley varieties with yields ranging from 4.89 – 5.11 t/ha.
- Protein (%) for all varieties averaged 13.1%, exceeding Malt 1 receival standards. As a result of high protein (%), no varieties met Malt 1 receival standards in 2023.
- Most varieties performed well across screenings (%), retention (%) and test weight (kg/hL), averaging 4%, 81.2% and 67.3 kg/hL, respectively.

Aim

This trial was conducted to compare the performance of new barley varieties alongside current industry standards.

Methodology

A trial was established at Hart, SA to evaluate barley variety performance (Table 1). It was a randomised block design with three replicates and included 16 barley varieties. The trial was managed with the application of pesticides to ensure a weed, insect and disease-free canopy. All plots were assessed for grain yield (t/ha), protein (%), test weight (kg/hL), screenings (2.2 mm screen) and retention (2.5 mm screen). Data was analysed using a REML spatial model (Regular Grid) in Genstat 23rd edition.

New varieties trialed at Hart in 2023 included Neo (IGB22102T) from InterGrain and Spinnaker (SCA21-Y003), commercially available through Seednet in 2025. Neo has been released for the 2024 growing season.

Table 1. Trial details for 2023 barley variety comparison at Hart, SA.

Plot size	1.75 m x 10.0 m	**Fertiliser**	Seeding: DAP Zn 1% + Flutriafol @ 80 kg/ha
Seeding date	May 12, 2023		
Location	Hart, SA		July 19: Urea (46:0) @ 142 kg/ha
Harvest date	October 23, 2023		
Previous crop	Mulgara oaten hay		A second application was top dressed in error on August 16 (Urea @ 80kg/ha)
Growing season rainfall	Decile 4 (236 mm)		

Results and discussion

Grain yield

The average grain yield (t/ha) for all barley varieties at Hart in 2023 was 4.66 t/ha (Table 2).

Feed variety Combat was the highest yielding barley, achieving 5.11 t/ha. Newer varieties Neo, Minotaur and Beast (pending malt accreditation) performed similarly to Combat, yielding 5.03, 4.96 and 4.89 t/ha, respectively (Table 2).

Combat and Minotaur have continued to achieve high yields across the past two seasons at Hart (Table 3) (Anderson, 2023). Alongside Neo, these varieties were ranked within the top five highest yielding varieties at Spalding and Salter Springs this year (GRDC National Variety Trials sites 2023). Minotaur, RGT Planet and Rosalind have also performed well at Hart across numerous seasons.

Grain quality

Grain protein (%) for all varieties exceeded the maximum protein accepted (12%) for Malt 1 and ranged from 12.7 – 13.7% (Table 2). High nitrogen application and below average rainfall leading into grain fill were contributing factors to high protein in 2023.

Excluding Neo (IGB22102T) and RGT Planet, all other malt or pending malt varieties met maximum grade for test weight (> 65 kg/hL), with a trial average of 67.3 kg/hL. Spartacus had the highest test weight at 71.0 kg/hL, with Neo recording the lowest weight of 61.8 kg/hL despite high yields.

Barley screenings for all varieties was low, with a trial average of 4%.

Zena CL (pending malt accreditation) had the highest screenings at 6.5%, however remained within receival requirements (7%) for Malt 1. Malting varieties Compass, Leabrook and Maximus performed best with Beast, Commodus, Laperouse and Titan AX (all pending malt accreditation) also performing well with low screenings between 1.3 and 2.3%.

Despite achieving superior yields, Combat, in addition to Zena CL had poor retention with an average of 68.3%. With the exception of RGT Planet, all malt varieties had high retention ranging from 85 – 92%, exceeding minimum Malt 1 receival standards.

As a result of high protein, no varieties met Malt 1 specifications despite several varieties meeting all other quality standards.

Photo: Barley variety trial at the Hart field site in 2023.

Table 2. Barley grain yield and quality results from Hart in 2023. Values shaded in blue indicate the best performing varieties.

Quality	Variety	Grain yield t/ha	% of site average	Protein %	% of site average	Test weight kg/hL	% of site average	Screenings %	% of site average	Retention %	% of site average
Feed	Rosalind	4.73^{cde}	101	13.3^{def}	102	69.4^{hi}	103	3.6^{de}	117	77.6^{bc}	96
	Combat (IGB1944)	5.11^{f}	109	12.9^{abc}	98	67.4^{de}	100	4.8^{ef}	155	68.3^{a}	84
Bar 1 Receival Standards				NA		>62.5		15.0		NA	
Malt	Compass	4.69^{bcd}	100	12.9^{abcd}	99	68.7^{ghi}	102	2.2^{abc}	70	88.0^{e}	108
	Leabrook	4.55^{abc}	97	12.8^{abc}	98	67.6^{ef}	100	1.6^{ab}	53	90.2^{e}	111
	Maximus CL	4.33^{a}	93	13.1^{abcde}	100	69.6^{i}	103	1.4^{a}	46	89.1^{e}	110
	RGT Planet	4.68^{bcd}	100	12.7^{ab}	97	64.5^{c}	96	5.4^{fg}	174	71.2^{ab}	88
	Spartacus CL	4.37^{a}	94	13.4^{ef}	103	71.0^{j}	105	2.6^{bcd}	85	85.1^{de}	105
Malt 1 Receival Standards				9-12%		>65		7.0		>70%	
Pending malt accreditation	Beast	4.89^{def}	105	12.9^{abcd}	98	69.2^{hi}	103	1.3^{a}	42	91.9^{e}	113
	Commodus CL	4.53^{abc}	97	13.1^{bcde}	100	68.6^{fgh}	102	1.5^{ab}	48	91.0^{e}	112
	Cyclops	4.49^{ab}	96	13.2^{cde}	101	67.8^{efg}	101	3.2^{cd}	102	78.3^{cd}	96
	Laperouse	4.40^{a}	94	13.7^{f}	105	69.0^{hi}	103	2.3^{abc}	74	86.1^{e}	106
	Minotaur	4.96^{ef}	106	13.1^{abcde}	100	67.0^{de}	100	2.9^{cd}	94	77.5^{bc}	95
	Neo (IGB22102T)	5.03^{f}	108	12.7^{a}	97	61.8^{a}	92	3.4^{cd}	108	77.8^{bc}	96
	Spinnaker (SCA21-Y003)	4.55^{abc}	97	13.4^{ef}	103	65.4^{c}	97	4.8^{ef}	154	70.6^{a}	87
	Titan AX	4.73^{bcde}	101	13.1^{abcde}	100	66.4^{d}	99	2.3^{abc}	73	88.1^{e}	109
	Zena CL (IGB20125T)	4.57^{abc}	98	13.0^{abcde}	99	62.9^{b}	94	6.5^{g}	207	68.3^{a}	84
Site average		**4.66**	**100**	**13.1**	**100**	**67.3**	**100**	**4.0**	**100**	**81.2**	**100**

Table 3. Long-term barley variety performance at Hart for 2019-2023 (expressed as % of trial average).

		% Trial average					Grain yield (t/ha)
Quality	**Variety**	**2019**	**2020**	**2021**	**2022**	**2023**	**2023**
Feed	Fathomⓓ	104	112	107	101		
	Hindmarshⓓ	103					
	Rosalindⓓ	107	100	105	101	102	4.73
	Combatⓓ (IGB1944)				112	110	5.11
Malt	Commanderⓓ	93	95				
	Compassⓓ	106	99	112	90	101	4.69
	La Trobeⓓ	107	94				
	Leabrookⓓ		107	107	96	98	4.55
	Maximus CLⓓ	102	95	96	91	93	4.33
	RGT Planetⓓ	101	111	86	119	100	4.68
	Spartacus CLⓓ	100	89	83	91	94	4.37
Pending malt accreditation	Beastⓓ		99	111	96	105	4.89
	Commodus CLⓓ			100	95	97	4.53
	Cyclopsⓓ			103	101	96	4.49
	Laperouseⓓ		105	112	87	94	4.40
	Minotaurⓓ			101	107	106	4.96
	Neoⓓ (IGB22102T)					108	5.03
	Spinnakerⓓ (SCA21-Y003)					98	4.55
	Titan AXⓓ				96	102	4.73
	Zena CLⓓ (IGB20125T)				117	98	4.57
	Average yield (t/ha)	**2.25**	**3.18**	**2.61**	**5.99**	**4.66**	
	Sowing date	May 15	May 16	May 3	May 5	May 12	
	April - Oct (mm)	162	355	232	355	236	
	Annual rainfall (mm)	189	503	401	519	355	

Acknowledgements

The Hart Field-Site Group would like to acknowledge the generous support of our sponsors who provide funding that allows us to conduct this trial. Proceeds from Hart's ongoing commercial crop also support Hart's research and extension program.

We would like to thank InterGrain, AGT and Seednet for providing seed to conduct this trial.

This trial is funded by HART

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Comparison of canola varieties - including genetically modified options

Rebekah Allen and Kaidy Morgan
Hart Field-Site Group

Key findings

- Despite a dry spring, canola performed well at Hart in 2023 with oilseed yields ranging from 1.71 to 2.75 t/ha.
- Several varieties produced high yields including conventional variety Nuseed Diamond, Clearfield® varieties Nuseed Ceres and Pioneer PY421C, genetically modified varieties Nuseed Hunter (TruFlex®) and Pioneer 44Y30 RR (Roundup Ready®), ranging from 2.55 to 2.75 t/ha.
- Overall yield penalties were observed for TT canola options, achieving 2.02 t/ha, a grain yield reduction of up to 0.44 t/ha when compared to other technology traits.
- All varieties, except for HyTTec Trophy, HyTTec Velocity, PY520TC and RGT Capacity achieved oil content above 42%, contributing to oil premiums that improve gross margins ($/ha).

Aim

In 2021, South Australian mainland growers saw the 16-year moratorium on genetically modified (GM) canola for commercial use lift. The addition of glyphosate and glufosinate tolerant technologies (including dual tolerance) provides additional varietal options for growers with in-crop herbicide registrations (Group 9 & 10) new to broadacre agriculture. An ongoing variety trial compares the performance of new canola varieties, including genetically modified (GM) options; Roundup Ready®, TruFlex® and LibertyLink®, alongside current conventional, Triazine Tolerant (TT) and Clearfield® (CL) varieties.

Methodology

A trial was implemented to evaluate the performance of canola varieties at Hart, SA in 2023 (Table 1). The trial was designed as a multistratum split-plot design, with 30 canola varieties blocked by technology across three replicates.

Table 1. Trial details for canola variety comparison at Hart, SA in 2023.

Plot size	2.0 m x 10.0 m	**Starting soil N**	105 kg N/ha (depth to 90 cm)
Seeding date	April 21, 2023	**Fertiliser**	Seeding: DAP (18:20) Zn 1% + Impact @ 80 kg/ha
Location	Hart, SA		
Harvest date	November 1, 2023		June 15: 37 kg N/ha (applied as urea)
Previous crop	Oaten hay		August 16: 37 kg N/ha (applied as urea)

The trial was managed with the appropriate application of pesticides to ensure a weed, insect and disease-free canopy. All plots were assessed for crop establishment (plants/m^2), flowering date (50% flower), crop yield (t/ha) and oil content (%). Canola partial gross margins (PGM) were also calculated for 2023 season as (grain yield x price) – (seed + herbicide cost).

Ten new varieties were included at Hart in 2023 including Triazine Tolerant (TT) varieties ATR-Swordfish, CT107 and Pioneer PY520 TC (stacked TT & Clearfield® tolerance), Hyola 410XX (TruFlex®), Nuseed Hunter (TruFlex®) stacked TruFlex® and Clearfield® varieties Hyola Battalion XC and Hyola Regiment XC and Clearfield® varieties Hyola Solstice CL, Nuseed Ceres and Pioneer PY421C.

Results and discussion

Canola yield and oil content

Excellent canola yields ranging from 1.71 – 2.75 t/ha were observed at Hart in 2023 (Table 2) and can be attributed to an April sowing after opening rains that favoured early crop establishment and biomass production. Of particular note, conventional variety Nuseed Diamond, Clearfield® varieties Nuseed Ceres, Pioneer PY421C and genetically modified varieties Nuseed Hunter (TruFlex®) and Pioneer 44Y30 RR (Roundup Ready®) produced yields of 2.55 – 2.75 t/ha.

Overall yield penalties were observed for TT canola options, achieving 2.02 t/ha, a grain yield reduction of up to 0.44 t/ha when compared to other technology traits.

Longer-term yield data at Hart (2021 – 2023) shows that Nuseed Diamond, Hyola Blazer TT, Nuseed Emu TF and Pioneer 44Y94 CL have performed well across multiple seasons within each technology (Table 3). Varieties that were evaluated over two seasons and performed well include RGT Baseline, SFR65-064TT, Pioneer 44Y30 RR and InVigor LR (Table 3). A number of newer lines trialed in 2023 also performed well but require further evaluation across multiple seasons.

Canola oil content (%) ranged from 41.4 – 45% with a number of varieties across herbicide technologies performing well. Varieties with superior oil content included Nuseed Quartz, RGT Baseline, Hyola Garrison XC, Hyola Regiment XC, Nuseed Emu TF, Pioneer 43Y92 CL and Pioneer 44Y94 CL. Nuseed Ceres also performed similarly, achieving both high yield and oil content.

Of the 30 varieties trialed, 26 achieved oil content above 42%, contributing to oil premiums (Table 2). The exceptions were HyTTec Trophy, HyTTec Velocity, Pioneer PY520 TC and RGT Capacity.

Flowering

Field trials conducted across five years (2014 – 2018) through the GRDC Optimised Canola Profitability project have shown that the optimum start of flowering (OSF) date for canola at Hart, is from July 25 with a large OSF window of up to 37 days. This means it is ideal for canola to start of flowering between July 25 and August 31 to minimise heat and water stress (Lilley 2018), however flowering dates will vary depending on crop phenology of varieties (time from sowing to flowering). First flower (growth stage 60 – first flowers open) occurred from July 10 to August 11 at Hart in 2023. Early maturing variety Nuseed Diamond was the first to flower with RGT Baseline TT (SFR65-059TT) the last to flower on August 11. Most varieties had reached 50% flower by late July – early August (Figure 1).

Table 2. Summary of canola yield (t/ha) and oil content (%) for varieties trialed at Hart in 2023. Shaded values in each column show the highest performing varieties across the trial. Partial gross margin ($/ha) was also calculated ((grain yield x price) – (seed + herbicide cost)) and should be used as a guide only. Costings based on 2024 forecasted pricing only and are sourced from the Farm Gross Margin Guide, 2024. Costings do not include oil premiums or discounts, expected to be an additional 1.5% of the price per tonne for every 1% oil content above or below 42% (PGM shading represents varieties which would receive a premium in 2023).

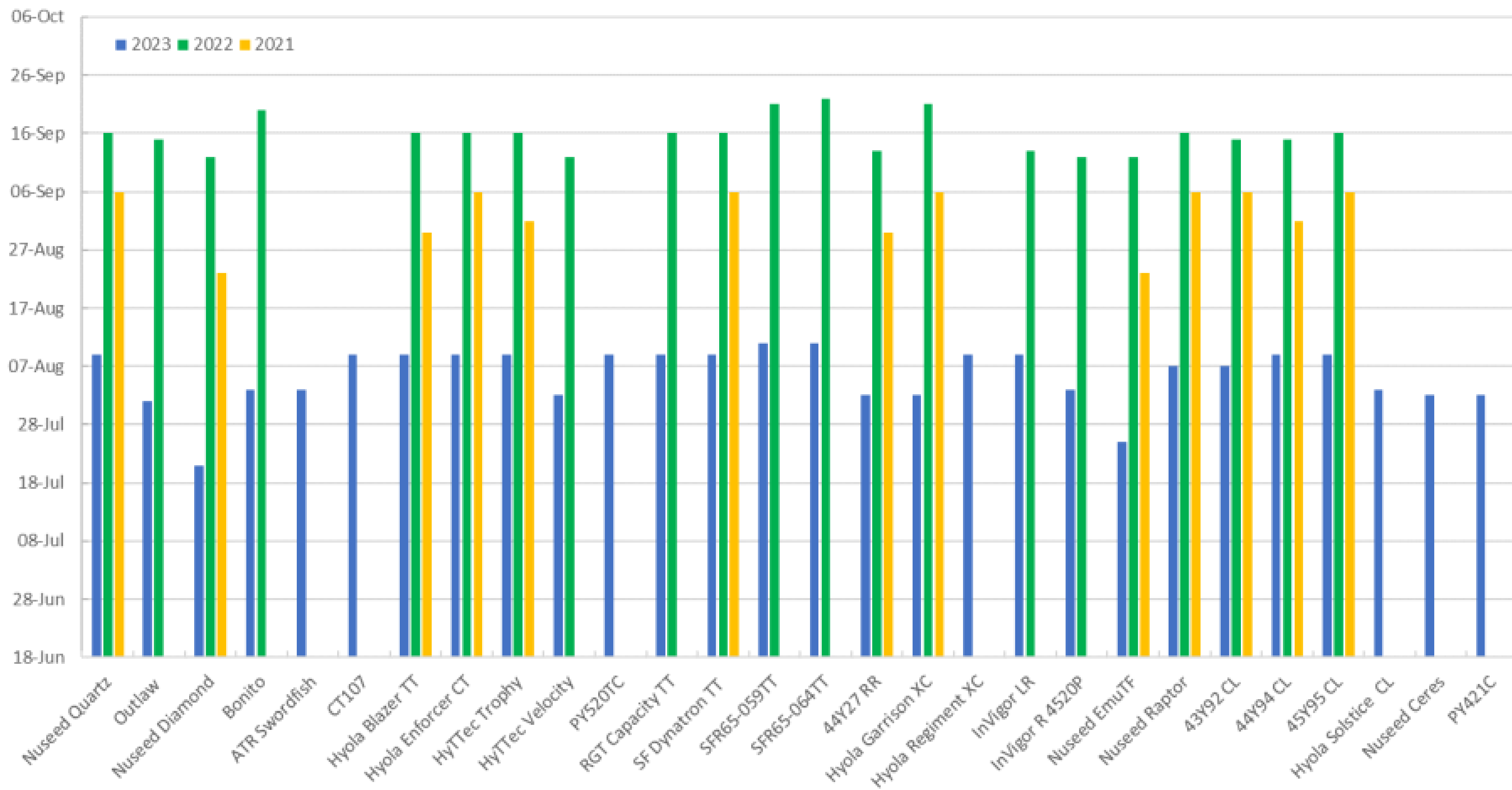
Technology	Variety	Yield (t/ha)	Oil content (%)	Partial gross margin ($/ha)	Yield (t/ha)	Oil content (%)
Conventional	Outlaw	2.26^{f-h}	43.0^{d-h}	$1,350	2.46^{b}	43.4^{ab}
	Nuseed® Quartz	2.39^{h-j}	44.4^{k-p}	$1,437		
	Nuseed® Diamond	2.75^{l}	43.1^{d-i}	$1,668		
Triazine Tolerant (TT) & dual triazine Clearfield® (CT)	ATR-Bonito	1.86^{ab}	43.0^{d-i}	$1,081	2.02^{a}	42.6^{a}
	ATR-Swordfish	1.71^{a}	43.4^{e-k}	$981		
	CT107	2.14^{ef}	43.4^{d-k}	$1,260		
	Hyola® Blazer TT	2.07^{c-f}	43.1^{d-j}	$1,214		
	Hyola® Enforcer CT	2.12^{def}	42.5^{a-e}	$1,238		
	HyTTec® Trophy	2.13^{def}	41.7^{abc}	$1,255		
	HyTTec® Velocity	2.18^{efg}	41.4^{a}	$1,284		
	Pioneer® PY520 TC	2.11^{def}	41.4^{a}	$1,239		
	RGT Capacity™ TT	1.87^{abc}	41.6^{ab}	$1,084		
	SF Dynatron® TT	1.93^{bcd}	43.5^{e-m}	$1,123		
	RGT Baseline™	2.02^{b-e}	45.0^{p}	1,179		
	SFR65-064TT	2.07^{def}	42.5^{b-e}	$1,217		
Genetically modified (glyphosate or glufosinate tolerant)	Pioneer® 44Y27 RR	2.4^{hij}	43.0^{d-g}	$1,417	2.48^{b}	44.0^{b}
	Pioneer® 44Y30 RR	2.63^{kl}	44.7^{nop}	$1,567		
	Hyola® Garrison XC	2.37^{g-j}	44.7^{mop}	$1,385		
	Hyola® Regiment XC	2.35^{ghi}	44.8^{op}	$1,369		
	InVigor® LR	2.54^{ijk}	44.6^{l-p}	$1,508		
	InVigor® R 4520P	2.39^{hij}	42.1^{a-d}	$1,410		
	Nuseed® Emu TF	2.48^{ijk}	44.2^{g-p}	$1,470		
	Nuseed® Hunter	2.68^{kl}	43.4^{e-k}	$1,598		
	Nuseed® Raptor TF	2.49^{ijk}	43.6^{e-n}	$1,479		
Clearfield® (CL)	Pioneer® 43Y92 CL	2.24^{fgh}	44.4^{k-p}	$1,314	2.45^{b}	43.5^{b}
	Pioneer® 44Y94 CL	2.51^{ijk}	43.7^{f-o}	$1,491		
	Pioneer® 45Y95 CL	2.27^{fgh}	43.3^{e-k}	$1,333		
	Hyola® Solstice CL	2.47^{ijk}	42.7^{c-f}	$1,468		
	Nuseed® Ceres	2.62^{kl}	44.2^{j-p}	$1,565		
	Pioneer® PY421 C	2.55^{jkl}	43.4^{e-l}	$1,520		
	P Value	**<0.001**	**<0.001**		**<0.001**	**<0.001**

Clearfield® technology = Imidazolinone tolerant varieties

Table 3. Long-term yield data for canola varieties at Hart from 2021 – 2023. Average yield data for each variety is benchmarked within herbicide technology.

	% Average				Yield (t/ha)
Technology	**Variety**	**2021**	**2022**	**2023**	**2022**
	Outlaw		99	92	2.26
Conventional	Nuseed® Quartz	98	100	97	2.39
	Nuseed® Diamond	102	101	111	2.75
	Average	**100**	**100**	**100**	**2.47**
	ATR-Bluefin	72	89		
	ATR-Bonito	78	94	92	1.86
	ATR Swordfish			85	1.71
	CT107			106	2.14
	Hyola® Blazer TT	108	100	103	2.07
Triazine tolerant (TT) & dual triazine and imidazolinone tolerant varieties (CT)	Hyola® Enforcer CT	107	97	105	2.12
	HyTTec® Trophy	97	102	106	2.13
	HyTTec® Velocity		98	108	2.18
	InVigor® T 4510	123	101		
	Pioneer® PY520 TC			104	2.11
	Renegade TT		101		
	RGT Capacity™ TT	95	106	93	1.87
	SF Dynatron® TT	105	104	96	1.93
	RGT Baseline™		104	100	2.02
	SFR65-064TT		104	103	2.07
	Average	**100**	**100**	**100**	**2.02**
	Pioneer® 44Y27 RR	114	99	97	2.40
	Pioneer® 44Y30 RR		109	106	2.63
	Hyola® 410XX	95	91		
	Hyola® Battalion XC	88	92		
Genetically modified (glyphosate or glufosinate tolerant)	Hyola® Garrison XC	98	96	96	2.37
	Hyola® Regiment XC			95	2.35
	InVigor® LR		104	102	2.54
	InVigor® R 4520P		105	96	2.39
	Nuseed® Emu TF	113	103	100	2.48
	Nuseed® Hunter			108	2.68
	Nuseed® Raptor TF	105	101	101	2.49
	Average	**100**	**100**	**100**	**2.48**
	Pioneer® 43Y92 CL	100	95	92	2.24
Clearfield® (CL)	Pioneer® 44Y94 CL	110	109	103	2.51
	Pioneer® 45Y95 CL	96	105	93	2.27
	Hyola® Equinox CL		91		
	Hyola® Solstice CL			101	2.47
	Nuseed® Ceres			107	2.62
	Pioneer® PY421 C			104	2.55
	Average	**100**	**100**	**100**	**2.44**
	Sowing date	May 3	June 9	April 21	
	Apr-Oct rain (mm)	231	355	236	
	Annual rain (mm)	401	519	355	

Figure 1. *Flowering dates (50% flower) for canola varieties trialed at Hart in 2021 – 2023 (not all data shown).*



Acknowledgements

The Hart Field-Site Group would like to acknowledge SAGIT for funding this trial.

We would also like to thank BASF, Nuseed, Pioneer® Seeds, RAGT Seed Force and Pacific Seeds for providing canola seed.

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Useful Resources

2024 South Australian Crop Sowing Guide. Available online.

Canola Flowering calculator. Available online.

Photo: Hart's regional intern Kaidy Morgan inspecting 2023 canola variety trial.

Comparison of lentil and field pea varieties

Kaidy Morgan and Rebekah Allen
Hart Field-Site Group

Key findings

- Lentil yields ranged from 1.47 – 2.01 t/ha with a trial average of 1.81 t/ha at Hart in 2023.
- The highest yielding lentil varieties were GIA Thunder and pre-commercial variety CIPAL2122, achieving 1.99 and 2.01 t/ha, respectively.
- CIPAL2122, GIA Thunder, GIA Lightning and PBA Jumbo2 have consistently performed well across multiple seasons at Hart.
- Average grain yield for all field pea varieties was 2.23 t/ha with yields ranging from 1.90 – 2.44 t/ha.
- The highest yielding field pea varieties were PBA Wharton and PBA Taylor, achieving 2.42 and 2.44 t/ha, respectively.
- PBA Taylor, PBA Pearl, Kaspa and PBA Butler have yielded well across multiple seasons at Hart.

Aim

To compare the performance of pre-commercial or newly released lentil and field pea lines to current variety options in the medium rainfall zone of the Mid-North at Hart, SA.

Methodology

Two trials were implemented at Hart, SA to evaluate the performance of lentil and field pea varieties (Table 1). Both trials were a randomised block design with three replicates. Twelve field pea varieties were trialed, including one new coded testing line, GIA2003P. Thirteen lentil varieties were trialed. No new lentil varieties were available for inclusion, however GIA Lightning, GIA Thunder, GIA Metro and GIA Sire were commercially released for the 2023 growing season.

Both trials were managed with the application of pesticides to ensure a weed, insect and disease-free canopy and all plots were assessed for grain yield (t/ha). Data was analysed using a REML spatial model (Regular Grid) in Genstat 23rd edition.

Table 1. Trial details for lentil and field pea variety trial at Hart in 2023.

Plot size (field pea)	2.0 m x 10.0 m	**Fertiliser**	MAP (10:20) + 1% Zn @ 80kg/ha
Plot size (lentil)	1.75 m x 10.0 m		
Seeding date	June 1, 2023		
Field pea harvest date	October 26, 2023		
Lentil Harvest date	November 2, 2023		
Location	Hart, SA		

Results and discussion

Lentil

Average grain yield for lentils was 1.81 t/ha, with variety yields ranging from 1.47 – 2.01 t/ha (Table 2) at Hart in 2023. Varieties CIPAL2122 and GIA Thunder performed best, yielding 1.99 and 2.01 t/ha, respectively. Newly released IMI tolerant varieties, GIA Metro and GIA Sire, as well as PBA Hurricane XT and PBA Hallmark XT recorded the lowest yields at Hart in 2023, ranging from 1.47 – 1.76 t/ha (Table 2). GIA Sire is a slow growing variety, best suited to early sowing and therefore is likely to have been impacted by a late sowing time on June 1, as well as limited spring rainfall (GRDC Sowing Guide, 2023).

GIA Metro is the first variety with imidazolinone and metribuzin herbicide tolerances, however, has a known yield penalty when compared to other varieties (GRDC Sowing Guide, 2023). Lentils performed similarly to the 2020 and 2021 seasons at Hart, however below average growing season rainfall (GSR) resulted in lower yields, when compared to 2022 (Table 3).

Field pea

The highest yielding field pea varieties were PBA Wharton and PBA Taylor, yielding 2.42 and 2.44 t/ha, respectively (Table 4). These varieties are both early to early-mid maturity and suited to a shorter season, allowing for improved performance in a season where sowing is delayed and spring rainfall is limited (GRDC sowing guide, 2023). GIA Ourstar yielded 1.90 t/ha and was the lowest yielding variety at Hart in 2023. Across a number of trials, GIA Ourstar has yielded 1-20% lower than varieties such as PBA Wharton and PBA Oura (Grains Innovation Australia, 2020). Yield penalties of 21.5 and 14.0% were noticed when comparing GIA Ourstar to PBA Wharton and PBA Oura at Hart in 2023.

Yield trends were consistent with NVT trials, with PBA Taylor performing well at other locations across the Mid-North, including Laura and Riverton sites (National Variety Trials, 2023). GIA Ourstar was among the lowest yielding varieties at both Laura and Riverton NVT sites and has been low yielding at Hart for several seasons (Table 5).

Table 2. Lentil grain yields at Hart in 2023. Shaded values indicate the highest yielding lentil varieties.

Lentil variety	Grain yield (t/ha)
GIA Metro	1.47^{a}
GIA Sire	1.67^{b}
PBA Hurricane XT	1.69^{b}
PBA Hallmark XT	1.76^{bc}
GIA Leader	1.79^{cd}
PBA Highland XT	1.81^{cde}
PBA Blitz	1.81^{cdef}
PBA Kelpie XT	1.87^{defg}
PBA Bolt	1.88^{defg}
PBA Jumbo2	1.90^{efg}
GIA Lightning	1.90^{egh}
GIA Thunder	1.99^{hi}
CIPAL2122	2.01^{i}

Table 3. Long-term yield data for lentil varieties at Hart 2020-2023.

	% of trial average				**Grain yield (t/ha)**
Variety	**2020**	**2021**	**2022**	**2023**	**2023**
PBA Kelpie XT	106	82	94	103	1.87
PBA Highland XT	100	99	104	100	1.81
PBA Jumbo2	104	110	108	105	1.90
PBA Hallmark XT	95	97	99	97	1.76
GIA Thunder (GIA2002L)		113	123	110	1.99
GIA Leader	1.58	103	105	99	1.79
PBA Hurricane XT	91	95	105	93	1.69
GIA Sire (GIA1703L)			80	92	1.67
GIA Metro (GIA2004L)			80	81	1.47
PBA Bolt			90	104	1.88
PBA Blitz			90	100	1.81
GIA Lightning (GIA2003L)			105	105	1.90
CIPAL2122			111	111	2.01
Average grain yield (t/ha)	**1.62**	**1.30**	**5.42**	**1.81**	
Sowing date	May 18	May 18	June 9	June 1	
April - Oct (mm)	355	232	355	236	
Annual rainfall (mm)	503	401	519	355	

Table 4. Field pea yields at Hart in 2023. Shaded values indicate the highest yielding varieties.

Field pea variety	**Grain yield (t/ha)**
GIA Ourstar	1.90[a]
GIA2202P	2.12[b]
PBA Percy	2.17[bc]
GIA Kastar	2.19[bc]
PBA Gunyah	2.19[bc]
PBA Oura	2.21[bc]
GIA2003P	2.25[bc]
PBA Butler	2.26[c]
Kaspa	2.26[c]
PBA Pearl	2.30[c]
PBA Wharton	2.42[d]
PBA Taylor	2.44[d]

Table 5. Long-term yield data for field pea varieties at Hart 2020-2023.

	% of trial average				Grain yield (t/ha)
Variety	**2020**	**2021**	**2022**	**2023**	**2023**
GIA Kastar	98	88	86	99	2.19
GIA Ourstar	111	93	84	85	1.90
PBA Wharton	83	98	99	109	2.42
PBA Butler	94	108	112	101	2.26
PBA Oura	101		101	99	2.21
Kaspa	112	113	106	102	2.26
PBA Gunyah			93	99	2.19
PBA Percy			99	98	2.17
PBA Taylor			105	110	2.44
PBA Pearl			106	103	2.30
GIA2202P			110	95	2.12
GIA2003P				101	2.25
Average grain yield (t/ha)	**1.38**	**1.61**	**3.63**	**2.23**	
Sowing date	May 18	May 18	June 9	June 1	
April - Oct (mm)	355	232	355	236	
Annual rainfall (mm)	503	401	519	355	

Acknowledgements

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We would like to thank Global Grain Genetics, Seednet and SARDI Clare for providing seed to conduct this trial.

This trial is funded by

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GRDC (2023), 2024 South Australian Crop Sowing Guide

Comparison of pasture varieties & mixes

Rebekah Allen and Kaidy Morgan

Hart Field-Site Group

Key findings

- Tillage Radish and pasture mixes Timok + Moby and Timok + Wintaroo were the best performing annual pastures ranging from 1.38 – 2.27 t DM/ha.
- All pasture varieties and mixes produced similar biomass when re-growth was assessed four weeks after simulated grazing.

Aim

A small pasture trial was conducted at Hart in 2023 (Table 1) to evaluate the performance of a range of pasture varieties and mixes in the medium rainfall zone of the Mid-North on a calcareous clay loam soil (Figure 1).

Methodology

The trial was a randomised block design with three replicates and 14 pasture varieties and mixes (Table 2). This trial was managed with the application of pesticides to ensure an insect-free canopy. Grazing simulation was conducted on July 25 by taking 1 x 1 m^2 biomass cuts from each plot. A second cut to measure pasture re-growth was conducted four weeks later on August 21. Pasture cuts were oven dried at 40°C for 72 hours to measure kilograms of dry matter per hectare (kg DM/ha). Data was analysed using ANOVA model in Genstat 23rd Edition.

Table 1. Trial details for 2023 pasture varieties and mixes comparison at Hart, SA.

Plot size	1.75 m x 10.0 m	**Fertiliser**	Seeding: MAP (10:22) @ 80 kg/ha
Seeding date	May 12, 2023		
Location	Hart, SA		
Grazing cut 1	July 25, 2023		
Grazing cut 2	August 21, 2023		

Figure 1. Pasture variety trial plots at the Hart field site on August 17, 2023.

Results

Pastures established late after a May 12 sowing in 2023, with emergence occurring in cold conditions at the end of May. Tillage Radish and pasture mixes Timok vetch + Moby barley and Timok + Wintaroo oats were the best performing annual pastures, ranging from 1.38 – 2.27 t DM/ha. All varieties and mixes performed similarly when pasture re-growth was measured in August, ranging from 112 – 558 kg DM/ha. The value of below ground plant material (for pasture options including Tillage Radish and Smart Radish) was not measured, however it would be expected to provide additional feed value to livestock.

Table 2. Performance of pasture varieties and mixes expressed as kg DM/ha. Biomass cuts for the HDL blend (Bartolo bladder clover 20%, Cavalier spineless burr medic 30%, Cobra balansa 10%, Dalsa sub clover 20% & Persian clover 20%) and Penfield barrel medic were not conducted in July due to delayed establishment; these pastures were estimated to be < 100 kg DM/ha (not included within analysis). Lettering within each column represents significance, pastures with the same letter are not significantly different.

Pasture type	**Sowing rate (kg/ha)**	**July 25 (kg DM/ha)**	**August 21 (kg DM/ha)**
HDL Blend	25	<100	199
Penfield barrel medic	15	<100	243
Timok	50	478^{a}	558
Studenica	50	482^{a}	449
Bouncer forage brassica	3	529^{a}	265
Timok + Smart Radish	30 + 4	754^{ab}	373
Subzero forage brassica	3	841^{ab}	112
Timok + RGT Nizza CL	45 + 3	841^{ab}	351
Timok + Tillage Radish	30 + 4	848^{ab}	188
RM4	45	917^{ab}	333
Smart Radish	8	1044^{ab}	181
Timok + Wintaroo	30 + 70	1380^{abc}	380
Timok + Moby	30 + 70	1540^{bc}	529
Tillage Radish	8	2268^{c}	272
LSD (P≤0.05)		**972**	**NS**

Acknowledgements

The Hart Field-Site Group would like to acknowledge the generous support of our sponsors who provide funding that allows us to conduct this trial. Proceeds from Hart's ongoing commercial crop also support Hart's research and extension program.

We would like to thank InterGrain, S&W Seeds and AGF Seeds for supplying seed to conduct this trial, and Pinion Advisory for consultation through trial design.

This trial is funded by HART

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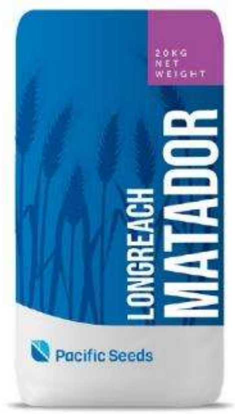

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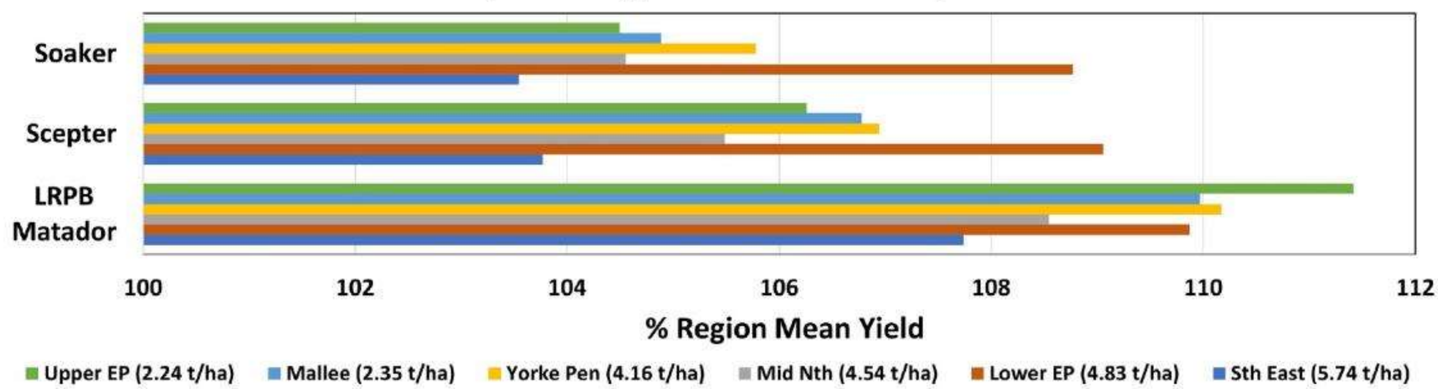
Predicted yield of Soaker and LRPB Matador compared to Scepter

(NVT Longterm MET 2019-23)



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Evaluating long coleoptile wheat performance in clay-loam soils

Kaidy Morgan and Rebekah Allen

Hart Field-Site Group

Key findings

- Plant establishment and grain yield (t/ha) was not improved through the selection of a long coleoptile wheat at Hart across two seasons (2022 - 2023).
- Early sowing resulted in higher yields for all varieties at three depths, despite greater plant establishment for later sown treatments sown at 40 and 80 mm.
- Observed yield trends for all varieties were consistent with expected yield potential and were not influenced by sowing depth or TOS in conditions where good starting soil moisture was present.

Introduction

Changes in climatic conditions and rainfall patterns noticed on a national and global scale have highlighted the importance of building resilient seeding practices to ensure adaptability to adverse conditions, including crop moisture stress. In addition to an increasing prevalence of drier cropping conditions, an increase in land size has resulted in many farm businesses having larger cropping programs (Stummer et. al., 2023). Farming methods that reduce risks associated with dry or early sowing allow farmers to sow a larger proportion of their farm earlier, with reduced impacts to grain yield, particularly in years where autumn rainfall is limited.

To maximise crop yield, it is essential that germination and establishment occur in a uniform and timely manner to utilise growing season rainfall, reduce weed pressure and increase the photoperiod of cash crops (Rebetzke et. al., 2022).

Through the development of long coleoptile wheat varieties, opportunities for dry sowing have potentially increased, allowing crops to access moisture stored deeper in the soil profile.

The coleoptile is a sheath that protects the emerging leaf of a germinating seed as it moves through the soil (Figure 1) (Meiklejohn, 2021). Varieties with a long coleoptile have improved emergence and vigour when sown at depth compared to varieties with shorter coleoptiles that are unable to protect the emerging plant until it reaches the soil surface (Stummer et. al., 2023).

This trial investigated the performance of three wheat varieties with various coleoptile lengths to determine benefits of improved establishment and yield for a long coleoptile variety on a calcareous dark reddish-brown clay-loam soil.

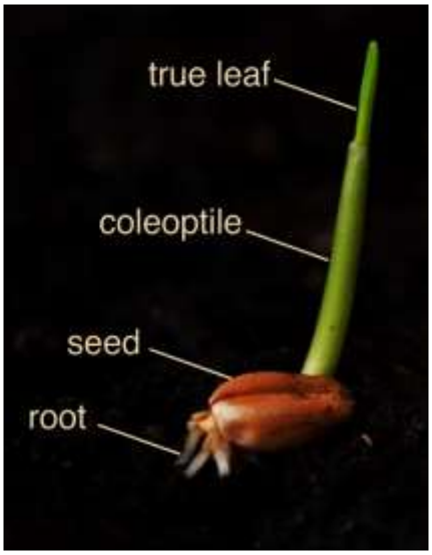

Figure 1. Germinating wheat seed showing coleoptile. Figure sourced from Salomé P, 2017 (Plants: the green starfish of the world, published in Plant Cell Extracts).

Methodology

A trial was implemented at Hart, SA as a split-split plot design with three replicates and 18 treatments. Treatments included two times of sowing (TOS) (Table 1), three sowing depths and three wheat varieties with different coleoptile lengths including Sunblade (61 mm), Scepter (90 mm) and Bale (120 mm). This trial was managed with the application of pesticides to ensure a weed, insect and disease-free canopy.

Table 1. Site details for the 2023 long coleoptile wheat trial at Hart, SA.

Plot size	1.75 m X 10.0 m	**Fertiliser**	Seeding: DAP Zn 1% + Flutriafol @ 80 kg/ha
Seeding date (TOS 1)	April 21, 2023		
Seeding date (TOS 2)	June 2, 2023		June 15 (TOS 1): 36.5 units N
Harvest date (TOS 1)	November 14, 2023		July 5 (TOS 2): 36.5 units N
Harvest date (TOS 2)	November 20, 2023		
Location	Hart, SA		
Previous crop	Mulgara Oaten Hay		

All wheat varieties were sown at a standard target plant density of 180 plants/m^2 at shallow (10 mm), standard (40 mm) and deep (80 mm) treatments. Soil moisture (%) at each TOS was measured to determine any influence of soil moisture at sowing on crop establishment. Soil moisture was measured regularly until crop emergence was complete and plant establishment counts (plants/m^2) were conducted. Normalised Difference Vegetation Index (NDVI) was also measured every two weeks until flowering, as an indicator of crop biomass production. Final wheat grain yield (t/ha) and grain quality as protein (%), screenings (%) and test weight (kg/hL) was measured, and all data was analysed using a REML spatial model (Regular Grid) in Genstat 23rd edition.

Results and discussion

2023 sowing conditions

Significant rainfall in mid-April (26 mm) resulted in 25.4 % soil moisture within the top 10 cm at TOS 1 on April 21. Although there was limited follow up rainfall in May, TOS 1 germinated from existing soil moisture and was able to utilise growing season rainfall (GSR) early in the season.

Following significant rainfall at the end of May, TOS 2 was sown on June 2 into 28% soil moisture and therefore had good emergence at all seeding depths (Figure 2). As there was minimal variation in soil moisture at seeding between TOS 1 and TOS 2 (Table 3), season length was likely the determining factor for yield response between the two times of sowing (Figure 2).

Plant establishment and soil moisture

The average plant establishment for wheat was improved at TOS 2 when sown deep at 80 mm and standard at 40 mm, however TOS 1 had higher establishment when sown shallow at 10 mm (Figure 2). Warmer soils from a late April sowing in addition to damp morning conditions retaining moisture within the soil surface are likely causes of this result.

Plant establishment was not improved through the selection of a long-coleoptile wheat, such as Bale, at Hart in 2023. A contributing factor to this result was favourable moisture present at both TOS across April and June. Results show that a long-coleoptile variety did not improve crop establishment when compared to Scepter sown at any depth (10 – 80 mm) in favourable moisture conditions.

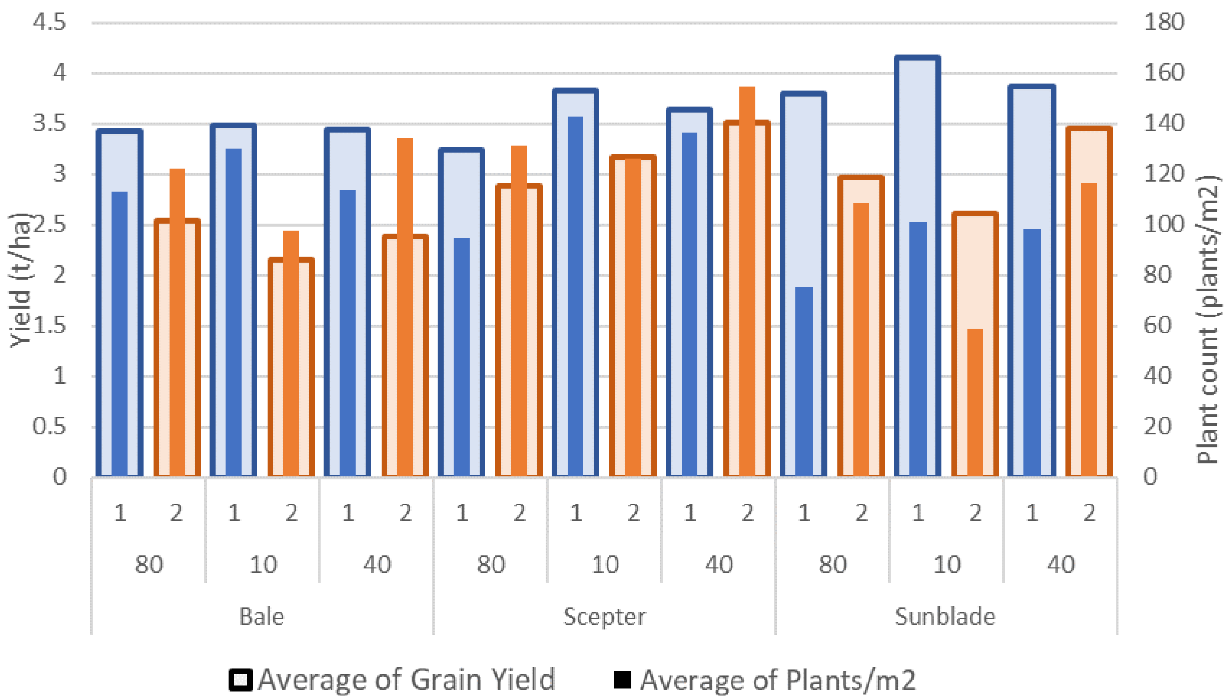

Figure 2. Comparison of plant establishment (plants/m^2) and grain yield (t/ha) for Bale, Scepter and Sunblade when sown at three depths and two TOS. The first time of sowing (TOS 1) is indicated by blue boxes (yield) and bars (plant establishment), while TOS 2 data is shown by orange boxes (yield) and bars (plant establishment).

Grain Quality

Neither protein or test weight were influenced by TOS or sowing depth, however as expected, there were differences noticed between varieties (Table 2). Bale recorded the highest protein of 12.3%, while Scepter and Sunblade performed similarly to each other. Scepter had the lowest screenings and highest test weight at 4.2% and 85.6 kg/hL, respectively. Shallow sown (10 mm) treatments recorded the lowest screenings, while increasing depth to standard (40 mm) or deep (80 mm) resulted in higher screenings.

Table 2. Yield and quality results for the long coleoptile wheat trial at Hart in 2023. Values shaded in blue indicate the best performing treatments, values with the same letters or no letters indicate that there was no differences between results.

	Yield (t/ha)	Predicted protein (%)	Screenings (%)	Test weight (kg/hL)
TOS 1	3.65^b	11.3	5.0	85.7
TOS 2	2.85^a	11.4	5.3	83.6
10 mm	3.23^a	11.3	4.7^a	84.8
40 mm	3.38^b	11.4	5.3^b	84.7
80 mm	3.14^a	11.4	5.4^b	84.6
Sunblade	3.48^b	10.8^a	6.3^c	84.7^b
Scepter	3.38^b	11^a	4.2^a	85.6^c
Bale	2.90^a	12.3^b	4.9^b	83.7^a

Grain yield

All treatments in TOS 1 resulted in higher grain yield, despite better plant establishment at TOS 2. This was a result of earlier germination increasing the season length for crops.

No yield benefits were observed for long coleoptile variety selection at Hart in 2023. Similar results were observed in a trial at the Hart field site in 2022 showing that Scepter sown at a standard depth (40 mm) or deep at 120 mm performed similarly to longer coleoptile varieties Calibre and Bale (Anderson et.al., 2022). Previous growth chamber research conducted at Waite, SA (Bruce, 2017) also shows that coleoptile length can potentially increase under cold conditions, with peak length at 15°C (Anderson et.al., 2022). Results across field trials at Hart in 2022 and 2023 highlight the possibility of coleoptile length increasing in cold environments.

The importance of season length is evident in yield results (Figure 2). Yield data shows that season length is, to an extent, able to compensate for reduced establishment as a result of plants being better able to utilise growing season rainfall early in the season. In a year where spring rainfall is limited, early sowing can significantly improve yield potential by increasing growing season length of crops.

As the Hart field site has a clay loam soil type, short-term deep water penetration is limited, with the majority of rainfall being stored in the upper horizons of the soil profile. This, along with below average summer rainfall reduced the potential benefits of deep sowing, as it is most successful in situations where there is soil moisture at depth. In conditions where there is no moisture benefit at depth, the efficiency of deep sowing to improve yield potential is likely to be reduced.

As expected, there were overall yield effects resulting from variety selection with Bale recording the lowest yield of 2.90 t/ha. Scepter and Sunblade performed similarly, yielding 3.36 and 3.45 t/ha, respectively.

Long coleoptile technology is gaining increasing attention for its potential yield benefits when sown deep. Data from this trial suggests that soil moisture and soil type will play a critical role in determining suitability of deep sowing and long-coleoptile variety selection as a beneficial management decision.

Summary

Although there are potential benefits of long coleoptile technology improving yield for deep sowing, it is important to consider seasonal conditions, soil type and variety selection. If there is no moisture benefit of deep sowing in a particular season, variety selection based on coleoptile length alone is unlikely to result in significant yield increases. The 2023 season was unfavourable to test the potential of long coleoptile varieties at depth, as there was adequate soil moisture at all sowing times and depths. The performance of long coleoptile varieties should be explored further across numerous sowing depths and soil types under different moisture constraints.

Acknowledgements

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This trial is funded by

We would like to thank AGT, LongReach Plant Breeders and Kybunga farmer and Hart board member, Rob Dall, for providing seed to conduct this trial.

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Photo: Long coleoptile wheat trial at the Hart field site, 2023.

Barley management options to close the yield gap and reduce pre-harvest losses

Tom Price[1], Nick Poole[1] and Rebekah Allen[2]
[1]Field Applied Research (FAR) Australia, [2]Hart Field-Site Group

Key findings

- Barley grain yield averaged 4.61 t/ha and ranged from 3.82 to 5.42 t/ha resulting from variety choice and management strategies.
- High fungicide inputs were required to maximise grain yield for RGT Planet, Cyclops and Leabrook across two consecutive years. High fungicide input was most profitable in varieties with leaf rust susceptibility and with high infection levels during grain fill. In the absence of leaf rust, high fungicide inputs were not profitable.
- There were no yield gains resulting from increasing nitrogen (N) application from low to high (60 – 140 kg N/ha). RGT Planet grain yields decreased in response to increasing nitrogen supply. High N supply also increased grain protein for all varieties, preventing them from meeting malt receival specifications.
- The application of plant growth regulators (PGRs) reduced crop lodging at the early time of sowing, however no yield increases were observed.
- The use of simulated grazing at GS 30 (beginning of stem elongation) resulted in a significant yield reduction for RGT Planet and Leabrook of 220 kg/ha and 180 kg/ha, respectively. No yield reduction was observed for Cyclops.

Introduction

While it is assumed that the new frontier for barley water use efficiency is 25 kg/ha/mm, this has rarely been demonstrated. Outside of variety selection, recent GRDC research (FAR2204-002SAX – Online Farm Trials HART and BCG 2022) has demonstrated that canopy management in barley, through the use of fungicides, sowing time, and plant growth regulators, can explain yield responses. These responses range from 3.5 – 7 t/ha using similar genetics in cooler and milder (high yield potential) production environments (T Price at al, 2022 Hart Trial Results). These factors have been more important than N management, particularly where yield potential exceeds 5 t/ha and crops are grown on fertile soils. There may be more scope to close the yield gap in the short to medium term with improvements in disease management, head loss, brackling and lodging control in these lower yielding environments. It is this rationale that lies behind the second and final year of this GRDC National Grower Network (NGN) project.

Methodology

Site selection and rainfall

A barley trial was located at Hart, SA in 2022 and 2023 investigating management strategies to close the yield gap and reduce pre-harvest losses. Starting soil nitrogen (N) was measured at the start of each season to determine in-crop N management (Table 1).

Table 1. Starting soil mineral N (kg N/ha) for barley trials in 2022 and 2023.

Starting soil N (kg N/ha)	Depth (cm) 0 – 10	10 - 30	30 – 60	60 - 90	90 - 120	Total soil N (0 – 120 cm)
2022	19.6	14.5	14.4	13.7	12.0	**74.2**
2023	31.8	17.9	20.2	15.9	17.6	**103.3**

The site received above average annual rainfall in 2022 with 519 mm (Decile 10), compared to the long-term average of 400 mm (Figure 1). Growing season rainfall (GSR) was 355 mm (April – October), 55 mm above Hart's long-term average of 300 mm. In contrast, the 2023 season had below average annual and GSR and was in the lowest 40% of rainfall records (Decile 4). Below average rainfall from August – November resulted in reduced yield potential, particularly for late sown crops.

Figure 1. Monthly rainfall at the Hart field site for 2022 and 2023 seasons (Source: Mid North Mesonet). Cumulative 2023 and long-term average annual rainfall (400 mm) at site is also shown.

Trial design and treatments

The trial was designed and analysed as a replicated split-plot design (Table 1). The trial investigated two times of sowing (TOS), three varieties and nine management treatments over two growing seasons from 2022 – 2023. Varieties trialed were RGT Planet, Cyclops and Leabrook (Table 2).

The nine management treatments (Table 3) included various seed treatments, in-crop fungicides (Table 4), nitrogen and canopy management (Table 5) by either defoliation or application of plant growth regulators (PGR) (Table 6). Defoliation was conducted by mowing plots to simulate the biomass removal by grazing at the start of stem elongation (GS 30).

Assessments conducted include NDVI (Normalised Difference Vegetation Index) as a measure of crop ground cover (associated with crop biomass) and canopy greenness, lodging scores, head loss assessment (heads/m^2), grain yield (t/ha) and quality analysis.

Table 2. Barley variety descriptions and disease ratings (as per GRDC's 2024 South Australian Crop Sowing Guide).

Variety	Description	Disease ratings Leaf scald	 Spot form net blotch (SFNB)	 Net form net blotch (NFNB)	 Leaf rust
RGT Planet	High yielding but disease susceptible	R-SVS	SVS	MRMS-SVS	MRMS-MS
Cyclops	High yielding low rainfall erect variety	S	MS	MR-MS	VS
Leabrook	Vigorous and lodging susceptible	MRMS-SVS	MS	MR-MSS	SVS

R= resistant, MR=moderately resistant, MS=moderately susceptible, S=susceptible, SVS=susceptible to very susceptible, VS= very susceptible.

Table 3. Site details for 2022 and 2023 barley management trial at Hart, SA.

2022	**Plot size**	1.75 m x 10.0 m	**Fertiliser**	Seeding: DAP + Zn 1% + Flutriafol @ 80 kg/ha
	TOS 1: Seeding date	April 17, 2022		
	TOS 1: Harvest date	November 28, 2022	**Low N:**	55 kg N/ha
	TOS 2: Seeding date	June 17, 2022	**High N:**	135 kg N/ha
	TOS 2: Harvest date	December 1, 2022		
2023	**Plot size**	1.75 m x 10.0 m	**Fertiliser**	Seeding: MAP @ 60 kg/ha
	TOS 1: Seeding date	April 27, 2023		
	TOS 1: Harvest date	October 23, 2023	**Low N:**	60 kg N/ha
	TOS 2: Seeding date	June 1, 2023	**High N:**	140 kg N/ha
	TOS 2: Harvest date	November 3, 2023		

Table 4. Summary of management levels.

Treatment	Fungicide	Canopy	Nitrogen Applied N (kg N/ha)	 Total N Supply*
Nil Fungicide Low N	Nil	Nil	60	150
Intermediate Low N	1 Unit	Nil	60	150
High Fungicide Low N	Full	Nil	60	150
Nil Fungicide High N	Nil	Nil	140	230
Intermediate High N	1 Unit	Nil	140	230
High Fungicide High N	Full	Nil	140	230
High Fungicide Canopy Management	Full	PGR @ GS 31 and GS 37	140	230
Dual Purpose System	Full	Defoliation#	140	230
Nil N	Full	Nil	0	86

*Total N supply considering soil N levels (0 – 90 cm) taken prior to sowing on April 13, 2023.
PGR= Plant growth regulator
# Defoliation = Simulated grazing

Table 5. Fungicide strategies applied.

Fungicide Treatment	**Sowing**	**GS 31**	**GS 39-49**
Nil	---	---	---
Intermediate (1 unit)	---	Prosaro @ 300 ml/ha	---
Full protection (3 units)	Systiva @ 150 ml/100 kg	Prosaro @ 300 ml/ha	Aviator Xpro @ 500 ml/ha

Table 6. Canopy intervention strategies applied.

Canopy intervention treatment	**GS 30**	**GS 33 - 37**
Nil	---	---
PGR	Moddus Evo @ 200ml/ha	Moddus Evo @ 200ml/ha
Defoliation#	Yes	---

Mechanical Defoliation = Simulated grazing

Results and discussion

Barley grain yields ranged from 3.82 t/ha to 5.42 t/ha across the trial at Hart in 2023 (Table 7). The highest grain yield came from Leabrook sown early (April 27) with high fungicide (3 units), high N supply (225 kg N/ha) and two PGR applications. Lowest yields came from Leabrook sown late (June 1) under low N supply (150 kg N/ha) and no fungicide management.

The trial produced significant yield differences that resulted from changing sowing date, variety selection and management decisions.

There was a significant interaction (P=<0.001) between management and barley variety indicating that the varieties responded differently to the management applied.

Photo: Aerial view of the barley management trial at the Hart field site, 2023.

Table 7. Influence of agronomic management and variety choice on barley grain yield (t/ha).

TOS 1	Nitrogen	Fungicide	Cyclops	RGT Planet	Leabrook	Average
Nil Fungicide_Low N	60N	0 units	4.62	5.03	4.63	**4.76**
Intermediate F_Low N	60N	1 unit	5.11	5.18	5.08	**5.12**
High Fungicide_Low N	60 N	3 units	5.19	5.33	5.30	**5.27**
Nil Fungicide_High N	140 N	0 units	4.67	4.99	4.58	**4.75**
Intermediate F_High N	140 N	1 unit	4.90	4.99	5.04	**4.97**
High Fungicide_High N	140 N	3 units	5.24	5.09	5.38	**5.24**
Full Potential + PGR	140 N	3 units	5.11	5.01	5.42	**5.18**
Dual Purpose System	140 N	3 units	4.96	4.91	5.12	**5.00**
Nil N	0N	3 units	4.38	5.06	4.26	**4.57**
Average			**4.91**	**5.06**	**4.98**	

TOS 2	Nitrogen	Fungicide	Cyclops	RGT Planet	Leabrook	Average
Nil Fungicide_Low N	60N	0 units	4.06	4.20	3.82	**4.03**
Intermediate_LowN	60N	1 unit	4.17	4.34	4.18	**4.23**
High Fungicide_Low N	60 N	3 units	4.62	4.61	4.56	**4.60**
Nil Fungicide_High N	140 N	0 units	3.92	4.17	3.97	**4.02**
Intermediate F_High N	140 N	1 unit	4.13	4.31	4.19	**4.21**
High Fungicide_High N	140 N	3 units	4.36	4.47	4.66	**4.50**
Full Potential + PGR	140 N	3 units	4.46	4.54	4.63	**4.54**
Dual Purpose System	140 N	3 units	4.35	4.22	4.56	**4.37**
Nil N	0N	3 units	4.32	4.59	4.33	**4.41**
Average			**4.26**	**4.38**	**4.32**	

Time of Sowing	P Value	0.001	LSD (P=0.005)	0.17
Management	P Value	<0.001	LSD (P=0.005)	0.22
Variety	P Value	<0.001	LSD (P=0.005)	0.05
TOS x Management	P Value	0.095	LSD (P=0.005)	ns
TOS x Variety	P Value	0.776	LSD (P=0.005)	ns
Variety x Management	P Value	<0.001	LSD (P=0.005)	0.16
Variety x Management	P Value	0.073	LSD (P=0.005)	ns

Intermediate F = 1 unit of fungicide (single application timing)

Fungicide

The fungicide strategies investigated included nil fungicide, a single foliar fungicide at early stem elongation, and up to 3 fungicide units which included Systiva seed treatment plus two foliar fungicides applied at the start of stem elongation and at flag leaf (1st awn emergence).

Disease pressure in 2023 was lower than levels experienced in 2022 (leaf area infection for 2023 presented in Figure 2). However, the disease observed were similar; net form of net blotch (NFNB) and spot form of net blotch early (primarily in RGT Planet) with high levels of leaf rust present later in the season (primarily in Leabrook and to a lesser extent Cyclops).

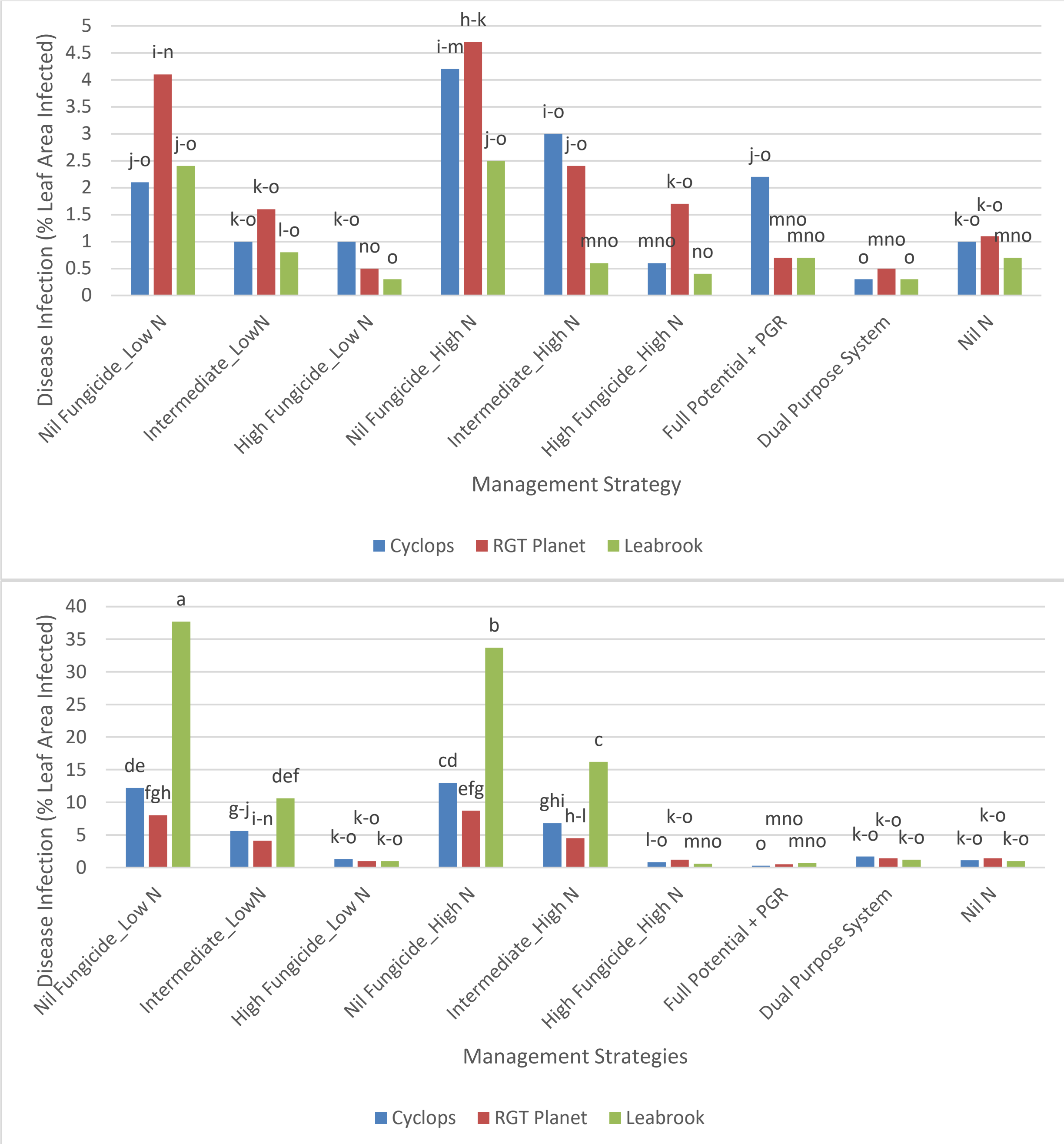

Figure 2. Influence of time of sowing (top: TOS 1, bottom: TOS 2) and management strategy on plot disease infection (% leaf area infection). Disease assessed at start of flowering (August 30: TOS 1, September 22: TOS 2). Bars with different letter are statistically different, P<0.001, LSD=3.7%.

**Note assessments conducted on different calendar dates, TOS 1 also saw high levels of disease later in the season as shown in TOS 2 assessment.*

Note: Bar graphs primarily represent the most important diseases in each variety, leaf rust in Leabrook and Cyclops and low levels of NFNB/SFNB in RGT Planet.

In 2023, fungicide management was the most important management practice with yield responses of up to 800 kg/ha (Leabrook, TOS1, High N, High fungicide). RGT Planet was least responsive to fungicide (0.1 – 0.4t/ha response) and provided the highest yields under the nil fungicide program (Figure 3), however the same trial conducted at Birchip showed RGT Planet to be the lowest yielding under nil fungicide management due to much higher levels of NFNB infection.

The most responsive variety to fungicide was Leabrook, with yield responses of 0.7 to 0.8 t/ha from nil to high. Although all three varieties maximised their grain yield under high fungicide input, it was uneconomic where the cultivar had leaf rust resistance (RGT Planet). The cost benefit ratio (money back for money spent) was greatest in varieties with leaf rust susceptibility in this trial (Table 8).

The best return for fungicide $ spent was for the GS 31 Prosaro (300 ml/ha) application with only two out 24 scenarios not providing a financial benefit (RGT Planet TOS 1, high N and Cyclops TOS 2 low N). In most cases, high fungicide input was not economical for RGT Planet due to generally low levels of disease, while Leabrook saw an increase of over $300/ha increase in income (almost 3 times the amount spent) due to high fungicide application.

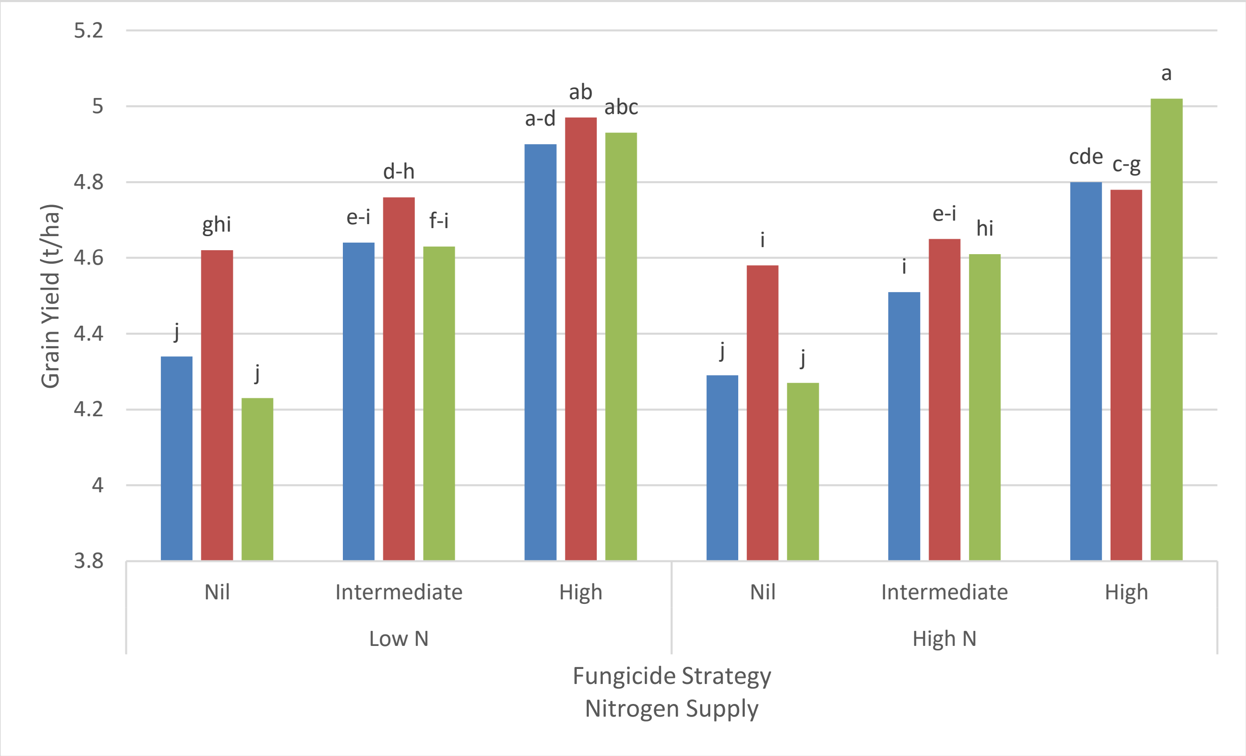

Figure 3. Influence of fungicide strategy on grain yield (t/ha) of three barley varieties under high and low nitrogen supplies. Values averaged across both sow dates. Bars with different letter are statistically different, P<0.001, LSD=0.16t/ha.

Table 8. Economic figures showing additional income resulting from different fungicide strategies at each TOS and nitrogen supply scenario, and the return ratio for each dollar spent on fungicides. Figures based on Intermediate fungicide program cost $32/ha and high fungicide program cost $105/ha. Income calculated on yield (t/ha) x grain price ($/t) taking into account bin grade. Highlighted cells show scenarios where applying fungicide was not economical.

	Cyclops		**RGT Planet**		**Leabrook**	
	Additional income ($/ha)	**Cost benefit ratio**	**Additional income ($/ha)**	**Cost benefit ratio**	**Additional income ($/ha)**	**Cost benefit ratio**
TOS 1 LOW N						
Intermediate	139.65	4.38	45.75	1.44	137.25	4.31
High	162.45	1.55	91.50	0.87	204.35	1.95
TOS 1 HIGH N						
Intermediate	65.55	2.06	-	-	131.10	4.11
High	162.45	1.55	28.50	0.27	228.00	2.17
TOS 2 LOW N						
Intermediate	31.35	0.98	39.90	1.25	186.20	5.84
High	159.60	1.52	116.85	1.11	302.10	2.88
TOS 2 HIGH N						
Intermediate	59.85	1.88	39.90	1.25	62.70	1.97
High	125.40	1.19	85.50	0.81	196.65	1.87

Nitrogen

Nitrogen supply was less important in 2023, especially when comparing low N supply (60 N + 85 soil N in 0 – 90 cm) to high N supply (140 N + 85 soil N in 0 – 90cm). There was no grain yield benefit resulting from increased N supply in 2023, with RGT Planet recording a yield reduction as N was increased (Figure 4). In treatments with no applied N, there was a grain yield loss of 440 kg/ha.

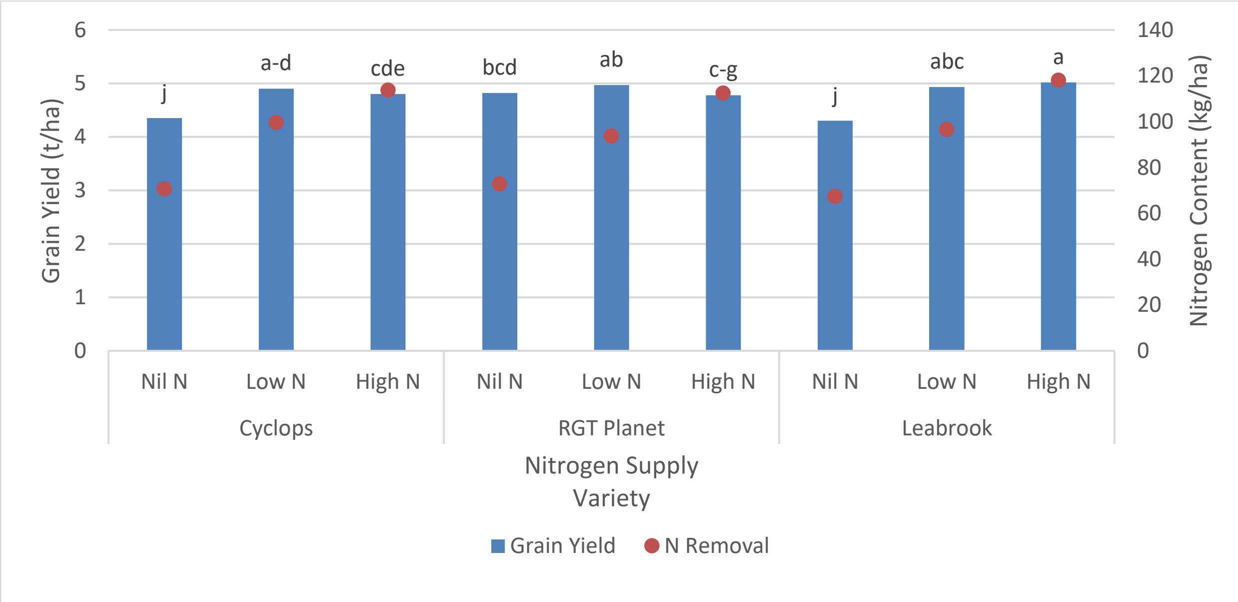

Figure 4. Influence of barley variety and nitrogen supply (under high fungicide input) on grain yield (t/ha) and total nitrogen content of crop (assuming 25% N in crop residues). Figures are averages of both TOS. Bars with different letters are statistically different, P<0.001, LSD=0.16 t/ha. Nitrogen content not statistically analysed.

Increasing N rate had a significant effect on grain quality (Table 9). Across all varieties, increasing N supply from low to high resulted in a grain protein increase of approximately 2%. In all cases this resulted in protein levels above maximum malt receival specifications, resulting in a decreased grain price. High N supply in RGT Planet increased screenings and decreased retention, likely due to an increase in grain number (through increased tillering as a result of high N) and being unable to fill all grains resulting in smaller grain size. In contrast, decreased screenings, increased retention, and increased test weight was observed as a result of being able to fill grains set where no fertilser N was applied. In addition to the observed yield penalty for nil N treatments, there was also a reduction in grain protein, dropping it below malt specifications.

Treatments with no applied N averaged 4.49 t/ha (ranging from 4.26 – 5.06 t/ha) and had grain protein levels of 8.4% (ranging from 7.9 – 8.9%). Based on these figures, it was calculated that the crop removed 53 kg N/ha. If it was assumed 25% of N was present in crop residue the N uptake would amount to approximately 70 kg N/ha. Given that the soil test showed 103 kg N/ha (0-120cm) the crop was likely not limited by nitrogen and nitrogen uptake was limited by either soil moisture and/or root exploration.

Table 9. Influence of variety and management choice (averaged across both TOS) on grain quality (retention (%), screenings (%), protein (%), and test weight (kg/hL)). Red figures and blue shading denote quality results outside of malt specification.

Variety	Fungicide Mgmt	N Supply	Canopy Mgmt	Retention (%)		Screenings (%)		Protein (%)		Test Weight (kg/hL)	
Cyclops	Nil	Low	---	71.4	gh	5.4	fgh	11	f	69.0	fg
Cyclops	Intermediate	Low	---	75.9	fg	4.4	hij	10.8	fgh	69.8	de
Cyclops	High	Low	---	81.4	de	3.4	ijk	10.9	fg	70.5	bc
Cyclops	Nil	High	---	56.5	lm	9.5	b	13.3	a	66.9	no
Cyclops	Intermediate	High	---	62.8	jk	6.9	def	12.9	ab	68.5	ghi
Cyclops	High	High	---	71.9	gh	5.1	gh	12.7	bc	69.4	ef
Cyclops	High	High	PGR	70.1	hi	5.3	gh	12.9	abc	69.2	ef
Cyclops	High	High	Defoliation	68.1	hi	5.2	gh	12.2	de	68.3	hij
Cyclops	High	Nil	---	91.4	b	1.6	lmn	8.7	j	71.9	a
RGT Planet	Nil	Low	---	60.4	kl	7.7	de	10.6	fgh	67.1	lmn
RGT Planet	Intermediate	Low	---	66.3	ij	6.3	efg	10.4	hi	67.7	jkl
RGT Planet	High	Low	---	70.5	hi	5.3	gh	10.1	i	68.0	ijk
RGT Planet	Nil	High	---	45.7	n	13.0	a	13.0	ab	65.6	q
RGT Planet	Intermediate	High	---	52.3	m	10.0	b	12.9	bc	66.4	op
RGT Planet	High	High	---	55.7	m	8.5	bcd	12.6	bcd	66.9	mno
RGT Planet	High	High	PGR	54.7	m	7.9	cd	12.9	bc	67.1	lmn
RGT Planet	High	High	Defoliation	54.5	m	9.4	bc	12.5	cde	66.6	no
RGT Planet	High	Nil	---	83.6	d	2.0	k-n	8.1	k	70.2	cd
Leabrook	Nil	Low	---	85.2	cd	2.9	jkl	10.5	ghi	67.1	lmn
Leabrook	Intermediate	Low	---	90.8	b	1.7	lmn	10.4	hi	68.9	fgh
Leabrook	High	Low	---	94.3	ab	1.0	mn	10.5	gh	70.0	cd
Leabrook	Nil	High	---	78.1	ef	4.4	hi	12.5	cde	65.9	pq
Leabrook	Intermediate	High	---	86.1	cd	2.5	klm	12.9	bc	67.5	klm
Leabrook	High	High	---	91.0	b	1.6	lmn	12.6	bcd	68.9	fg
Leabrook	High	High	PGR	91.4	b	1.5	lmn	12.8	bc	69.1	fg
Leabrook	High	High	Defoliation	89.7	bc	1.8	k-n	12.0	e	67.7	kl
Leabrook	High	Nil	---	96.6	a	0.7	n	8.4	jk	70.9	b
Average				**73.9**		**5.0**		**11.5**		**68.3**	
P Value				**<0.001**		**<0.001**		**0.028**		**<0.001**	
LSD (P≤0.05)				**4.7**		**1.6**		**0.4**		**0.6**	

Canopy management

There were no yield gains resulting from canopy management strategies (based on high N, high fungicide and PGR) in 2023. The application of plant growth regulators (PGR) was not effective at reducing lodging.

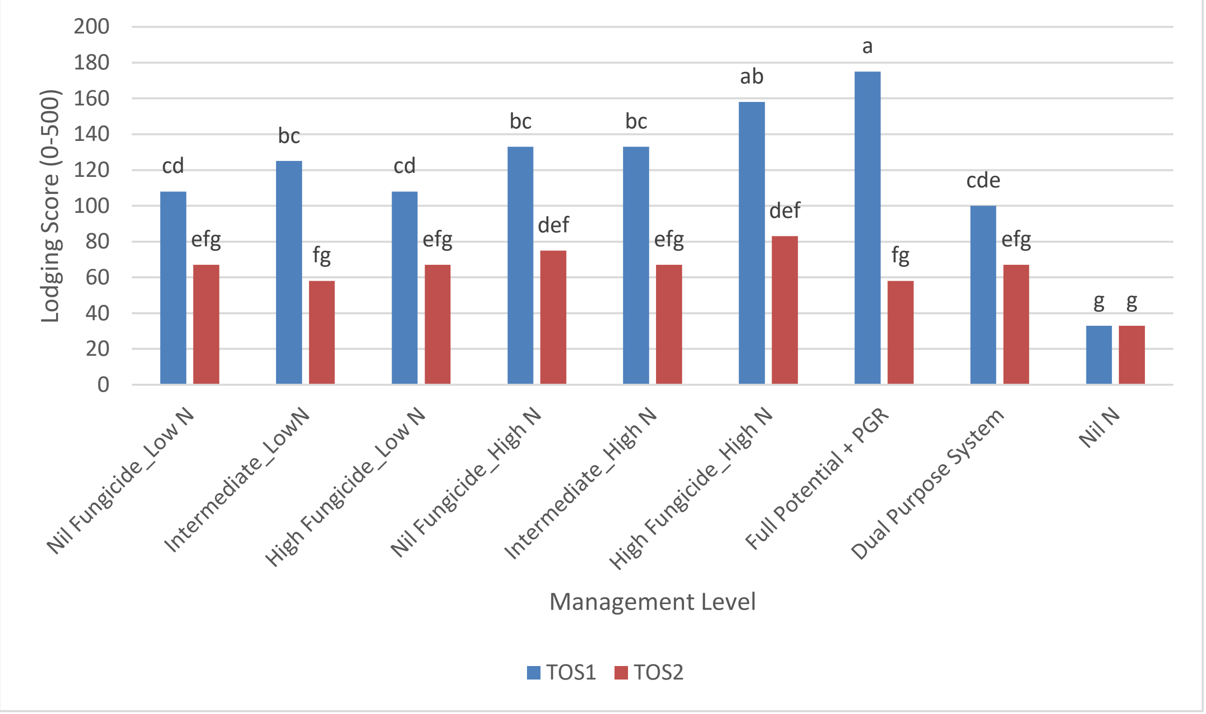

Figure 5. Influence of sowing date and management strategies on crop lodging (averaged across varieties).

The use of simulated grazing did result in a reduction of crop lodging, however this also came with a yield penalty for RGT Planet and Leabrook. The most effective way to reduce lodging when sowing early was to select a stronger strawed variety. Cyclops had significantly less lodging than RGT Planet, which also had less lodging than Leabrook (data not shown).

At TOS 2, no management strategy affected crop lodging (Figure 5), likely a result of delayed sowing time and below average spring rainfall. In 2022, highest grain yields were achieved through simulated grazing. This treatment reduced overall biomass production improving conversion to grain yield in a Decile 8 growing season.

Variety

Variety choice was a significant factor influencing grain yield at Hart in 2023. The highest yielding variety was RGT Planet, achieving 5.06 t/ha at TOS 1 and 4.38 t/ha at TOS 2. While RGT Planet was the highest yielding variety, only one of nine management strategies achieved malt quality (Low N, high fungicide). Despite Cyclops having the lowest levels of disease and crop lodging, it was the lowest yielding variety achieving 4.91 t/ha at TOS 1 and 4.26 t/ha at TOS 2.

Time of sowing

Sowing date had a significant effect on grain yields achieved in 2023. Delaying sowing to June 1 resulted in an average yield penalty of 660 kg/ha.

Time of sowing also influenced disease levels. It is generally expected that early sown crops experience higher disease pressure however that wasn't the case in this trial. With low levels of NFNB present in the trial, the delayed sowing plots experienced higher levels of barley leaf rust, with warmer temperatures during stem elongation and flowering period favouring leaf rust.

Summary

The season in 2023 highlighted the importance of early sowing and variety selection to maximise yield potential. Measuring the level of nitrogen supply from the soil is essential to manage N application. In 2023 the level of N supply from the soil was slightly higher across the soil profile than in 2022 (approx. 30 N). Despite lower yield potential in 2023 compared to 2022 (average yields of 4.65 t/ha vs. 5.51 t/ha), protecting the upper canopy (flag sheath, flag-1 and flag-2) with higher fungicide input was the most important management decision to close the yield gap after variety and sowing date. This was done using an SDHI seed treatment (Systiva) and two in crop fungicide applications. The use of plant growth regulators provided no yield benefit and did not provide any advantages to help prevent crop lodging in this experiment.

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T. Price., N. Poole., (2022). NGN Barley management options to close the yield gap and reduce pre-harvest losses. *https://www.farmtrials.com.au/trial/37618*

Acknowledgements

This research was funded by the GRDC as part of the National Grower Network project ‘Barley management options to close the yield gap and reduce pre-harvest losses’ (FAR2204-002SAX).

Photo: Aerial view of the barley management trial at the Hart field site, 2023.

Evaluating management strategies to reduce pod shatter in lentils

Kiady Morgan and Rebekah Allen
Hart Field-Site Group

Key findings

- In 2022, pod shatter (seeds/m2) was affected by variety selection and time of harvest (TOH), as strong winds between TOH 1 and TOH 2 were conducive to seed loss. In 2023 conditions between TOH 1 and 2 were mild and there were no noticeable differences in pod shatter.
- Variety selection influenced seed and pod loss, with PBA Jumbo2 being among the best performing varieties for yield and losses.
- The application of EnviroShield® at green pod or desiccation had no effect on seed loss or final grain yield (t/ha) across two seasons at Hart.
- Although PBA Kelpie XT is resistant (R) for pod shatter, it recorded higher losses (1.8% of total yield) than moderately resistant (MR) rated variety PBA Highland XT (0.3% of total yield) in 2022.

Introduction

Pre-harvest seed losses are an issue for most lentil growers due to impacts of pod shatter or pod drop reducing harvested yield. Unfavourable weather conditions leading into harvest including high temperatures and wind events damage pods, increasing pod shatter and seed loss (Parker et. al., 2021). Plant breeding has played an important role in improving the resilience of lentil varieties to pod shatter, however in many cases seasonal conditions and management practices still result in losses (Parker et. al., 2021).

In addition to plant breeding, pod protector or plant growth regulator (PGR) products are being explored for their ability to improve the strength of lentil pods or influence canopy structure to prevent seed losses. New research aims to understand production losses on farm ($/ha), resulting from seed loss and evaluate novel management strategies to improve lentil seed retention.

Trials at Hart, SA from 2022 – 2023 investigated variety selection, harvest timing and pod protector product EnviroShield® as management tools to reduce pod shatter in lentils.

Methodology

In 2022, a two-year trial investigating lentil pod shatter was established at Hart, SA (Table 1). This trial included four varieties, two application timings and two times of harvest. Four lentil varieties with varying maturity and pod shatter resistance were tested, including PBA Blitz, PBA Highland XT, PBA Kelpie XT and PBA Jumbo2 (Table 2). Time of harvest (TOH) was evaluated to compare a standard (harvesting on time) and late harvest. The late harvest timing occurred approximately 2 weeks after TOH 1 and was dependent on weather conditions post TOH 1.

A foliar applied product EnviroShield® was selected to trial across two seasons at Hart. EnviroShield® is a polymer pod protector aiming to provide benefits of a protective coating on the pod to reduce shattering across numerous crop types prone to seed loss.

Two application timings were trialed with foliar sprays applied at green pod (most pods reached final size but are still green) and desiccation, as a pre-harvest application. All applications of EnviroShield were applied at 1 L/ha (100 L water rate). Selected varieties were treated with EnviroShield® for a standard harvest timing, however all varieties were treated for late TOH treatments in both seasons (Table 3).

Table 1. Site details for 2022 and 2023 lentil pod shatter trial at Hart, SA.

2022	**Plot size**	1.75 m x 10.0 m	**Fertiliser**	Seeding: MAP Zn 1% @ 80 kg/ha
	Seeding date	May 12, 2022		
	Harvest date	Standard: November 29 Late: December 14	**Treatments**	Green pod: October 21 Desiccation: November 22
2023	**Plot size**	1.75 m x 10.0 m	**Fertiliser**	Seeding: MAP Zn 1% @ 80 kg/ha
	Seeding date	June 1, 2023		
	Harvest date	Standard: November 2 Late: November 15	**Treatments**	Green pod: October 6 Desiccation: October 26

Trials were managed with the application of pesticides to ensure a weed, insect and disease-free canopy. In 2022 and 2023 seasons, all plots were assessed for pod shatter by post-harvest seed counts (seeds/m^2). In 2023, pod drop (pods/m^2) was also measured post-harvest. All plots were assessed for grain yield (t/ha), 1000 grain weight and inspected for weather damage where required, including discoloration. Data was analysed using an ANOVA model in Genstat 23rd Edition.

Table 2. Lentil varieties with maturity, shatter and pod drop resistance ratings.

Variety	Maturity	Pod shatter resistance	Pod drop resistance
PBA Blitz	Early	MR	MR
PBA Highland XT	Early – mid	MR	MR
PBA Kelpie XT	Early – mid	R	MR
PBA Jumbo2	Mid	R	MR

*MR = Moderately resistant, R = Resistant

Table 3. Treatment details for lentil pod shatter trial at Hart in 2022 and 2023.

	TOH 2 (2022)		TOH 2 (2023)	
Timing	**Green pod**	**Desiccation**	**Green pod**	**Desiccation**
Variety	*PBA Blitz	PBA Blitz,	*PBA Blitz	PBA Blitz
	PBA Kelpie	PBA Kelpie	PBA Kelpie	PBA Kelpie
	PBA Highland	PBA Highland	*PBA Highland	PBA Highland
	PBA Jumbo 2	PBA Jumbo 2	PBA Jumbo 2	PBA Jumbo 2

**Varieties which were applied with EnviroShield at green pod for TOH 1 in each season.*

Results and discussion

Time of harvest

Time of harvest (TOH) influenced pod shatter in 2022, with late harvest treatments showing higher losses (Figure 1).

In 2022, unfavourable weather conditions occurred between standard and late TOH, and significant pod shatter effects were noticed. Seven of the 15 days between harvest timings recorded wind gusts of more than 50 km/h, with 59 km/h wind gusts experienced the day prior to harvest (Table 4). As a result, PBA Kelpie XT and PBA Blitz recorded the highest seed losses from pod shatter of 111.5 and 122.3 kg/ha, respectively (Figure 1). Although losses from pod shatter were observed, this did not impact overall grain yield (t/ha).

The effects of TOH on pod shatter were not evident in 2023, likely resulting from mild conditions between the two harvest timings. Only two of the 13 days between standard and late harvest experienced strong wind gusts of more than 50km/h (Table 4). Although there was no difference in pod shatter between TOH 1 and 2, late harvest resulted in a 0.4 t/ha yield penalty. High pod losses from delayed harvest may have contributed to this yield reduction (Table 5). Pod drop was measured in 2023 only (one year of data).

Table 4. Weather conditions for the week prior to standard harvest and for all days between standard and late harvest timings for both seasons.

Year	Weather conditions	TOH 1	TOH 2
2022	Average daily maximum temperature (°C)	22.5	22.9
	Days with wind gusts > 50 km/h	1 of 7	7 of 15
	Average wind speed (km/h)	17.1	20.5
2023	Average daily maximum temperature (°C)	23.7	28.9
	Days with wind gusts > 50 km/h	1 of 7	2 of 13
	Average wind speed (km/h)	22.4	22.6

Variety

Pod shatter resistance varied between the four varieties trialed at Hart (Table 2), with PBA Jumbo2 and PBA Kelpie XT both rated resistant (R) for pod shatter.

At Hart in 2022, PBA Jumbo2 yielded higher than PBA Kelpie XT, PBA Blitz and PBA Highland XT (Table 5). Although PBA Kelpie XT is rated R for pod shatter, it recorded higher losses (1.8% of total yield) than MR rated variety PBA Highland XT (0.3% of total yield) in 2022.

In 2023 no differences in pod shatter were noticed between varieties, however there was a variety effect on pod drop ($P < 0.001$). Pod loss (measured as pods/m^2) was lowest for PBA Jumbo2 (4.8% of total yield), with PBA Kelpie recording the highest amount of pod drop (19.9%) (Table 5).

Table. 5 Yield and % yield loss from pod shatter and pod drop in 2022 and 2023. Significant differences are indicated by different letters. Shaded values indicate best performing treatments.

	Treatment	Yield (t/ha)	% yield loss from pod shatter	% yield loss from pod drop
2022	PBA Blitz	3.57[a]	2.2[b]	-
	PBA Highland XT	3.76[a]	0.3[a]	-
	PBA Kelpie XT	3.73[a]	1.8[b]	-
	PBA Jumbo2	4.41[b]	0.5[a]	-
	P value	**P < 0.001**	**P < 0.001**	
	Standard harvest	3.77	0.6	-
	Late harvest	3.96	1.7	-
	P value	**NS**	**P < 0.001**	
	EnviroShield® @ Green pod	3.91	1.6	-
	EnviroShield® @ Desiccation	3.99	1.8	-
	Nil	3.86	1.1	-
	P value	**NS**	**NS**	
2023	PBA Blitz	2.06	2.7	9.8[b]
	PBA Highland XT	1.85	2.3	15.7[c]
	PBA Kelpie XT	1.83	1.9	19.9[c]
	PBA Jumbo2	1.94	0.4	4.8[a]
	P value	**NS**	**NS**	**P < 0.001**
	Standard harvest	2.13	1.0	9.6
	Late harvest	1.71	2.7	15.5
	P value	**P = 0.003**	**NS**	**P = 0.018**
	EnviroShield® @ green pod	1.89	1.6	12.1
	EnviroShield® @ desiccation	1.77	2.3	11.6
	Nil	1.92	1.7	11.8
	P value	**NS**	**NS**	**NS**

Application of EnviroShield®

EnviroShield® applications at 1 L/ha (100 L water rate) had no effect on pod shatter when applied at green pod or desiccation across two seasons at Hart (Table 5). Further investigation into application rates and timings would provide additional information to make informed management decisions.

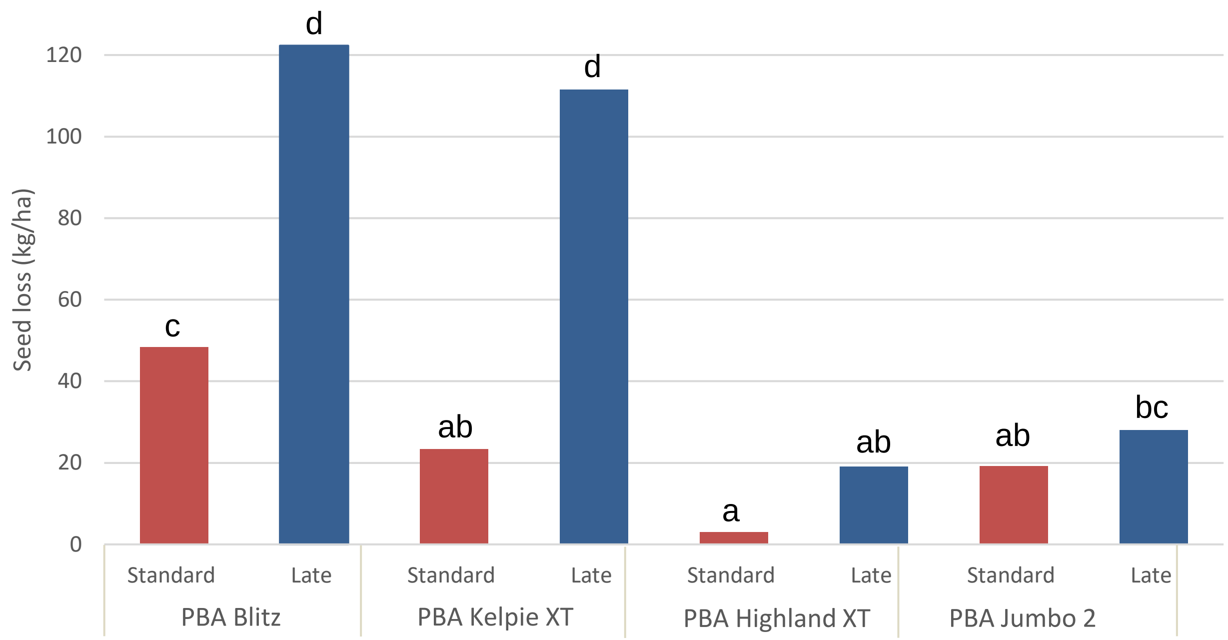

Figure 1. Seed loss (pod shatter) for all varieties and harvest times at Hart in 2022. Significant differences in seed loss (kg/ha) from pod shatter between treatments are indicated by different letters.

Summary

Variety selection and time of harvest impacted yield losses from pod shatter in 2022 when windy conditions were present prior to harvest, however losses were not significant when considering total yield.

Seasonal variation in variety performance was noticed, however PBA Jumbo performed well for yield and pod shatter in both seasons of the trial. In 2023, the majority of losses were as a result of pod drop rather than pod shatter, which was not measured in the first year of the trial.

EnviroShield® applied as a foliar spray at green pod or desiccation had no yield or pod shatter effect for any treatment across both seasons. Further investigation into application rates and timings would provide additional information to make informed management decisions.

Variety selection and timely harvesting are critical for reducing pod shatter losses in years where conditions may be unfavourable leading into harvest, however additional management strategies should be further explored over several years.

Acknowledgements

The Hart Field-Site Group would like to acknowledge the generous support of our sponsors who provide funding that allows us to conduct this trial. Proceeds from Hart's ongoing commercial crop also support Hart's research and extension program.

We'd also like to gratefully acknowledge the various organisations who provided product and seed to conduct this trial.

This trial is funded by HART

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Legume and oilseed herbicide tolerance

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Key findings

- Most IBS treatments had slight to moderate effects on legume and oilseed crops at Hart in 2023. This was likely contributed to wet conditions at seeding favouring herbicide activity coupled with late seeding in June slowing crop emergence and growth.
- When applied standalone at 800 and 1200 mL /ha, Crucial® provided a good level of control across cereals and some legumes. The new generation of Group 14 spike herbicides Voraxor® and Terrad'or® provided an additional level of control (rating 5 and 6) across most crop types at Hart.

Aim

To compare the tolerance and control of canola and legume varieties to a range of herbicide timings and rates.

Methodology

The 2023 legume and oilseed herbicide tolerance trial was set up as a demonstration and is a non-replicated matrix (Table 1). Eighteen varieties were sown in strips across 10 different crop types including canola, faba bean, field pea, chickpea, lentil, vetch, sub clover and barrel medic. Barley and oats were also included in 2023 and 48 herbicide treatments were applied across all 18 crops at various timings. The trial was split into two components: pulse crop safety (1A) and pulse control (1B). The trial was sown into wet soils on June 20 providing good conditions for pre-emergent and post sowing pre-emergent (PSPE) herbicide activity.

Table 1. Trial details for legume and oilseed herbicide tolerance at Hart, SA.

Plot size	2.2 m x 2.0 m	**Fertiliser**	MAP (10:22) + 1% Zn + Impact @ 80 kg/ha
Seeding date	June 20, 2023		
Location	Hart, SA	**Soil type**	Clay loam

Some herbicides used in this demonstration are not registered for crops that have been sprayed. It is important to check herbicide labels before following these strategies used. In 2023, a number of herbicide treatments displayed varying crop tolerances that were not expected. Care should be taken when interpreting these results, as herbicide effects can vary between seasons and is also dependent upon conditions at application, soil type and weather conditions. This trial is an un-replicated matrix and observations are based on visual assessment at one point in time only.

Application timings:

Incorporated by sowing (IBS)	June 20
Post seeding pre-emergent (PSPE)	June 20
Early post emergent (3-4 node)	July 27
Post emergent (5-6 node)	August 21
Post emergent (Group 14 spike at 5-6 node)	September 1

Treatments were visually assessed and scored for herbicide effects approximately six weeks after each application from June – September (Table 2 & 3). Crop damage ratings were:

1 = no effect	4 = increasing effect
2 = slight effect	5 = severe effect
3 = moderate effect	6 = death

Results and discussion

Crop safety

Most IBS treatments had slight – moderate effects on legume and oilseed crops at Hart in 2023 (Table 2). This was in contrast to previous seasons (2020 – 2022) and was likely due to wet conditions at seeding and significant rainfall post seeding (30 mm in three days), increasing herbicide activity. This coupled with a late seeding in June which saw slow crop emergence and growth, particularly for crops such as Zulu II clover.

Pre-emergent herbicides with the highest levels of visual crop damage were Terrain® Flow, Sentry®, Reflex® and Tenet®. Observed crop damage (rating 4 – 5) could be expected across oilseed crops for Terrain Flow as this product is not registered for this use. Some unexpected and moderate damage was seen across lentil and chickpeas, which could be due to physical soil movement into the furrow.

Tenet® and Ultro®, both registered for control or suppression of some grasses had increasing effect on Compass barley and Kingbale oats. Tenet® showed moderate damage one some of the pasture species, along with some of the pulses and vetch.

A number of PSPE treatments displayed severe effects to crop death across a range of canola, pasture and pulse treatments (Table 2).

Pulse control

A range of treatments provided high levels of control (rating 5 – 6) at Hart in 2023 (Table 3).

Saracen® + Cando®, Paradigm + MCPA LVE + Uptake®, Talinor® + Hasten® and Velocity® + Hasten provided excellent control of most oilseed and legume species when applied at 5 – 6 node. Similar to 2022, Triathlon® and Flight® EC performed equally, providing slight to severe control across all legume and oilseed crops. The least effective herbicide combination for controlling a range of oilseed, pulses and pasture was Brodal® Options + MCPA Amine 750, with most ratings between 1 – 3 (no – moderate effect).

As expected, most Group 14 (previously Group G) herbicides provided a high level of control across oilseed, legume and cereal crops. Similarly to 2021 – 2022, the new generation of Group 14 spike herbicides Voraxor® and Terrad'or® provided an additional level of control (rating 5 and 6) across most crop types at Hart when compared to carfentrazone, Sledge®, Terrain® Flow and butafenacil, particularly for crop types such as canola and volunteer lentil or chickpea.

Crucial® was applied standalone at 800 and 1200 mL /ha and provided a good level of control across cereals and some legumes. In previous years, pulse and oilseed control was improved when applied with a Group 14 herbicide, however in 2023, glyphosate standalone visually performed similar to older Group 14 herbicides applied with Crucial®. Control was slightly improved in 2023 with the addition of Group 14 chemistry for crop types such as glyphosate tolerant canola, field peas and pasture.

Acknowledgements

The Hart Field-Site Group would like to acknowledge the generous support of our sponsors who provide funding that allows us to conduct this trial. Proceeds from Hart's ongoing commercial crop also support Hart's research and extension program. We'd also like to gratefully acknowledge the various organisations who provided product and seed to conduct this trial.

This trial is funded by HART

Table 2. Crop damage ratings for the legume and oilseed herbicide tolerance trial at Hart in 2023.

CROP SAFETY – Part 1A

CROP SAFETY				Canola				Barley	Oats	Bean		Pea		C/pea	Lentil		Vetch			Medic	Clover
	Timing	Treatment	Rate	HyTTec Trophy	Pioneer 44Y94 CL	Pioneer 44Y30 RR	InVigor LR 4540P	Compass	Kingbale	PBA Bendoc	PBA Samira	Wharton	GIA Ourstar	Genesis090	Jumbo 2	PBA Hallmark XT	RM4	Timok	GIA2202V	Sultan SU	Zulu II
1	IBS | June 20	**NIL**		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2		Sakura	118 g	5	3	2	3	2	4	2	2	2	2	2	3	2	3	1	3	3	5
3		Boxer Gold	2500 mL	1	2	1	1	1	1	2	2	2	2	2	2	2	2	2	1	1	4
4		Propyzamide	1000 mL	2	1	1	1	2	3	2	3	2	2	2	2	1	2	1	1	2	2
5		Tenet	1800 mL	3	2	2	3	4	4	2	3	4	3	2	4	3	3	4	4	4	3
6		Ultro	1700 g	1	1	1	2	4	4	2	2	2	1	1	2	2	1	2	1	1	1
7		Reflex	1000 mL	3	3	3	5	1	2	1	1	1	1	1	1	1	1	2	1	5	5
8		Luximax	500 mL	1	1	1	2	2	3	1	1	1	1	1	3	2	2	1	2	1	4
9		Overwatch	1250 mL	1	2	1	2	1	2	1	2	1	2	2	3	2	3	2	4	1	4
10		Sentry	50 g	5	2	5	5	3	2	2	2	2	2	1	4	1	2	3	3	1	5
11		Mateno Complete	1000 mL	2	3	2	4	2	4	3	2	3	3	2	3	2	2	1	2	2	5
12		Terrain Flow	190 mL	5	4	4	4	1	1	2	3	2	2	3	3	3	3	1	1	4	6
13	PSPE | June 20	**NIL**		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
14		Reflex	1250 mL	6	6	6	6	1	2	2	2	1	1	2	2	3	2	2	2	6	6
15		Diuron (900 g/kg)	825 g	4	5	5	5	2	1	2	2	2	2	3	2	2	2	2	1	5	6
16		Simazine (900 g/kg)	825 g	2	6	5	5	3	3	2	3	2	2	2	3	3	3	3	2	6	6
17		Metribuzin (750 g/kg)	280 g	3	6	6	6	4	5	2	2	2	2	2	4	4	4	3	1	1	6
18		Terbazine (875 g/kg)	1000 g	1	6	6	6	3	3	2	3	2	2	3	3	3	3	2	1	6	6
19		Balance + Simazine	100 g + 830 g	5	6	6	6	4	5	3	4	4	4	4	6	6	6	4	4	6	6
20	3-4 Node | July 27	**NIL**		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
21		Metribuzin (750 g/kg)	280 g	2	6	6	6	2	1	2	2	1	2	3	2	1	4	4	3	5	6
22		Broadstrike + Wetter 1000	25 g + 0.2%	5	1	5	5	3	1	1	3	2	1	2	1	1	5	3	4	3	4
23		Thistrol Gold + Cando	2000 mL + 0.5%	6	5	5	6	1	1	2	3	3	2	3	5	5	5	5	4	4	4
24		Brodal Options	150 mL	2	2	2	3	1	1	3	2	2	1	4	2	1	1	3	3	3	4
25		Spinnaker + Wetter 1000	70 g + 0.2%	5	3	5	5	4	2	2	2	2	1	3	3	1	1	1	2	1	2
26		Ecopar + Wetter 1000	800 mL + 0.2%	4	4	4	5	1	1	2	2	4	4	1	4	4	2	1	3	2	1
27		Intercept + Hasten	750 ml + 0.5%	6	2	6	5	6	2	3	5	5	3	5	5	1	5	4	2	2	6

Table 3. Crop damage ratings for the legume and oilseed herbicide tolerance trial at Hart in 2023.

PULSE CONTROL – Part 1B

PULSE CONTROL				Canola				Barley	Oats	Bean		Pea		C/pea	Lentil		Vetch			Medic	Clover
	Timing	Treatment	Rate	HyTTec Trophy	Pioneer 44Y94	Pioneer 44Y30 RR	InVigor LR 4540P	Compass	Kingbale	PBA Bendoc	PBA Samira	Wharton	GIA Ourstar	Genesis090	Jumbo 2	PBA Hallmark XT	RM4	Timok	GIA2202V	Sultan SU	Zulu II
1	5 - 6 node | August 21	**NIL**		1	1	1	1	1	1	1	1	1	1	1	1	1	1	5	5	1	1
2		Ally + Wetter 1000	7 g + 0.1%	6	1	4	6	2	1	4	5	4	3	5	5	3	5	5	5	2	6
3		Lontrel Advanced	150 mL	1	2	1	1	2	1	6	6	4	5	6	5	6	6	6	6	6	6
4		Ecopar + MCPA Amine 750	400 mL + 330 mL	3	4	4	4	1	1	3	3	3	2	4	3	4	3	5	5	2	2
5		Carfentrazone + MCPA Amine 750	100 mL + 330 mL	6	6	6	6	3	1	4	3	3	3	4	5	5	4	5	5	3	3
6		Velocity + Hasten	670 mL + 1.0%	6	6	6	6	2	2	6	6	6	6	4	6	6	6	6	6	6	6
7		Talinor + Hasten	750 mL + 1 %	6	6	6	6	2	3	6	6	6	6	6	6	6	6	6	6	6	6
8		**NIL**		1	1	1	1	1	1	1	1	1	1	1	1	1	1	5	5	1	1
9		Saracen + Cando	100 mL + 0.5%	6	4	6	6	1	3	6	6	5	5	6	6	5	6	6	6	2	6
10		Paradigm + MCPA LVE + Uptake	25 g + 500 mL + 0.5%	6	6	6	6	1	1	6	5	5	5	6	6	5	6	6	6	6	6
11		Flight EC	720 mL	6	6	6	5	1	2	6	6	2	2	6	5	5	4	6	6	4	2
12		Triathlon	1000 mL	6	6	6	6	1	2	6	5	2	2	6	4	4	4	6	6	3	2
13		Rexade + Wetter 1000	100 g + 0.25%	5	1	6	6	4	4	5	6	4	4	4	5	4	5	5	5	5	6
14		Brodal Options + MCPA Amine 750	125 mL + 125 mL	2	2	2	4	1	1	2	3	1	1	3	2	2	2	5	5	1	4
15		Liberty (double knock)	2 L	6	4	5	1	5	5	6	6	6	6	6	6	6	6	6	6	6	6
16	Group 14 spike | September 1	**NIL**		1	1	1	1	1	1	1	1	1	1	1	1	1	1	4	4	1	1
17		Crucial	800 mL	6	6	1	2	6	6	6	5	4	4	5	6	6	4	6	5	4	4
18		Crucial	1200 mL	6	6	1	2	6	6	6	5	5	6	5	6	6	4	6	6	5	5
19		Carfentrazone 400 + Crucial + MSO	15 mL + 800 mL + 1%	6	6	4	4	6	6	6	5	5	5	5	6	5	4	5	5	5	6
20		Sharpen + Crucial + MSO	17g + 800 mL + 1%	6	6	5	5	6	6	6	6	5	6	6	6	6	5	6	6	6	6
21		Sledge + Crucial + MSO	50 mL + 800 mL + 1%	5	5	3	4	6	6	5	4	5	5	5	5	5	4	6	6	5	4
22		Terrain Flow + Crucial + MSO	30 mL + 800 mL + 1%	5	5	4	4	6	6	6	6	5	5	5	6	6	5	6	6	5	5
23		Butafenacil + Crucial + MSO	55 mL + 800 mL + 1%	5	5	4	4	6	6	6	6	5	5	5	5	5	4	6	6	4	4
24		Terrad'or + Crucial + MSO	15 g + 800 mL + 1%	6	6	6	6	6	6	6	6	6	6	5	6	6	5	6	6	6	6
25		Oxyflurofen 240 + Crucial + MSO	75 mL + 800 mL + 1%	5	5	2	3	6	6	6	4	4	4	5	6	5	5	6	5	4	4
26		Voraxor + Crucial + MSO	100 mL + 800 mL + 1%	6	6	6	6	6	6	6	6	6	6	6	6	6	5	6	6	6	6
27		Terrad'or + Crucial + MSO	40 g + 800 mL + 1%	6	6	6	6	6	6	6	6	5	5	5	6	6	4	6	6	6	6

A summary of pre-emergent herbicide performance

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Key findings

- A major factor influencing pre-emergent herbicide activity from year to year is the timing and quantity of received rainfall.
- Rainfall within ten days of herbicide application is desired. Most pre-emergent herbicides are relatively stable in dry soils, however, warm conditions and dew on the soil surface can begin breakdown of herbicides.
- Lighter soil types are more likely to have herbicide leaching, particularly if dry sown and is a problem for the more soluble herbicides, such as Tenet® and Luximax®.
- Weed control by pre-emergent herbicides needs the herbicide near the seed. Leaching, breakdown and tillage are all factors that reduce weed control when resistance is not present.

Introduction

With the increasing extent of resistance to post-emergent herbicides, pre-emergent herbicides have become the most important tool for managing annual ryegrass in crops. The challenge is getting the best out of the suite of products available. In terms of weed control, there are several things that can go wrong with pre-emergent herbicides. The complexity of behaviour of pre-emergent herbicides and the rainfall required to activate the different products can result in different results in different years.

The importance of rainfall

Rainfall, how much and when, is probably the main factor that influences pre-emergent activity from year to year. Most of the pre-emergent herbicides that are being used to control annual ryegrass are absorbed by the roots or where the shoot emerges from the seed. There are two main exceptions to this. Trifluralin is converted to a gas on contact with water and then absorbed by weeds. Triallate is absorbed by the coleoptile as it moves through the herbicide. For all pre-emergent herbicides, rainfall is essential after application for the herbicide to work. Rainfall dissolves the herbicide and moves it into the correct zone in the soil to be taken up by the weeds. Some herbicides require more rainfall than other herbicides to be effective.

The more soluble herbicides (Table 1), such as Boxer Gold, cinmethylin (Luximax) and metazachlor (Tenet) require less rainfall after application to be effective than the less soluble herbicides, such as pyroxasulfone (Sakura), propyzamide or Mateno Complete. This is because rainfall requirement is lower to move the more soluble products to the location of the weed seeds. As a rule of thumb, 5-10 mm of rainfall within 7 days of application is sufficient for Boxer Gold, whereas 10-15 mm of rainfall is required for Sakura.

Soil type plays a lesser role to rainfall in activating herbicides. Herbicides will move further with rainfall in sandy soils compared to loams and clays. However, as pre-emergent herbicides typically need to move only a few millimetres though the soil to contact most grass weed seeds, differences in soil type matter less than differences in rainfall.

Table 1. Solubility and soil binding (K_{OC}) of some pre-emergent herbicides used for grass weed control.

Pre-emergent herbicide	**Trade name**	**Solubility (mg L^{-1})**		**K_{OC} (mL g^{-1})**	
S-Metolachlor	Dual Gold®, Boxer Gold*	480	High	226	Medium
Metazachlor	Tenet®	450	High	45	Low
Cinmethylin	Luximax®	63	Medium	300	Medium
Bixlozone	Overwatch®	42	Medium	400	Medium
Prosulfocarb	Arcade®, Boxer Gold®*	13	Low	2000	High
Propyzamide	Edge	9	Low	840	High
Tri-allate	Avadex® Xtra	4.1	Low	3000	High
Pyroxasulfone	Sakura®, Mateno® Complete*	3.5	Low	223	Medium
Aclonifen	Mateno® Complete*	1.4	Low	7126	High
Trifluralin	TriflurX	0.2	Very low	15,800	Very high

**Boxer Gold contains both prosulfocarb and S-metolachlor, Mateno Complete contains aclonifen, pyroxasulfone and diflufenican*

Rainfall timing and amount

The timing of rainfall can strongly influence the performance of pre-emergent herbicides. Ideally, rainfall within 10 days of application of the herbicide is desired. Most pre-emergent herbicides are relatively stable in the soil if it is dry and there is no rainfall. However, dew can begin the breakdown of herbicides on the soil surface. Leaving pre-emergent herbicides on the soil surface for extended periods prior to rainfall may see some reduction in control.

A more problematic situation occurs where there is rainfall prior to sowing and no rainfall afterwards. In these circumstances, the weed seeds may be germinated by the initial rainfall event and the herbicides not activated. This problem occurs most commonly with the less soluble herbicides, such as propyzamide, Sakura and Mateno Complete. The herbicides will still be there when the rain arrives but will have failed to control the early cohort of weeds.

Too much rainfall in the period after application can result in herbicides being leached out of the weed seed zone resulting in poor weed control. Leaching is more likely to occur on lighter soil types and with dry sowing. Leaching is more of a problem for the more soluble herbicides, such as Tenet and Luximax. However, herbicides that have low binding to soil components, such as Sakura, can also leach in specific circumstances.

Continual rainfall through the season can lead to additional germination of annual ryegrass. If the ryegrass is germinating after the pre-emergent herbicides have been broken down, then that late ryegrass will not be controlled. This is exacerbated in large populations of annual ryegrass, where the late plant numbers will be higher, or where ryegrass has evolved increased dormancy leading to delayed emergence.

In our early trials we observed that when the winter was relatively dry, Boxer Gold performance on annual ryegrass was as good as Sakura. However, with rainfall through winter and spring, Sakura would always offer better performance. This is because the activity of Boxer Gold declined earlier than Sakura.

Impact of tillage on pre-emergent herbicides

The high efficacy that can be achieved by pre-emergent herbicides relies on weed seeds being on the soil surface and the herbicide being placed near the seed. Tillage prior to application of pre-emergent herbicides through soil renovation or summer weed control is going to mix weed seeds to the depth of tillage. This is going to make it more difficult for the pre-emergent herbicides applied to the soil surface to reach the weed seeds. For herbicides with low solubility, such as Sakura and Mateno Complete, prior tillage can reduce their efficacy.

Herbicide resistance

Resistance to trifluralin is common in South Australia and resistance to prosulfocarb and triallate is increasing. If resistance is present, then pre-emergent herbicides will work less well. Understanding the resistance status of paddocks will make choice of appropriate pre-emergent herbicides more effective.

Summary

Understanding how pre-emergent herbicides behave in the various soil types on- farm can assist in choosing the best products for use, such as avoiding the most soluble products on light soils where they move too far. Ideally, choosing the correct product for each individual situation would be the best approach. However, choices of products need to be made before the beginning of the season. For a number of the problems listed above, mixtures of pre-emergent herbicides are useful, as where one product fails, the other will provide some control. In our trials we found that Sakura applied with Avadex performs well even if there is insufficient rainfall in the week after sowing for Sakura to be properly activated.

There is also the opportunity to use Boxer Gold, Arcade or Mateno Complete early post-emergent to improve control. Boxer Gold and Arcade can be used as a salvage application if pre-emergent herbicides work poorly, because they are more soluble. They should be applied to 1-leaf annual ryegrass for the best results and follow up rainfall is required.

Mateno Complete due to its lower solubility is unsuited for a salvage application. If insufficient rainfall occurs after application, Mateno Complete will not control existing plants. Mateno Complete is best used as part of a planned program in high ryegrass paddocks where it is used at the 2-leaf crop stage and before the second flush of ryegrass has germinated.

Useful resources

Preston, C., (2024). Optimising efficacy of pre-emergent chemistry. *GRDC Update Paper.* P 182 – 185. Available online

Investigating glufosinate herbicide for annual ryegrass control; preliminary results

Rebekah Allen and Kaidy Morgan

Hart Field-Site Group

Key findings

- Seasonal conditions at Hart and Hill River were relatively dry from July through to Spring reducing emergence of annual ryegrass (ARG) populations. Trials conducted at these two sites targeted varying susceptibility; 100% susceptible to all chemistry (Hart) and moderate resistance to Group 1 – DIM herbicides + and strong resistance to Group 2 – Imidazolinone herbicides (Hill River).
- Data from field trials show that Liberty® herbicide (200 g/L glufosinate) applied as a two-spray approach, tank mixed with either clethodim or registered glyphosate products in early applications controlled annual ryegrass.
- Liberty® herbicide at low label rates of 2 L/ha (+2% Liase) applied at two timings ~14 days apart is not adequate for the control of annual ryegrass. In only one of two field trials, higher label rates of 3 L/ha were able to reduce weed number, however overall ARG head suppression was observed at both sites under low ARG populations.

Introduction

A new project across SA in 2023 investigated best-use strategies for the control of annual ryegrass (ARG) with glufosinate herbicide. A series of agronomic field experiments were conducted, in addition to pot experiments exploring the effects of temperature and humidity on herbicide efficacy. In this article, preliminary data from field experiments at two locations across the Mid-North region of SA will be provided.

Methodology

Site selection and rainfall

Two field trials were implemented in the medium rainfall zone of the Mid-North in 2023 to evaluate the efficacy of glufosinate herbicide (Table 1).

The core trial site was located at Hill River with a known background population of ARG, susceptible to glyphosate and glufosinate herbicides. The site had moderate resistance to Group 1 – DIM herbicides (45% survival) and strong resistance to Group 2 – Imidazolinone herbicides (60% survival). Total annual rainfall received was 388 mm with 312 mm of growing season rainfall (GSR). Early rainfall from April – June promoted germination of ARG, however rainfall from late July through to spring were below average (Figure 1) supressing conditions for further ryegrass populations to emerge.

Similar conditions were observed at the Hart field site, SA where a secondary trial was located, however both GSR and annual rainfall were lower, receiving 236 and 355 mm, respectively.

Table 1. Site details for glufosinate trials at Hart and Hill River, SA in 2023.

Hart	**Plot size**	2.0 m x 10.0 m	**Water rate**	100 L/ha
	Seeding date	April 2, 2023	**Nozzle type**	Coarse
	Seed rate	45 plants/m^2		
	Previous crop	Oaten hay		
Hill River	**Plot size**	2.0 m x 10.0 m	**Water rate**	70 – 100 L/ha
	Seeding date	June 16, 2023	**Nozzle type**	Coarse
	Seed rate	45 plants/m^2		
	Harvest date	November 22, 2023		
	Previous crop	Oaten hay		

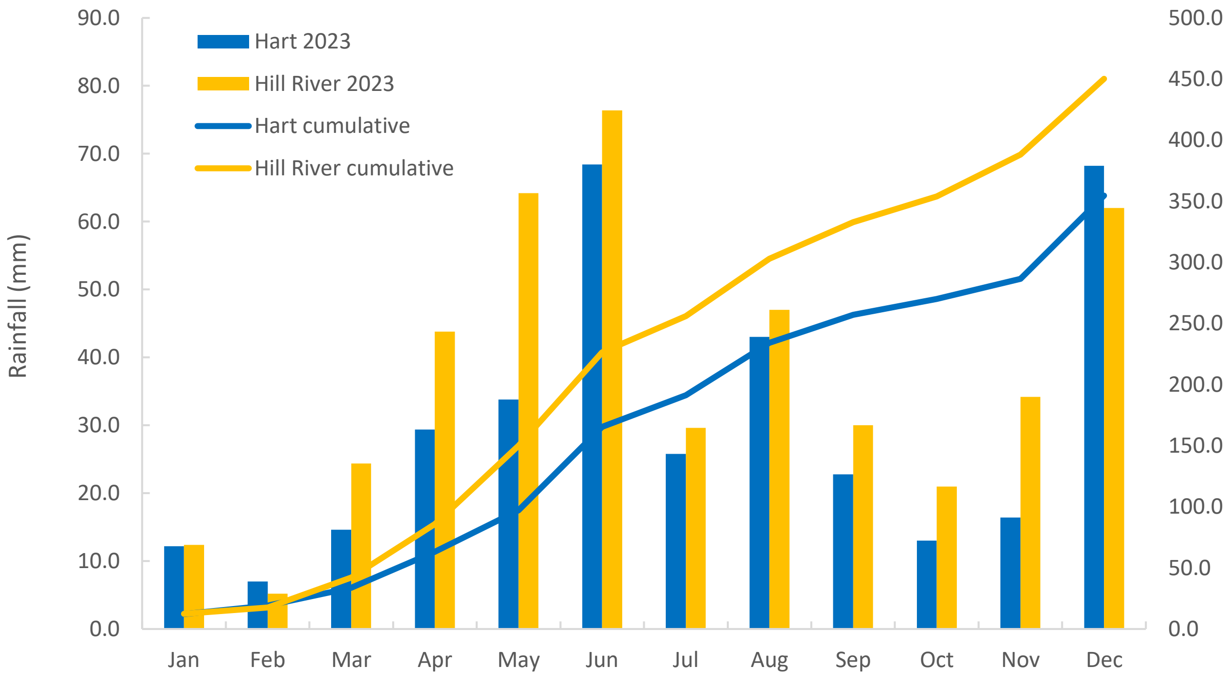

Figure 1. Monthly and cumulative rainfall for Hart and Clare (nearest Mesonet station to Hill River) in 2023 (Source: Mid-North Mesonet).

Trial design and treatments

Hill River

A trial was located at Hill River, SA as a randomised complete block layout with a complex treatment structure, where a full set of treatments were randomised within a replicate. There were three replicates, each containing 16 treatments. The aim of this trial was to investigate and test best-use spray strategies required to optimise ARG control with the use of glufosinate herbicide (Table 2). The trial compares the effects of:

- Liberty® herbicide at two rates (2 and 3 L/ha)
- Rate of Liase (2% and 4%)
- Liberty® herbicide +/- Liase
- Application timing (7, 14 and 21 days after initial application)
- Water rate (70 or 100 L/ha)
- Tank mixes as either glyphosate or clethodim
- Extended application window (first flower)
- Spray conditions (low temperature)

Three varieties with herbicide tolerances, including the LibertyLink® trait were included:

- InVigor LT 4530P: LibertyLink® + Triazine Tolerant (TT) + PodGuard® (TT) (early – mid maturity)
- InVigor LR 4540P: LibertyLink® + TruFlex® + PodGuard® (early – mid maturity)
- InVigor R 4520P: TruFlex® + PodGuard® (early – mid maturity)

The glufosinate herbicide product used was Liberty (200 g/L glufosinate) and Liase was selected as the ammonium sulphate (417 g/L) inclusion. Roundup Ready PL herbicide was selected as the glyphosate option, however Crucial is also registered for use on Roundup Ready®, TruFlex® or Optimum GLY® canola options. Herbicide applications were applied from August 11 to September 13, 2023 (Table 2 and Figure 2).

Hart field site

A secondary trial was implemented at the Hart field site and was designed as a split-plot design with five treatments and three application timings. This trial investigated Liberty herbicide standalone at two rates, with Liase (ammonium sulphate) or in tank mixes to evaluate the control of ARG at different growth stages (Table 3). Application dates and climate data can be found in Appendix 1.

The trial was sown to Liberty tolerant InVigor LR 4540P canola by a knife point press wheel system on April 2, 2023. Prior to seeding, ARG with a known susceptibility to all herbicide groups was spread across the site ensuring adequate background populations emerged (250 plants/m^2).

Four herbicide treatments were applied at three ARG growth stages from early emergence through to tillering (2 – 4 leaf, 1 – 2 tiller and 3 – 4 tiller) using a 100 L/ha water rate and coarse nozzles. No residual herbicides were applied pre-seeding.

Field assessments for both trials at Hart and Hill River included weed counts (weeds/m^2) and panicle counts (heads/m^2) as a measure of seed set, impacting weed management in consecutive years. Oilseed yield (t/ha) was also measured at Hill River. All data was analysed using a REML spatial model (Regular Grid) in Genstat 23rd edition.

Table 2. Treatment list and application dates for glufosinate trial located at Hill River, SA in 2023.

Trt	PSPE		2-4 Leaf		6-8 Leaf (7 days later)		10-Leaf (14 days later)		Stem elongation (21- 28 days later)		First flower (≤10%)	
	June 16		August 11		August 21		August 25		August 28		September 13	
	Product	Rate	Product	Rate	Product	Rate	Product	Rate	Product	Rate	Product	Rate
1	Nil											
2	Atrazine	1 kg	Liberty + clethodim + Uptake + Liase	2 L + 330 mL + 0.5% + 2%			Liberty + Liase	2 L + 2%				
3			Liberty + Roundup PL + Liase	2 L + 1.67 L + 2%			Liberty + Liase	2 L + 2%				
4			Roundup PL + clethodim + Uptake + Liase	1.67 L + 330 mL + 0.5% + 2%			Roundup PL + Liase	1.67 L + 2%				
5			Liberty + Roundup PL	2 L + 1.67 L			Liberty	2 L				
6			Liberty + Roundup PL + Liase	2 L + 1.67 L + 4%			Liberty + Liase	2 L + 4%				
7			Clethodim + Liberty + Uptake + Liase	330 mL + 2 L + 0.5% +2%			Liberty + Liase	2 L + 2%				
8			Liberty + Roundup PL + Liase	1.15 L + 0.5% + 2%			Liberty + Liase	2 L + 2%				
9			Liberty + Liase	2 L + 2%			Liberty + Liase	2 L + 2%				
10			Clethodim + Liberty + Uptake + Liase	330 mL + 2 L + 0.5% + 2%					Liberty + Liase	2 L + 2%		
11			Clethodim + Liberty + Uptake + Liase	330 mL + 2 L + 0.5% +2%	Liberty + Liase	2 L + 2%						
12			Liberty	2 L			Liberty	2 L				
13			Liberty + Liase	3 L + 2%			Liberty + Liase	3 L + 2%				
14			Clethodim + Liberty + Uptake + Liase	330 mL + 2 L + 0.5% + 2%			Liberty + Liase	2 L + 2%				
15			Liberty + Liase	2 L + 2%			Liberty + Liase	2 L + 2%			Roundup PL + Liase	1.67 L + 2%
16*			Clethodim + Liberty + Uptake + Liase	330 mL + 2 L + 0.5% +2%			Liberty + Liase	2 L + 2%				

**Second application applied early morning in cold temperatures of 9 degrees Celsius (°C).*

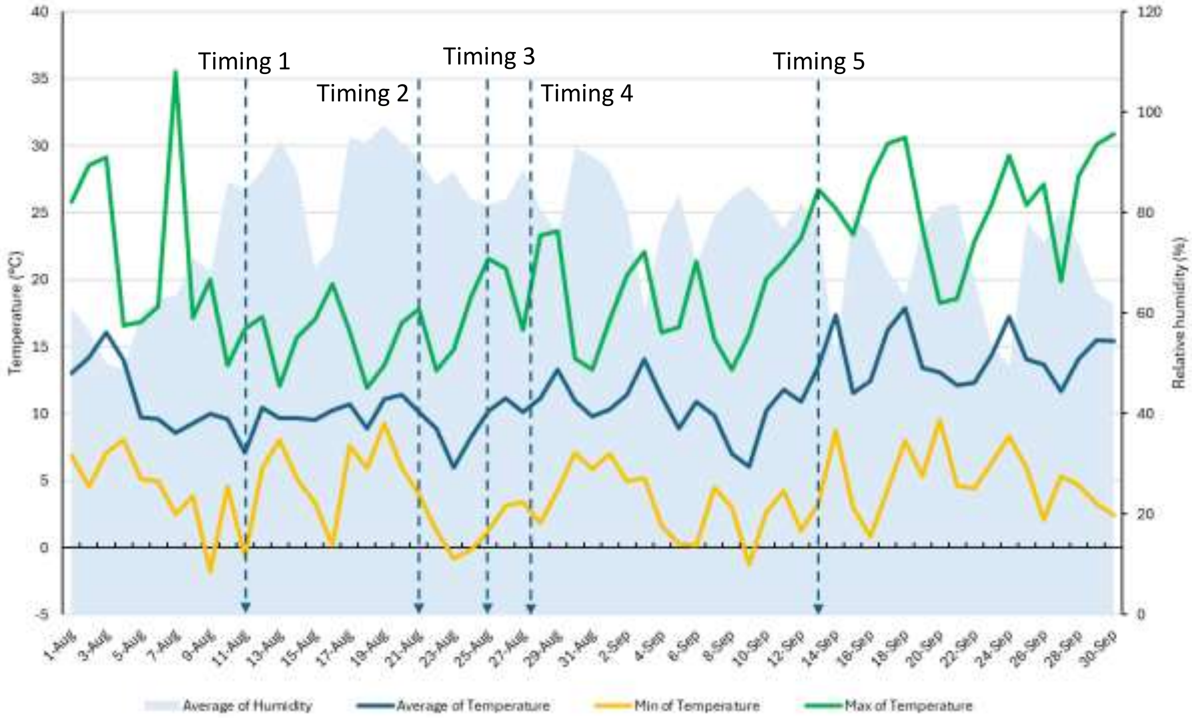

Figure 2. Minimum, maximum, average temperature (ºC) and average relative humidity (shaded area) (RH%) for Hill River, SA. Arrows indicate each application timing.

Table 3. Treatment list for glufosinate trial located at the Hart field site, SA in 2023. Each treatment was applied to annual ryegrass at three different growth stages.

Trt	Timing 1		Timing 2 (10 – 14 days later)	
1	Nil			
2	Liberty + Liase	2 L + 2%	Liberty + Liase	2 L + 2%
3	Liberty + Liase	3 L + 2%	Liberty + Liase	3 L + 2%
4	Liberty + Roundup PL + Liase	2 L + 1.67 L + 2%	Liberty + Liase	2 L + 2%
5	Liberty + clethodim + Uptake + Liase	2 L + 330 mL + 0.5% + 2%	Liberty + Liase	2 L + 2%

Results and discussion

Hill River

Weed control

Initial ARG numbers were low across the trial site at Hill River in 2023 (61 plants/m^2), despite the paddock having a known high annual ryegrass pressure. Low ARG numbers likely resulted from effective pre-emergent herbicide activity in wet conditions, combined with below average winter rainfall from July onwards.

The untreated control (Nil treatment) had the highest level of ARG present of 120 plants/m^2 when final weed counts were conducted on October 9, 2023. It also had the highest number of ARG heads with 195 heads/m^2 (Figure 3).

Reduced weed control was observed for all standalone Liberty treatments (Treatments 9 and 12) at 2 L/ha +/- Liase, applied as a two-spray approach (Figure 3). A trend showing that Liberty herbicide applied at 3 L/ha + Liase as a two-spray approach (Treatment 13) could improve weed control, however significantly lower ARG control was observed when compared to all other herbicide treatments.

Similar trends were observed for ARG head counts for standalone Liberty treatments at 2 L/ha +/- Liase, with a greater number of heads measured (43 heads/m^2). When rates of Liberty were increased to 3 L/ha (+ Liase), overall weed control at maturity, as a measure of potential seed set for consecutive years, increased and was similar to all other treatments, with an average of 1 head/m^2.

Liberty treatments tank mixed with clethodim, uptake and Liase, showed no negative impact resulting from reduced water rates at applications from 100 – 70 L/ha. There was also no effect observed by delaying follow-up applications of Liberty from 7 – 21 days, however it is important to note that ARG populations across the site were low.

TruFlex spray regimes including applications of Roundup Ready PL + clethodim (fb Roundup Ready PL) performed similarly to Liberty herbicide options when applied with glyphosate or clethodim at an initial spray timing (fb Liberty ~14 days later), despite moderate levels of Group 1 – DIM resistance.

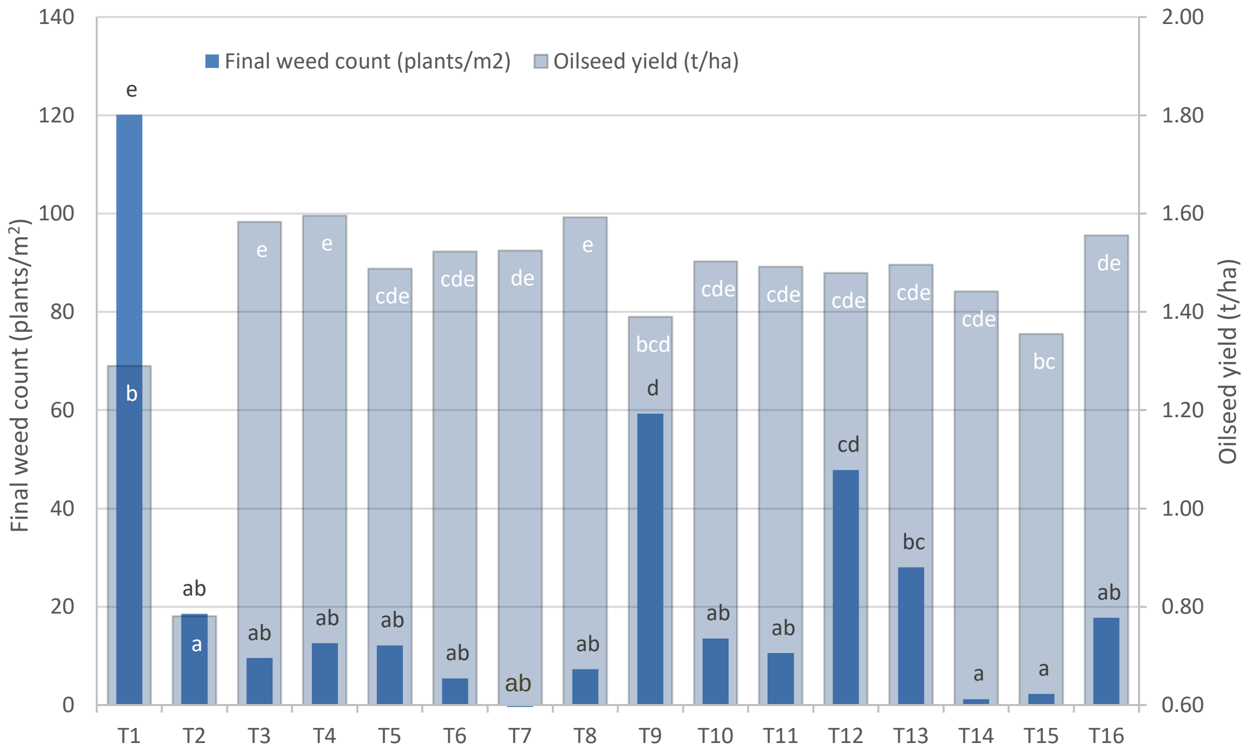

Figure 3. Final weed count (plants/m^2) and oilseed yield (t/ha) for all treatments at Hill River, SA in 2023. Columns for final weed count (■) or oilseed yield (■) with the same letter are not significantly different.

Grain yield

The lowest grain yield observed at Hill River was stacked tolerance variety InVigor LT 4530P (LibertyLink + Triazine Tolerant + PodGuard). This result was not expected and may be associated with a yield penalty at times observed from TT herbicide tolerance traits. The untreated control also performed poorly (1.29 t/ha), in addition to Liberty herbicide at 2 L (+/-Liase) as a two-spray regime (1.36 – 1.39 t/ha). These results are attributed to higher ARG numbers, competing with canola for soil moisture and nutrition (Figure 3).

Hart

Weed control

Results at the Hart field site in 2023, on a susceptible ARG population show that herbicide regime was most significant in determining weed control (plants/m^2). It is important to note that while applications were made to ARG at varying growth stages from 2 – 4 leaf to 2 – 4 tiller, tillering ARG plants were small and sprayed early (not at stem elongation). Similar humidity (RH%) and temperature (°C) conditions were observed at each application (see Appendix 1).

Similarly to Hill River results, applications of Liberty standalone sprayed as a sequential two-spray regime had reduced ARG control (62 plants/m^2), when compared to Liberty tank mixed with clethodim or Roundup Ready PL (23 plants/m^2) in initial spray timings (Liase included at all spray timings). Liberty at 3 L/ha performed similarly, reducing weed number which was a contrasting result to observations at Hill River.

The untreated control had the highest level of ARG present, with an average of 219 plants/m^2 (Figure 4).

Figure 4. Photos: Post final application for 2-4 leaf treatments; 2 L/ha Liberty + 330 mL clethodim + 2% Liase (left), untreated control (middle) and 2 L/ha Liberty + 2% Liase (right). All treatments were followed by 2 L/ha Liberty + 2% Liase 12 days later.

Summary

Preliminary data from field trials across Hill River and Hart in the Mid-North of SA show that Liberty herbicide tank mixed with either clethodim or registered glyphosate options in early spray applications, can control annual ryegrass. Liberty herbicide at low label rates of 2 L/ha + ammonium sulphate are not adequate for the control of ARG. In only one of two field trials, higher label rates of 3 L/ha were able to reduce weed number, however overall ARG head suppression was observed at both sites. A detailed report outlining further results will be published in 2024.

Acknowledgements

The authors would like to gratefully acknowledge South Australian Grains Industry Trust (SAGIT) for their financial contribution supporting this project. We'd also like to thank project partners Plant Science Consulting and local growers for kindly hosting field trials in addition to the various organisations for their supply of chemical and seed to conduct these trials.

References

Appendix 1. Application timing details for glufosinate trial at Hart, 2023.

ARG growth stage timing at Application 1: **2-4 leaf**	**Application 1**	
	Canola growth stage:	2-4 leaf
	Date:	June 29
	Time:	12:30pm
	Cloud cover:	10%
	RH%	66%
	Temperature:	12
	Application 2	
	Canola growth stage:	2-4 leaf
	Days since application:	**12**
	Date:	July 11
	Time:	12:30pm
	Cloud cover:	10%
	RH%	59%
	Temperature:	17
ARG growth stage timing at Application 1: **1-2 tiller**	**Application 1**	
	Canola growth stage:	6 Leaf
	Date:	July 21
	Time:	1:00pm
	Cloud cover:	15%
	RH%	69%
	Temperature:	13
	Application 2	
	Canola growth stage:	10 leaf
	Days since application:	**17**
	Date:	August 7
	Time:	12:00pm
	Cloud cover:	90% but conditions still bright
	RH%	62%
	Temperature:	17
ARG growth stage timing at Application 1: **2-4 tiller**	**Application 1**	
	Canola growth stage:	10 leaf
	Date:	August 7
	Time:	12:00pm
	Cloud cover:	90% but conditions still bright
	RH%	62%
	Temperature:	17
	Application 2	
	Canola growth stage:	stem elongation - budding
	Days since application:	**14**
	Date:	August 21
	Time:	1:00pm
	Cloud cover:	10% cloud cover from 3pm + small amount of rain
	RH%	67%
	Temperature:	18

Management of annual ryegrass in genetically modified canola options

Rebekah Allen
Hart Field-Site Group

Key findings

- It remains key for growers to monitor the survival of ARG populations in paddocks and resistance test where required to implement appropriate management strategies.
- Seasonal conditions at Hill River in 2022 were wet with 506 mm growing season rainfall (GSR). This favoured conditions for multiple germinations of annual ryegrass (ARG) to occur throughout the growing season.
- Weed control benefits were observed in glyphosate tolerant canola when compared to traditional Triazine Tolerant (TT) and Clearfield® (CL) options. This resulted from their extended application window (> crop stage 6-leaf) in addition to herbicide susceptibility to glyphosate.
- Herbicide treatments for dual tolerance technologies Liberty® + TruFlex® (LR) and Liberty® + Triazine Tolerant (LT) performed well, providing ≥ 79% in-crop weed control. However, Liberty® + LT spray regimes were not able to provide similar suppression of ARG heads when compared to glyphosate and other dual tolerant glyphosate options in a high production year.

Introduction

In 2021, the genetically modified (GM) moratorium in South Australia lifted, providing mainland growers the opportunity to grow GM canola for the first time.

Current canola technologies include Triazine Tolerant and Clearfield® (imidazolinone tolerant) options, however, the development of metabolic resistance to these chemistries, including Group 1 (previously Group A) herbicides in weeds such as annual ryegrass (ARG) has become a growing concern. Current resistance levels of annual ryegrass in South Australia, tested within the past 5 years, show that approximately 49% of paddocks have confirmed resistance to imidazolinone herbicides and > 10% to clethodim (Boutsalis et al. 2021). New GM technology options including Roundup Ready® (RR), TruFlex® and LibertyLink®, alongside various mixed tolerance options will provide additional weed management tools on-farm, assisting growers to manage weeds with glyphosate or glufosinate.

Trials conducted across the medium rainfall zone of the Mid-North aim to demonstrate a best-use-approach for in-crop management of annual ryegrass (ARG) in GM canola through the use of on-label glyphosate and some glufosinate options. The trials will also compare new technologies to current TT and CL options as an industry benchmark.

Methodology

A field trial was conducted at Hill River, SA in 2022 (Table 1). The trial was a randomised block design with 22 treatments, including various canola technologies, herbicide regimes and application timings. Variety inclusions were Pioneer 44Y94 (CL), HyTTec Trophy (TT), Pioneer 44Y27 (RR), Nuseed Raptor TF (TruFlex®) and Hyola Garrison XC (stacked Clearfield® and TruFlex® tolerance). The trial was managed with the use of pesticides to ensure an insect and disease-free canopy.

The site had a high background population of ARG with 1287 plants/m^2 when assessed post seeding. It was lightly burnt in April prior to seeding to remove significant ground cover affecting herbicide efficacy and seeding operations. The trial was sown on May 7, after IBS treatments were applied using a standard knife-point press wheel system on 22.5 cm (9”) spacings. Follow up herbicide applications were applied, including a post sowing pre-emergent (PSPE) for the Liberty® + TT treatment (Table 2).

Various in-crop applications of glyphosate and glufosinate with mixing partners were applied when canola was at two-leaf (2L), four-leaf (4L) and 8-leaf (8L) (Table 2). These in-crop application timings were applied early due to high ryegrass populations emerging post-seeding. Late applications of glyphosate were also applied to some treatments at first flower to evaluate a three-spray regime, however due to a spray error at final application, this data could not be analysed. Selected treatments were trialed again at Hill River in 2023 to investigate efficacy of late applications of glyphosate, however low rainfall conditions contributed to a low ryegrass population.

All plots in 2022 and 2023 were assessed for crop establishment (%), ARG weed control (%) and ARG head suppression (heads/m^2) at maturity to assess potential seed set in consecutive years. Spray regimes ($/ha) were also calculated to estimate herbicide costs (Table 3).

All 2022 and 2023 data was analysed using a REML spatial model (Regular Grid) in Genstat.

A resistance test (quick test) was conducted at each site in 2022 and 2023 to determine resistance levels to clethodim (Group 1), Intervix (Group 2), atrazine (Group 5) and glyphosate (Group 9). At these sites, ARG was shown to have low-level but detectable resistance to clethodim at 500 ml/ha and medium-level resistance to Intervix. No resistance to Group 5 or 9 herbicides was present.

Table 1. Details for glyphosate trials at Hart and Hill River, SA (2021 – 2023).

	Plot size	2.0 m x 10.0 m	**Water rate**	100 L/ha
	Seeding date	June 3, 2022	**Nozzle**	Coarse
2022	**Location**	Hill River, SA		
	Harvest date	December 15, 2022		
	Previous crop	Scepter wheat		
	Plot size	2.0 m x 10.0 m	**Water rate**	100 L/ha
	Seeding date	June 16, 2023	**Nozzle**	Coarse
2023	**Location**	Hill River, SA		
	Harvest date	November 22, 2023		
	Previous crop	Oaten hay		

Two trials were also conducted across the Mid-North region in 2021 at Hart and Spalding. These trials investigated in-crop herbicide regimes focusing on a 2-spray approach, targeting medium rainfall environments. All in-crop applications of glyphosate were applied to young ARG plants prior to tillering.

Table 2. Herbicide treatments and canola technologies trialed at Hill River in 2022. Roundup Ready PL= abbreviated to Roundup PL.

	Technology	Pre-emergent (1)		PSPE (2)		Crop stage 2L (3)		Crop stage 4L (4)		Crop stage 8L (5)		1st Flower (6)	
		Product	Rate (L)	Product	Rate	Treatment	Rate	Treatment	Rate	Treatment	Rate	Treatment	Rate
1	CL												
2	CL	Propyzamide	1 L										
3	CL	Overwatch	1.25 L										
4	CL	Propyzamide	1L			Clethodim 360 + Intervix + Hasten	330 ml + 600 ml + 1%						
5	CL	Overwatch	1.25 L			Clethodim 360 + Intervix + Hasten	330 ml + 600 ml + 1%						
6	TT	Propyzamide + Simazine	1 L + 1 kg			Clethodim 360 + Atrazine + Hasten	330 ml + 1kg + 1%						
7	TT	Overwatch	1.25 L			Clethodim 360 + Atrazine + Hasten	330 ml + 1kg + 1%						
8	RR	Propyzamide	1 L			Roundup PL	1.67 L			Roundup PL	1.67 L		
9	RR	Propyzamide	1 L			Roundup PL	1.67 L						
10	LibertyLink + TT	Propyzamide	1 L	Atrazine	1 kg	Liberty + Clethodim 360 + Uptake	2 L + 330 ml + 0.5%	Liberty + uptake	2 L + 0.5%				
11	LibertyLink + TruFlex	Propyzamide	1 L			Liberty + Roundup PL + Uptake	2 L + 1.67 L + 0.5%	Liberty + uptake	2 L + 0.5%				
12	TruFlex	-				Roundup PL	1.15 L	Roundup PL	1.15 L				
13	TruFlex	Propyzamide	1 L			Roundup PL	1.15 L	-	-				
14	TruFlex	Propyzamide	1 L			Roundup PL	1.67 L	-	-				
15	TruFlex	Propyzamide	1 L			Roundup PL	1.15 L	Roundup PL	1.15 L			Roundup PL	1.15 L
16	TruFlex	Propyzamide	1 L			Roundup PL	1.67 L	Roundup PL	1.67 L				
17	TruFlex	Propyzamide	1 L			Roundup PL	1.67 L	Roundup PL	1.67 L			Roundup PL	1.67 L
18	TruFlex	Propyzamide	1 L			Roundup PL	1.67 L					Roundup PL	1.67 L
19	TruFlex	Propyzamide	1 L			Roundup PL + Clethodim 360 + Hasten	1.15 L + 330 mL + 1%	Roundup PL	1.15 L				
20	TruFlex	Overwatch	1.25 L			Roundup PL + Clethodim 360 + Hasten	1.15 L + 330 mL + 1%	-	-			Roundup PL	1.15 L
21	TruFlex	Overwatch	1.25 L			Crucial	1.5L	Crucial	1.5 L				
22	TruFlex + CL	Propyzamide	1 L			Roundup PL + Intervix + Hasten	1.67 L + 600 ml + 1%	Roundup PL	1.67 L				

Results and discussion

Seasonal conditions

Following a dry April, seasonal conditions at Hill River in 2022 were wet (Figure 1), with the site receiving approximately 506 mm growing season rainfall (GSR). This provided an environment for consecutive germinations of ARG to occur throughout the growing season.

Total annual rainfall received at Hill River in 2023 was 388 mm with 312 mm of growing season rainfall (GSR). Early rainfall from April – July promoted germination of ARG, however seasonal conditions from July through to spring were below average (Figure 1) supressing conditions for further ryegrass populations to emerge.

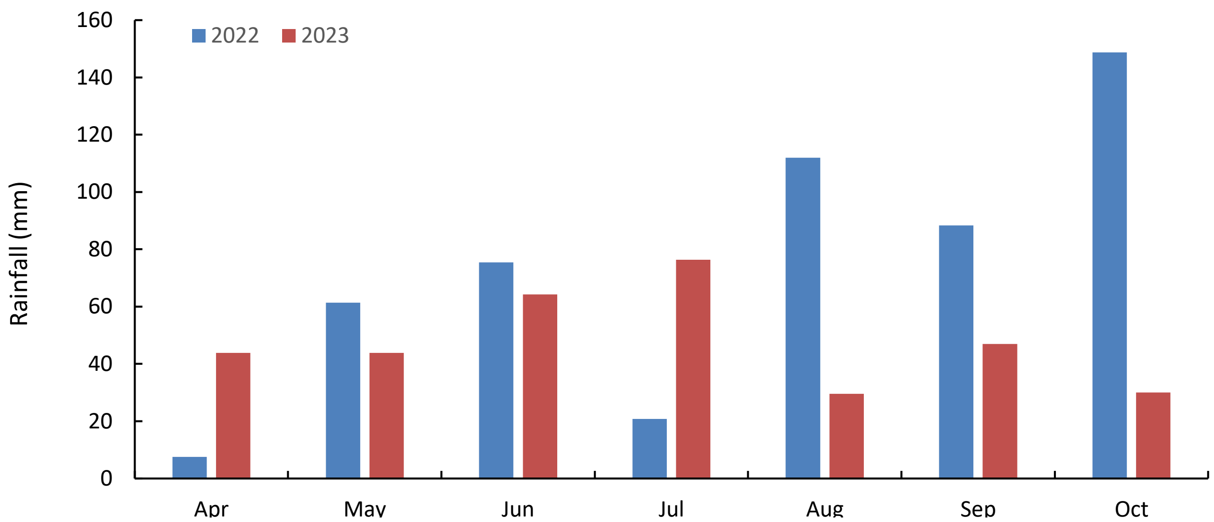

Figure 1. Monthly growing season rainfall near Hill River (2022 – 2023). Rainfall data sourced from the Mid North Mesonet, Clare station.

Pre-emergent herbicides

Background ARG populations at Hill River in 2022 were high (1287 plants/m^2) with pre-emergent herbicides Overwatch and propyzamide providing similar control. Pre-emergent herbicides alone did not provide any benefits over the nil (no herbicide applied) treatment, likely a result of the knockdown herbicide not effectively controlling newly germinated annual ryegrass seedlings prior to the application of pre-emergent herbicides.

This was in contrast to trials conducted in 2021, with propyzamide at 1 L/ha providing increased weed control when compared to Overwatch at 1.25 L/ha (data not shown). This was due to the increased persistence of propyzamide in soils after a significant opening rain event in May (23 mm) following dry conditions, controlling ARG for a longer period of time. After in-crop applications were applied at crop stage 6 – 8 leaf, no differences in weed control were observed between treatments with either propyzamide or Overwatch applied (Allen R., 2021).

Weed control

Annual ryegrass control was improved when a two-spray herbicide regime was implemented in-crop at Hill River in 2022 (Figure 2).

Two in-crop applications of glyphosate as Roundup® Ready PL at 1.67 L/ha, performed similarly when compared to two in-crop applications at lower rates, of either Roundup Ready PL at 1.15 L or Crucial at 1.5 L/ha. This was a result of ARG populations testing 100% susceptible to glyphosate at Hill River.

When glyphosate was applied as a single application early in-crop, weed control was reduced. It was also noted that single applications of Roundup Ready PL at high rates of 1.67 L/ha increased control when compared to the lowest on-label rate of 1.15 L/ha. This suggests that when high populations of

ARG are present, higher rates of glyphosate may be required for sufficient control. A trial at Spalding (data not shown) in 2021 showed that Roundup Ready PL at 1.15 L/ha performed similarly to rates of 1.67 L/ha under low ARG populations (Allen R 2021). This gives growers confidence that lower rates may be applied to susceptible ARG populations, still achieving effective weed control while reducing input costs. When ARG is present in high numbers, higher rates may be required in-crop, but only when a maximum of two glyphosate applications will be applied.

Single applications of glyphosate provided similar control to CL and TT treatments (Figure 2), however when more than one in-crop application of glyphosate was applied to TruFlex varieties and dual tolerance varieties, control was improved. This shows that new herbicide technologies with extended application windows will provide additional control when compared to traditional options. Weed control data collected from trials conducted at Hart in 2021 also show that TT and CL options can provide similar levels of ARG control to glyphosate options in lower rainfall years (reduction in subsequent ARG germinations), and where susceptible populations are present.

Due to below average rainfall at Hill River in 2023, single applications of Roundup Ready PL (1.15 or 1.67 L/ha) were sufficient to control annual ryegrass. Follow-up applications 14 days later (crop stage 6-8 leaf) through to first flower were not economical. Reduced control was observed for Clearfield treatments (in crop application of 330 mL Clethodim 360 + 600 mL Intervix + 1% Hasten), due to ARG resistance of Group 1 and 2 herbicides. Triazine Tolerant treatment (in crop application of 330 mL Clethodim 360 + 1 kg atrazine + 1% Hasten) performed similarly to single applications of Roundup Ready.

Liberty® herbicide

Liberty herbicide applied with either glyphosate or clethodim at 2-leaf canola stage, followed by a second application of Liberty within 14 days performed similarly to glyphosate standalone when applied as a two-spray regime at Hill River in 2022 (Figure 2). Similar trends were observed for weed control (%) and ARG head suppression (Table 1 and Figure 2). All glyphosate treatments with two in-crop applications (+/- mixing partners) significantly reduced ARG head numbers by 79 – 100% (Table 1). The stacked Liberty + TT treatment was not able to provide similar suppression of ARG heads when compared to glyphosate and other dual glyphosate tolerant options in a two-spray regime.

Tank mixing

The presence of clethodim tank mixed with glyphosate at early in-crop timings was effective but did not improve ARG control where low-level resistance to Group 1 herbicides was identified. This result is due to the effectiveness of glyphosate on susceptible ARG populations to Group 9 herbicides. Incorporating additional modes of action into a spray program is important and can reduce the potential development of metabolic resistance to herbicides and continue to provide effective weed control.

Previous research conducted by Plant Science Consulting has shown that some populations of ryegrass are resistant to clethodim, glyphosate or both herbicides. Pot studies conducted in 2020 show that tank mixes of 1.15 L/Roundup Ready PL and 500 ml/ha Clethodim 240 had effective control across most populations tested, with control of ARG averaging 95%, compared to 73% for standalone glyphosate and 79% for standalone clethodim (Boutsalis et al. 2021). It will be important for growers to resistance test to implement appropriate in-crop spray regimes.

Table 3. Annual ryegrass head counts (plants/m²) for treatments at Hill River. Treatments with the same letter are not significantly different. Shading indicates highest level of ARG head suppression.

Treatment	ARG head counts (heads/m²)	ARG head counts (% control)
1	1884[i]	0
2	1353[h]	28
3	1123[gh]	40
4	642[def]	66
5	824[efg]	56
6	996[fgh]	47
7	1382[h]	27
8	1[a]	100
9	406[bcd]	78
10	449[bcd]	76
11	195[ab]	90
12	392[a-d]	79
13	612[cde]	68
14	487[b-e]	74
16	0[a]	100
19	397[a-d]	79
21	168[ab]	91
22	232[abc]	88

Photo: The Hill River trial site, 2023.

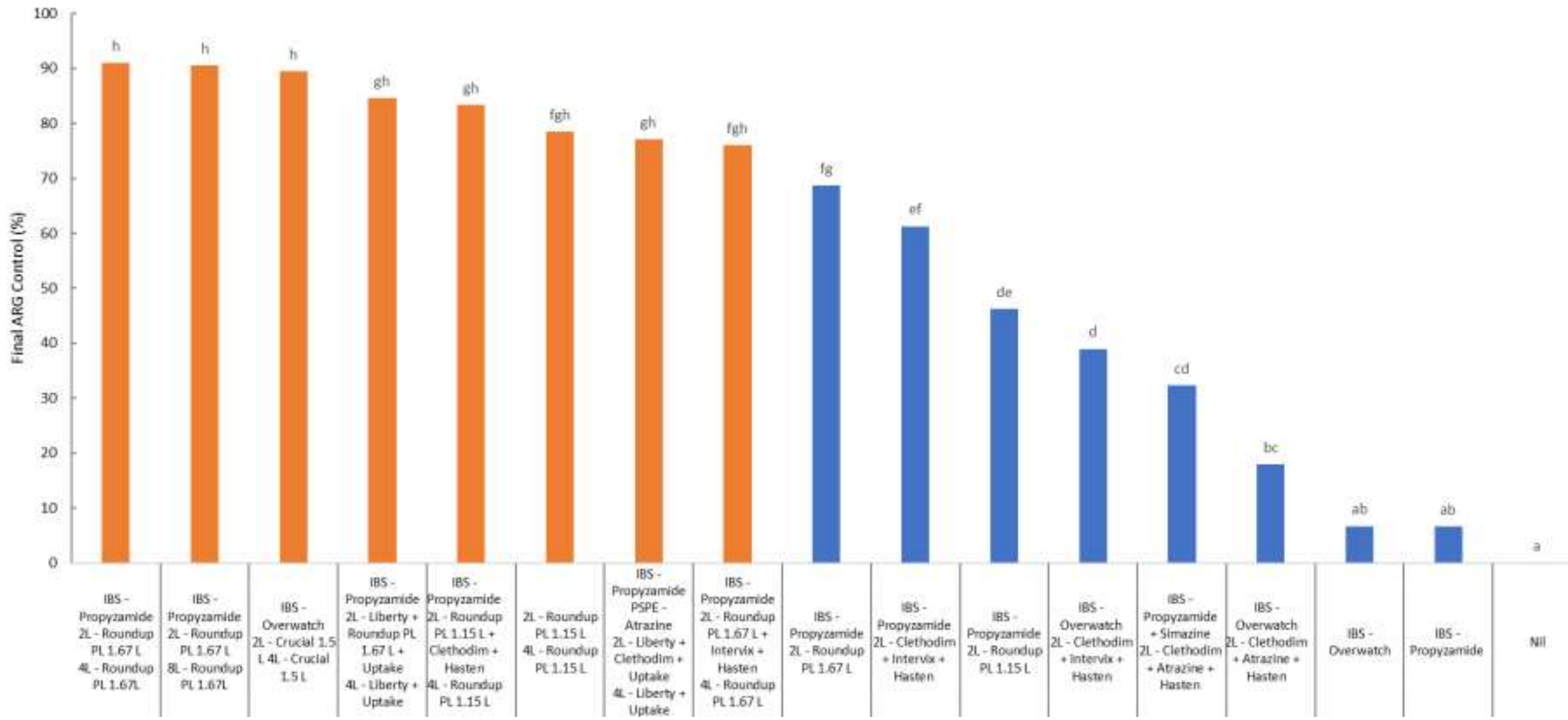

Figure 2. Final assessment for weed control (%) on herbicide treatments at Hill River in 2022. Treatments with same letter are not significantly different. Orange columns represent herbicide regimes which provided the highest level of annual ryegrass control. Columns with an asterix (*) show treatments with the highest suppression of ARG head emergence (heads/m^2). Roundup Ready PL is abbreviated to Roundup PL.

Table 4. Herbicide costs ($/ha) for various spray regimes trialed at Hill River in 2022. Herbicide costs should be used as a guide only.

Technology	Spray regime	Rates /ha	Herbicide costs ($/ha)
Clearfield	IBS: Propyzamide Post-emergent: Clethodim 360 + Intervix + Hasten	1 L 330 mL + 600 mL + 1%	$78.55
TT	IBS: Propyzamide + Simazine Post emergent: Clethodim 360 + Atrazine + Hasten	1 L + 1 kg 330 mL + 1 kg + 1%	$82.68
RR / TruFlex	IBS: Propyzamide Post-emergent: Roundup Ready PL (1 application)	1 L 1.67 L	$70.05
RR / TruFlex	IBS: Propyzamide Post-emergent: Roundup Ready PL (2 applications)	1 L 1.67 L	$95.10
RR / TruFlex	IBS: Propyzamide Post-emergent: Roundup Ready PL (2 applications)	1 L 1.15 L	$79.5
LibertyLink + TT	IBS: Propyzamide PSPE: Atrazine Post-emergent 1: Liberty + Clethodim 360 + Uptake Post-emergent 2: Liberty + Uptake	1 L 1 kg 2 L + 330 mL + 0.5% 2 L + 0.5%	$130.45
LibertyLink + TruFlex	IBS: Propyzamide Post-emergent 1: Liberty + Roundup Ready PL + Uptake Post-emergent 2: Liberty + Uptake	1 L 2 L + 1.67 L + 0.5% 2 L + 0.5%	$136.25
TruFlex	IBS: Propyzamide Post-emergent: Roundup Ready PL (3 applications)	1 L 1.15 L	$96.75
	IBS: Propyzamide Post-emergent: Crucial (2 applications)	1 L 1.5 L + 1.5 L	$90.00
	IBS: Propyzamide Post-emergent 1: Roundup Ready PL + Clethodim 360 Post-emergent 2: Roundup Ready PL	1 L 1.15 L + 330 mL 1.15 L	$89.75
TruFlex + CL	IBS: Propyzamide Post-emergent 1: Roundup Ready PL + Intervix + Hasten Post-emergent 2: Roundup Ready PL	1 L 1.67 L + 600 mL + 1% 1.67 L	$118.4

Estimated costs per litre or gram: propyzamide $45.00, clethodim $20.50, Intervix $31.00, Hasten $4.70, simazine $7.53, Uptake $6.20, atrazine $15.20, glyphosate and glufosinate $15.00. Values sourced from: Farm Gross Margin and Enterprise Planning Guide, 2022.

Summary

Genetically modified canola options including Roundup Ready and TruFlex will be useful to growers for controlling ARG, particularly where Group 1 and 2 herbicide resistance is present. Through various trials from 2021 - 2023, applications of glyphosate have shown to be equally or more effective when compared to traditional Clearfield or TT herbicide options. This has been dependent on both seasonal conditions and herbicide resistance levels present in the field. In years where conditions are favourable for germinations of ARG throughout the growing season, an extended application window of TruFlex variety options will provide additional weed control. It is important that growers monitor and test for herbicide resistance on farm to appropriate select varieties and spray regimes. Further research investigating glufosinate through SAGIT project HAR 00523 - Improving efficacy of glufosinate for annual ryegrass control in canola, will provide further data to inform management decisions (data to be released in 2024).

Acknowledgements

The Hart Field-Site Group would like to acknowledge SAGIT for funding this project.

We would also like to thank BASF, Nuseed, Pioneer® Seeds and Pacific Seeds for providing seed, and Nufarm, Bayer and BASF for providing herbicides trialed.

Hart would also like to kindly acknowledge the support from growers who hosted these trials from 2021 – 2022 at Spalding and Hill River.

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Boutsalis P, Kleeman S, Preston C., (2021) Canola technologies and herbicide resistance. 2021 Hart Field Day Guide.

2021 Farm Gross Margin and Enterprise Planning Guide (2021). Available online

Photo: Third year ag science students from the University of Adelaide inspect the trial at Hart in September 2023.

The performance of residual and cumulative P applications on soils in the Mid-North of SA

Sam Trengove[1], Stuart Sherriff[1], Jordan Bruce[1] & Sean Mason[2]

[1]Trengove Consulting, [2]Agronomy Solutions

Key findings

- Residual phosphorus (P) (from a one-off application of a high rate in year one) provided a grain yield response in the second and third year at two of the three sites.
- The method for applying a high rate (90 kg P/ha) of P fertiliser was not important in these trials. High rates of P applied by either deep banding, spreading MAP or chicken litter spread in front of the seeder, all produced the same yield response at each site and year.
- At Hart and Crystal Brook repeated applications of P fertiliser rates showed the crop P requirements were not satisfied by lower rates in the second and third season. The highest repeated P rates (50 and 90 kg P/ha) were still increasing yields in year three at these sites.
- Partial gross margin (PGM) analysis showed within the range of MAP prices of $500-$1500/t the district practice strategy was never the highest PGM on these P responsive sites.
- When MAP reached $1500/t the chicken litter treatment became the highest PGM at Crystal Brook and one of the highest at Hart, despite freight and spreading costs.

Background

High fertiliser prices have increased grower interest in phosphorus (P) responses on variable soil types and improving returns from P fertiliser inputs. Recently, two SAGIT funded projects (TC219 and TC221) have examined P fertiliser response on a range of soil types with varying soil P availability. The trial locations were determined using soil pH maps and satellite NDVI imagery. To date 49 phosphorus response trials have been established across the Mid and Upper North and Northern Yorke Peninsula (NYP) to validate the P sufficiency index (pHnNDVI) methodology (refer to method section) of predicting P response based on these data layers.

Included in the 49 P response trials were three long term (3 year) trials established in 2021 at Spalding, Crystal Brook and Hart. These three sites are highly P responsive alkaline soil types. The project aims to address the following questions.

- What is the residual value of high rates of P from year 1 in following years?
- What is the effect of repeated high-rate P application vs district practice?
- What alternative application strategies can be implemented at high response sites in lieu of variable rate P application through the seeder?

Methods

In SAGIT project TC219, a methodology for estimating crop P responsiveness, the P sufficiency index, was developed. The P sufficiency index combines soil pH maps and historical satellite NDVI to estimate how responsive a given site will be to applied P fertiliser. The P sufficiency index has been given the acronym pHnNDVI as it is the pH value divided by NDVI normalised to the paddock average using the formula below:

pHnNDVI = soil pH / (NDVI/paddock NDVI average)

Areas of a paddock with high soil pH (> 7) and low relative NDVI (< 0.9) result in a high pHnNDVI value and are likely to be highly responsive to applied P. Areas with low pH (< 6.5) and high relative NDVI (> 1.1) result in a low pHnNDVI value and are likely to be unresponsive to applied P in the paddocks tested. This methodology has proven useful in determining the optimal site-specific P rate in paddocks tested across the Mid and Upper North and Northern Yorke Peninsula.

At the beginning of 2021 three highly P responsive sites were identified using the P sufficiency index methodology (Table 1). These sites were soil sampled (0-10 cm) pre-seeding in 2021. Soil pH levels ranged from 7.7 – 7.9 pH $CaCl_2$ which is categorised as moderately alkaline. The DGT-P values were low ranging from 18-23 µg/L (critical limit 60 µg/L). Full comprehensive soil test analysis was conducted for each site and no other nutritional constraints were identified (data not presented).

The crop sown at each location/year were chosen based on the hosting growers' rotation (Table 1).

Table 1. Average (Av) growing season rainfall (GSR = April – October), soil properties and crop sown for long-term P response sites.

Location	Soil pH ($CaCl_2$)	DGT-P µg/L	Colwell P mg/kg	PBI	pHnNDVI	2021 crop	2022 crop	2023 crop
Crystal Brook Av GSR 289 mm	7.8	23	29	88	11.9	Compass barley	PBA Highland XT lentil	Calibre wheat
Spalding Av GSR 268 mm	7.7	18	20	77	11.7	Scepter wheat	Spartacus CL barley	Commodus CL barley
Hart Av GSR 291 mm	7.9	17	40	110	10.0	Scepter wheat	PBA Jumbo 2 lentil	Calibre wheat

The long-term P fertiliser trials sown at all three sites can be divided into four main management strategies (Table 2) which were used to answer specific questions throughout the project. Phosphorus fertiliser was applied as MAP and nitrogen was balanced at seeding with urea to match the amount of nitrogen (N) in the 90 kg P/ha treatment. In the main treatments, the fertiliser was applied below the seed using a knife point press wheel system on 250 mm row spacing.

The chicken litter sourced for these trials had a total P concentration of 1.48%, total nitrogen concentration of 4.14% and moisture content of 15.4%. This treatment had a target of 75 kg P/ha broadcast as chicken litter (equivalent to 6250 kg/ha chicken litter) prior to seeding plus 15 kg P/ha as MAP applied below the seed, resulting in a total of 90 kg P/ha. The actual total P applied in the chicken litter treatment was 93 kg P/ha in the first year (Table 2). As the nitrogen in all other treatments was balanced to the 90 kg P/ha treatment it is important to note that the chicken litter treatment received an additional 178 kg N/ha compared to all other treatments.

Table 2. Treatment list showing units of P (kg P/ha) applied, the equivalent rate applied as MAP fertiliser (kg/ha) and cumulative P rate for the long-term P response trials in the Mid-North, SA.

Treat	Management strategy	2021 P rate (kg P/ha)	*Equivalent MAP (kg/ha)*	2022 P rate (kg P/ha)	*Equivalent MAP (kg/ha)*	2023 P rate (kg P/ha)	*Equivalent MAP (kg/ha)*	Cumulative P rate (kg P/ha)
1	Residual value of high P rates applied in year one	0	*0*	15	*68*	15	*68*	30
2		7.5	*34*	15	*68*	15	*68*	37.5
3		15	*68*	15	*68*	15	*68*	45
4		22.5	*102*	15	*68*	15	*68*	52.5
5		30	*136*	15	*68*	15	*68*	60
6		50	*227*	15	*68*	15	*68*	80
7		90	*409*	15	*68*	15	*68*	120
8	Alternative P management strategies	Spread MAP (90)*	*341 fb 68*	15	*68*	15	*68*	120
9		Chicken litter (93)**	*CL fb 68*	15	*68*	15	*68*	123
10	Value of repeated P rates over three years	0	*0*	0	*0*	0	*0*	0
11		7.5	*34*	7.5	*34*	7.5	*34*	22.5
12		22.5	*102*	22.5	*102*	22.5	*102*	67.5
13		30	*136*	30	*136*	30	*136*	90
14		50	*227*	50	*227*	50	*227*	150
15		90	*409*	90	*409*	90	*409*	270
16	Compare strategies above to high P rates in year three only	15	*68*	15	*68*	0	*0*	30
17		15	*68*	15	*68*	7.5	*34*	37.5
18		15	*68*	15	*68*	22.5	*102*	52.5
19		15	*68*	15	*68*	30	*136*	60
20		15	*68*	15	*68*	50	*227*	80
21		15	*68*	15	*68*	90	*409*	120

** 75 kg P/ha spread prior to sowing as MAP + 15 kg P/ha banded as MAP*
***78 kg P/ha spread as chicken litter prior to sowing + 15 kg P/ha banded as MAP*

Grain yield data was analysed using ASREML in R. Partial gross margin was calculated as cumulative income minus cumulative fertiliser cost.

Results and discussion

The long-term trials aimed to address three key research areas and the discussion has been structured around responding to these topics.

What is the residual value of high rates of P from year 1 in following years?

Banded MAP

The residual effect of P fertiliser rates (ranging from 0 – 90 kg P/ha) were assessed in year two and three in treatments where district practice applications (15 kg P/ha) followed the range of rates in the first season. The results from year three show at two of the sites, Hart and Crystal Brook, there was still evidence of residual P from high application rates in the first season (Figure 1 and 2). In contrast, at the Spalding site in the third season there was no grain yield response to the range of P rates (0-90 kg P/ha) applied in year one (Figure 3).

At Hart in year one, grain yields reached 137% of the untreated where rates of 50 kg P/ha or more were applied. High rates of P continued to produce higher grain yields in year two and three (Figure 1). These results show at Hart residual effects of high P rates in year one, were still being observed in year three.

Crystal Brook was the most responsive site in year one, where grain yields reached 170% of the untreated at a rate of 90 kg P/ha. In the second year the grain yield response to increasing P remained significant with maximum grain yields coming from the year one 90 kg P/ha application. In the third season the response to high rates of P in year one was not consistent (Figure 2). The 50 kg P/ha applied in the first year remained higher yielding compared to 0 kg P/ha however, the 90 kg P/ha was not different to the untreated.

Similarly, the Spalding site was highly responsive to P rates in year one, reaching 149% of the untreated with 90 kg P/ha. The chicken litter treatment produced higher grain yields than the comparable 90 kg P/ha MAP in all three years indicating other yield limitations (Figure 3). Protein data (not presented) showed nitrogen was limiting in year two which may have masked the P response in that season. Higher rates of nitrogen and foliar trace elements were applied in the third season to address any possible nutrient limitations. However, no response to high P rates applied in year one was recorded in year three (Figure 3). This indicates there was no legacy effect of the higher P rates carrying into the third year.

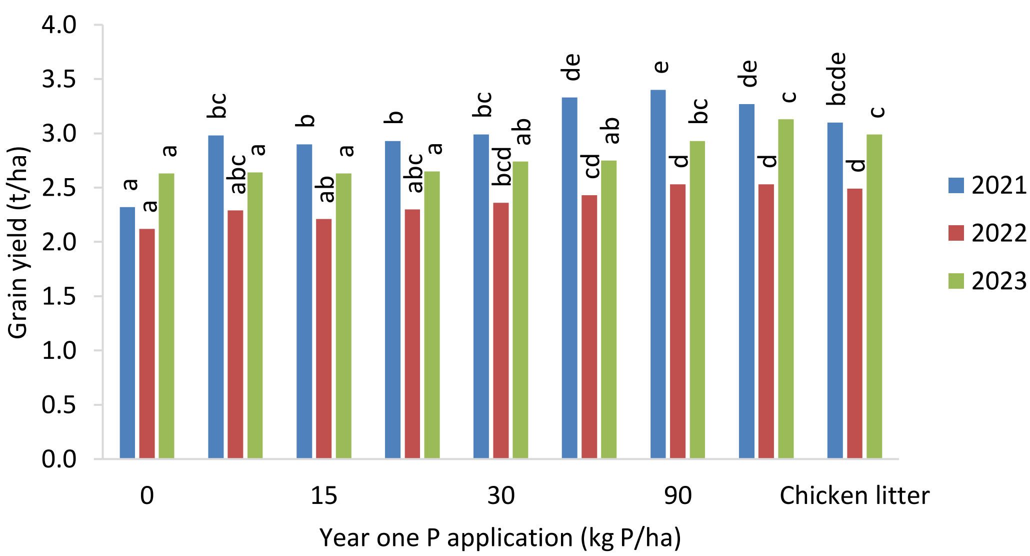

Figure 1. Grain yield (t/ha) over three seasons for P rates applied in year one at Hart, SA from 2021-2023. (P value for all 21 treatments; 2021 <0.001, 2022 <0.001 and 2023 <0.001). Bars within a year level that share a common letter are statistically similar.

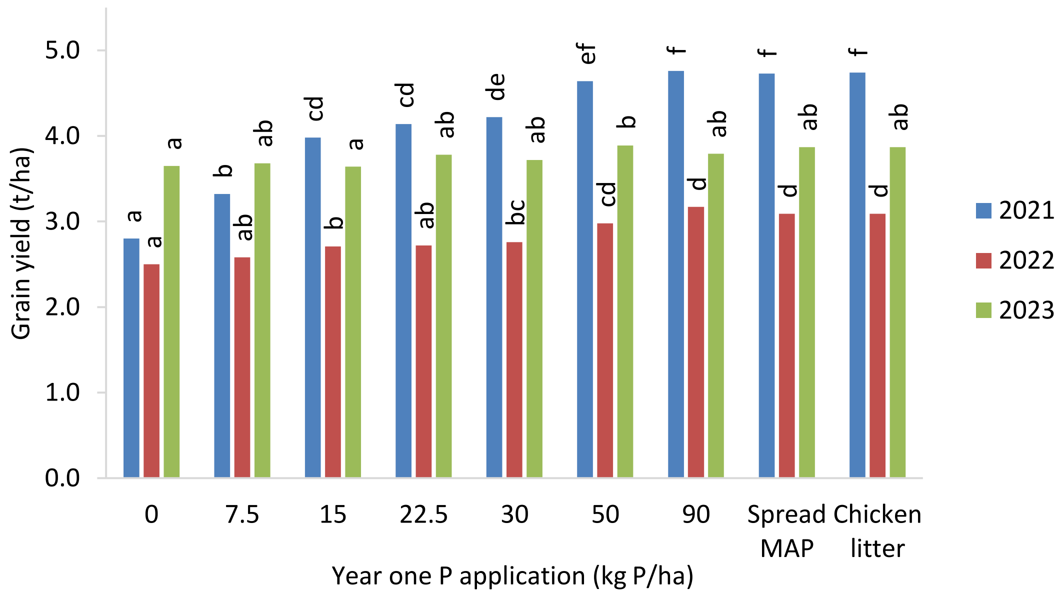

Figure 2. Grain yield (t/ha) over three seasons for P rates applied in year at Crystal Brook, SA from 2021-2023 (P value for all 21 treatments; 2021 <0.001, 2022 <0.001 and 2023 <0.001Bars within a year level that share a common letter are statistically similar.

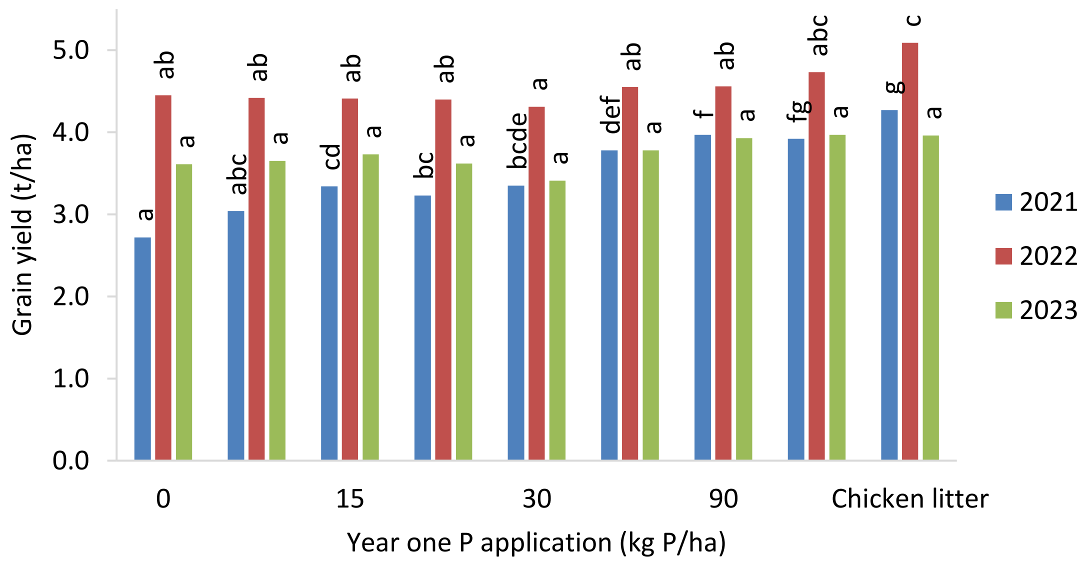

Figure 3. Grain yield (t/ha) over three seasons for P rates applied in year one at Spalding, SA from 2021-2023. (P value for all 21 treatments; 2021 <0.001, 2022 <0.001 and 2023 <0.001). Bars within a year level that share a common letter are statistically similar.

What alternative strategies can be implemented at high response sites in lieu of variable rate P application through the seeder?

Spread MAP and chicken litter application

At all three sites and in all seasons, the spread MAP treatment (75 kg P/ha spread in front of the seeder plus 15 kg P/ha MAP deep banded in year one) produced similar grain yields to the equivalent treatment of 90 kg P/ha MAP deep banded (Figures 1-3). The chicken litter treatment (78 kg P/ha of chicken litter spread in front of the seeder plus 15 kg P/ha MAP deep banded in year one) also produced similar grain yields to the equivalent treatment of 90 kg P/ha MAP deep banded at Hart and Crystal Brook in all three seasons. At these highly P responsive sites this result indicates the P fertiliser efficiency was similar regardless of application method.

At Spalding, grain yields from the chicken litter treatment were higher compared to the 90 kg P/ha deep banded in the first and second season. The chicken litter treatment received an additional 173 kg N/ha compared to other treatments. Grain protein data (not presented) indicated that the additional N likely contributed to the grain yield response in the first two seasons. In the third season there was no difference between the chicken litter treatments and the equivalent deep banded MAP treatment.

What is the effect of repeated high-rate P application vs district practice?

The district practice treatment refers to the repeated application of 15 kg P/ha (Table 2). This treatment is representative of the P management strategy used by all three trial cooperators in previous years.

The Crystal Brook and Hart sites showed similar responses with highest grain yields coming from repeated P rates of 50 and 90 kg P/ha in the trials in years two and three (Figure 4 and 5). At Hart, repeated applications of 30 kg P/ha were enough to outyield the district practice in years two and three (Figure 4). The same treatment increased yields above district practice in year two at Crystal Brook but no yield advantage was seen in year three. Repeated applications of 22.5 kg P/ha yielded the same as district practice for the three years at both Crystal Brook and Hart.

It was anticipated that with repeated applications of high rates, the crop P requirements would be satisfied by smaller applications in the second and third season. This was not observed with the highest repeated P rates still increasing yield into the third year at these sites. Further investigation is required to understand if higher yields continue from the highest P rates or if a point of P saturation occurs allowing lower P rates to satisfy crop requirements.

At Spalding, the application of P rates of 50 and 90 kg P/ha resulted in increased yields compared to the district practice in year one (Figure 6). Individual year analysis indicates a small grain yield response above 15 kg P/ha in year two and three. However, the cumulative grain yield analysis shows significant grain yield increases above district practice P rates with repeated applications of 50 and 90 kg P/ha. As discussed above, it is likely that nitrogen was a limiting factor at this site and confounds the grain yield results. The chicken litter treatment was the highest yielding at this site in year two.

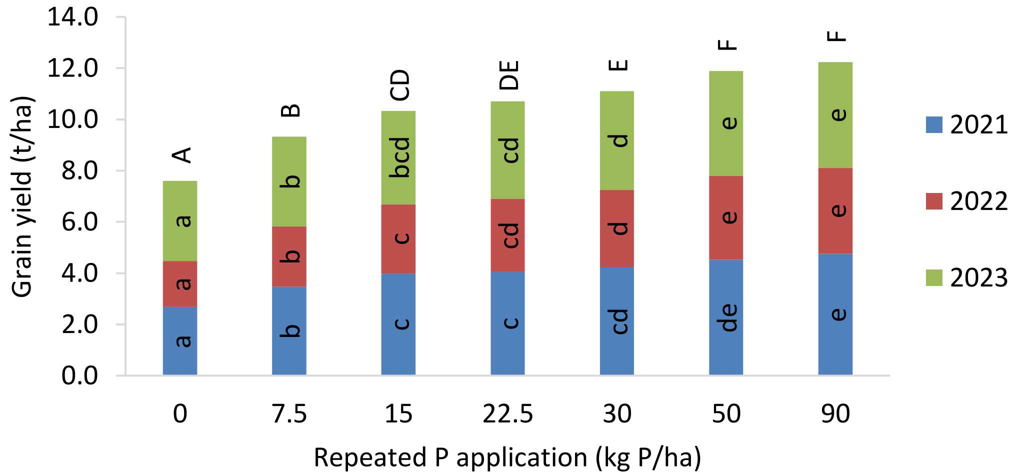

Figure 4. Hart cumulative grain yield for repeated applications of P fertiliser, P values = 2021 <0.001, 2022 <0.001, 2023 <0.001 and cumulative <0.001. Bars within a year level that share a common letter are statistically similar, capital letters refer cumulative yield analysis.

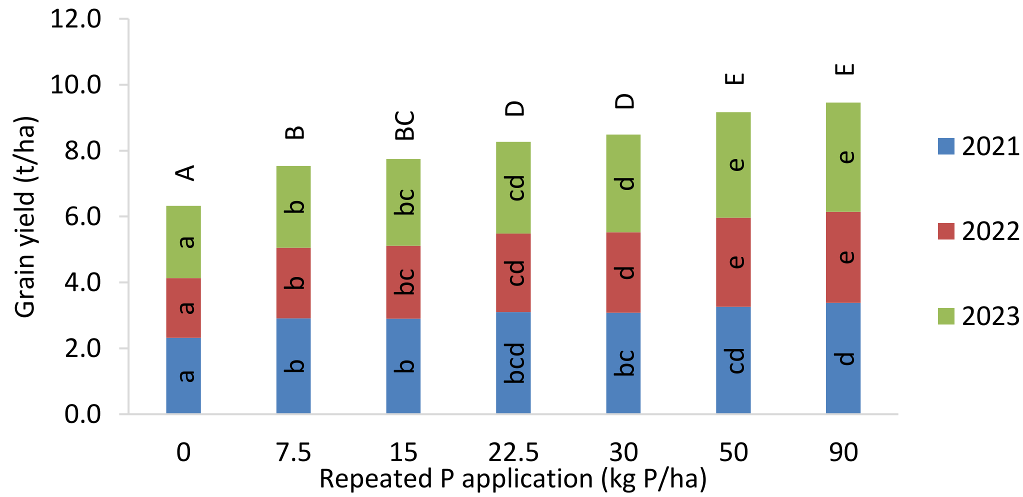

Figure 5. Crystal Brook cumulative grain yield for repeated applications of P fertiliser, P values = 2021 <0.001, 2022 <0.001, 2023 <0.001 and cumulative <0.001. Bars within a year level that share a common letter are statistically similar, capital letters refer cumulative yield analysis.

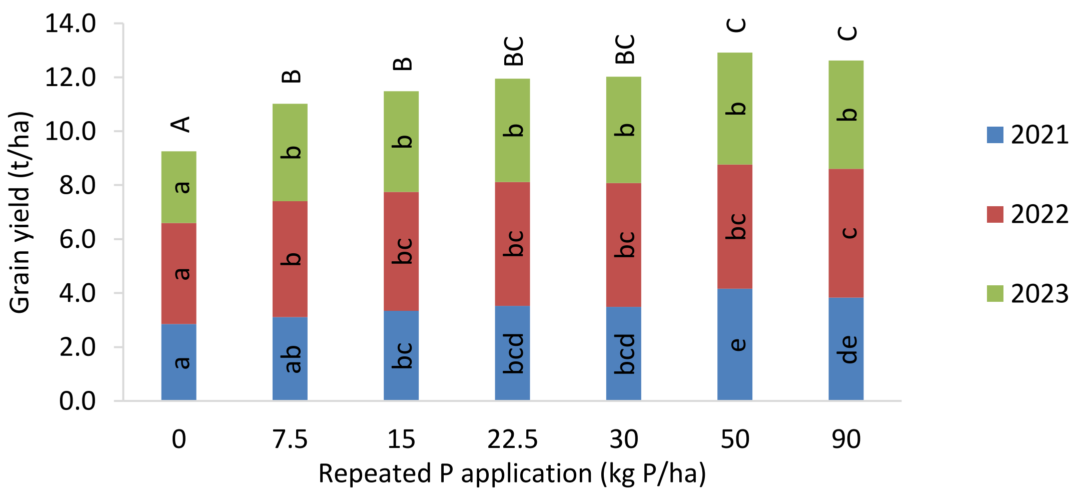

Figure 6. Spalding cumulative grain yield for repeated applications of P fertiliser, P values = 2021 <0.001, 2022 <0.001, 2023 <0.001 and cumulative <0.001. Bars within a year level that share a common letter are statistically similar, capital letters refer cumulative yield analysis.

Economic analysis of the different P management strategies

Whilst the repeated application of high P fertiliser rates has resulted in the largest cumulative grain yields, the cost of fertiliser also needs to be considered. The partial gross margin (PGM) has been calculated on the cumulative grain yield for all sites and presented with variable MAP pricing scenarios (Table 3 – next page).

The Spalding PGM values have been impacted by the variability of the site and due to the N limitation in year one and two, which affected grain yields in all treatments except for chicken litter (Appendix 1).

The Hart and Crystal Brook sites behaved similarly in terms of grain yields over the three years and therefore the PGMs are similar (Appendix 1). Firstly, within the range of MAP prices of $500-$1500/t the district practice treatment is never the highest PGM on these responsive sites. Therefore, the alternative P management strategies tested have potential to improve profitability. Secondly, when fertiliser prices are low (MAP $500/t) there is an economic advantage of achieving consistently higher yields with repeated P rates of 50 kg P/ha, which produces the highest PGM for these sites. As fertiliser prices increase, the optimum P rate for repeat applications declines, ultimately resulting in a lower PGM. This is where the value of residual P becomes important. Under high fertiliser prices (MAP $1500/t) the one-off high P rates in year one of 50 - 90 kg P/ha has a greater PGM than the repeat high applications. However, we would expect that the repeated applications of higher rates will have higher reserves to support ongoing productivity in the near future compared with the one-off high application rates. Soil testing planned for these trials will explore this.

Treatment 5-7 show the value of addressing P deficiency immediately, rather than putting it off for two seasons as in treatment 19-21. On average, at Hart and Crystal Brook there is a $272/ha advantage for addressing deficiency in year one with 30-90 kg P/ha, compared with year three (Appendix 1).

Under high MAP fertiliser prices ($1500/t) the chicken litter treatment provided the greatest PGM at Crystal Brook and one of the highest at Hart (Appendix 1). This alternative source of P becomes important under high MAP prices assuming the price does not increase from demand because of high synthetic P fertiliser prices. Not only is the chicken litter supplying P to the crop, but it is also supplying other nutrients which can potentially reduce the total synthetic fertiliser inputs, such as urea, to further decrease input costs whilst maintaining grain yields which ultimately increase PGM further.

Acknowledgements

The authors gratefully acknowledge the financial support from SAGIT to deliver this project (TC221) ‘Improved management of variable phosphorus requirement and strategies frog highly responsive soils’.

We also thank the participating growers involved in hosting the long-term field trials.

Appendix 1. Predicted cumulative yield and partial gross margin (PGM) for the three seasons at differing MAP fertiliser prices.

Treatment	2021 P rate (kg/ha)	2022 P rate (kg/ha)	2023 P rate (kg/ha)	Predicted cumulative yield (t/ha)			MAP $500/t			MAP $1000/t			MAP $1500/t		
				Crystal Brook	Hart	Spalding	Crystal Brook	Hart	Spalding	Crystal Brook	Hart	Spalding	Crystal Brook	Hart	Spalding
1	0	15	15	8.95	7.07	10.78	$3,477	$2,901	$2,763	$3,409	$2,833	$2,695	$3,340	$2,764	$2,626
2	7.5	15	15	9.58	7.91	11.11	$3,655	$3,204	$2,844	$3,570	$3,119	$2,759	$3,484	$3,033	$2,674
3	15	15	15	10.33	7.74	11.48	$3,882	$3,104	$2,935	$3,779	$3,001	$2,832	$3,677	$2,899	$2,730
4	22.5	15	15	10.64	7.88	11.25	$3,954	$3,165	$2,855	$3,834	$3,045	$2,735	$3,715	$2,926	$2,616
5	30	15	15	10.70	8.09	11.07	$3,967	$3,235	$2,799	$3,830	$3,098	$2,662	$3,694	$2,962	$2,526
6	50	15	15	11.51	8.51	12.11	$4,231	$3,343	$3,035	$4,049	$3,161	$2,853	$3,868	$2,980	$2,671
7	90	15	15	11.72	8.86	12.46	$4,273	$3,397	$3,041	$4,001	$3,125	$2,768	$3,728	$2,852	$2,495
8	Spread MAP	15	15	11.68	8.93	12.62	$4,215	$3,418	$3,078	$3,942	$3,146	$2,806	$3,669	$2,873	$2,533
9	Chicken litter	15	15	11.70	8.58	13.32	$4,065	$3,126	$3,099	$3,963	$3,024	$2,997	$3,860	$2,921	$2,895
10	0	0	0	7.60	6.32	9.26	$2,862	$2,620	$2,458	$2,862	$2,620	$2,458	$2,862	$2,620	$2,458
11	7.5	7.5	7.5	9.32	7.53	11.02	$3,511	$3,064	$2,859	$3,460	$3,013	$2,808	$3,409	$2,962	$2,757
12	22.5	22.5	22.5	10.70	8.27	11.95	$3,994	$3,280	$3,011	$3,841	$3,126	$2,857	$3,687	$2,973	$2,704
13	30	30	30	11.10	8.49	12.02	$4,117	$3,318	$2,975	$3,913	$3,114	$2,770	$3,708	$2,909	$2,566
14	50	50	50	11.89	9.17	12.62	$4,312	$3,490	$3,006	$3,971	$3,149	$2,665	$3,630	$2,808	$2,324
15	90	90	90	12.23	9.46	12.92	$4,158	$3,328	$2,824	$3,544	$2,715	$2,211	$2,931	$2,101	$1,597
16	15	15	0	10.08	7.57	10.48	$3,854	$3,087	$2,708	$3,786	$3,019	$2,640	$3,718	$2,950	$2,571
17	15	15	7.5	10.04	7.69	11.12	$3,800	$3,106	$2,856	$3,715	$3,021	$2,771	$3,629	$2,935	$2,685
18	15	15	22.5	10.30	7.90	11.78	$3,857	$3,147	$2,991	$3,737	$3,027	$2,871	$3,618	$2,908	$2,752
19	15	15	30	10.21	7.98	11.84	$3,807	$3,162	$2,994	$3,671	$3,025	$2,857	$3,534	$2,889	$2,721
20	15	15	50	10.46	8.09	11.91	$3,797	$3,149	$2,959	$3,615	$2,967	$2,777	$3,433	$2,786	$2,595
21	15	15	90	10.51	8.40	12.37	$3,750	$3,147	$2,991	$3,477	$2,875	$2,719	$3,204	$2,602	$2,446

Assumed grain pricing wheat $300/t, barley $250/t, lentil $700/t.
Chicken litter $54.70/t which includes cost of product, spreading and transport (averaged across the three sites).
White cells = grain yields at Spalding which were not nitrogen limited.

Using grain protein maps to optimise nitrogen fertiliser to paddock scale nitrogen variability

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Key findings

- Wheat grain protein in 2022 showed a moderate correlation with soil available N pre-seeding in the following season at Bute and Redhill.
- The 2022 grain protein data was able to predict the in-paddock variability in fertiliser N requirement in the following crop at both experimental paddocks. However, there was a large variation between the paddocks despite having similar yield potentials. At 10% protein in 2022 the N fertiliser rate required to maximise partial gross margin (PGM) at Redhill was 125 kg N/ha compared to 61 kg N/ha at Bute.
- Crop N removal (combination of yield and protein) in 2022 had a strong relationship with N rate to optimise PGM in 2023 both Redhill and Bute.

Why do the trial?

In paddocks with significant spatial variation there is an opportunity to utilise data layers that can provide information at the site-specific level and aid nitrogen (N) decision making. The use of on combine protein analysers is becoming more common among grain growers. At harvest this technology allows growers to blend and segregate different grades of grain based on protein. However, the resulting grain protein maps also have the potential to assist N decision making by showing the spatial variation in protein (and therefore N) across a paddock. This variation can be used to assign zones and produce variable rate fertiliser maps.

The aims of this project are to increase the profitability derived from N fertiliser applications by:

- Examining the relationship between soil mineral N pre-seeding with grain yield and protein maps from the previous season.
- Examining the relationship between historical grain yield and protein maps, and the spatial variability of nitrogen response across paddocks in the Mid North and Yorke Peninsula.
- Provide information towards the potential for protein maps to create variable rate nitrogen application maps.

How was it done?

Paddock and trial site information

Two growers using standard yield monitors and retrofitted CropScan 3000H grain analysers were identified at Bute and Redhill. Wheat grain yield and protein maps from 2022 were analysed and one paddock per grower was selected for small scale field trials (Figure 1 and Figure 2).

Four sites per paddock were identified based on the 2022 data layers for small plot trials (Table 1). Each of the sites was predicted to have a different level of N fertiliser response based on historical crop performance. The 2022 grain yield and protein data from each of the selected trial sites are shown in Table 1. Soil available N for the Redhill site ranged from 38 – 56 kg N/ha and at Bute ranged from 31 – 56 kg N/ha. Organic carbon levels at both sites were low to moderate. There were no other constraints identified in the soil properties tested (data not shown).

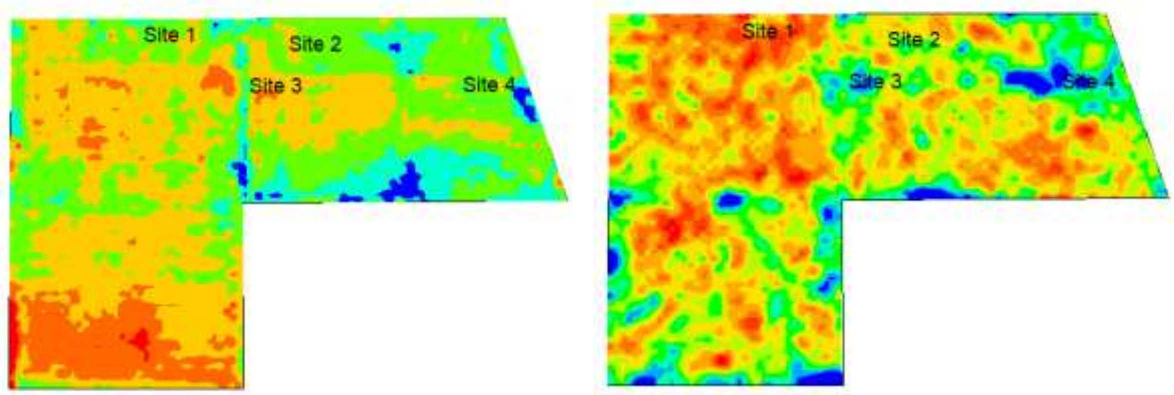

Figure 1. The 2022 Redhill paddock wheat yield map (left) and protein map (right).

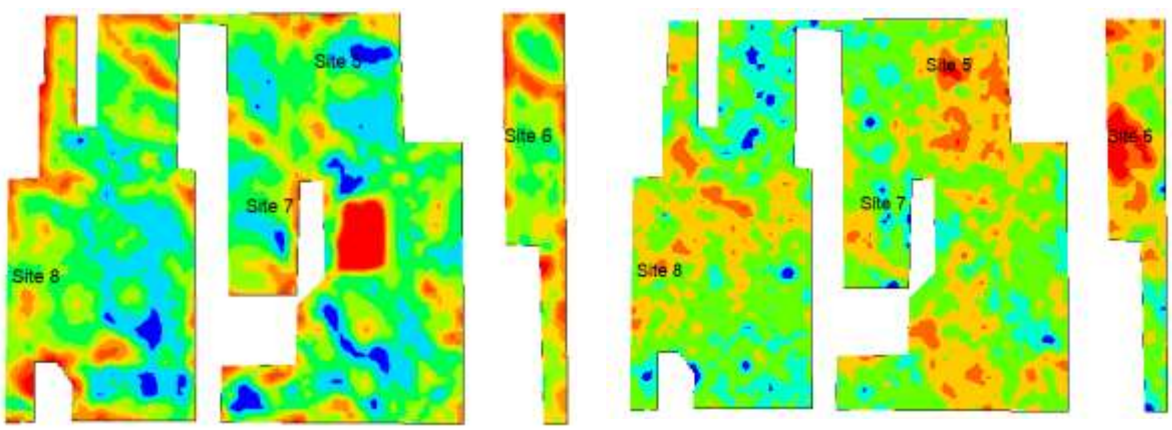

Figure 2. The 2022 Bute paddock wheat yield data (left) and protein map (right).

Table 1. Grain yield (2022), protein (2022), soil available N (sampled March 2023) and organic carbon for the small-scale plot trial locations.

N trial site	Location	Description*	2022 Wheat grain yield (t/ha)	2022 Grain yield (relative)	2022 Protein (%)	2022 Protein (relative)	Soil available N (0-100 cm)	Organic carbon (%)
1	Redhill	MYLP	5.6	1.02	9.8	0.93	38	1.3
2		MYMP	5.7	1.04	11.1	1.06	38	1.4
3		MYHP	5.3	0.96	11.3	1.07	49	1.3
4		HYHP	5.8	1.05	11.8	1.12	56	1.2
5	Bute	HYLP	7.9	1.11	9.7	0.91	31	0.9
6		MYLP	7.2	1.03	9.3	0.88	48	0.9
7		MYHP	7.0	1.01	11.3	1.06	56	1.0
8		MYMP	7.0	1.01	10.2	0.96	38	1.0

**Example MYLP = medium yield, low protein*

Nitrogen fertiliser rate plot trials

The trials were randomised complete block designs with three replicates. Plot dimensions were 1.5 m x 10 m. The N fertiliser response at each trial site was assessed with fertiliser rates of 0, 25, 50, 75, 100, 150 and 200 kg N/ha applied as urea early post emergent.

Trial management details for the individual sites are shown in Table 2. Plots were sown with a knife point press wheel system on 250 mm spacing. All plots were harvested for grain yield and grain quality was assessed. Grain yield and quality statistical analysis was performed using ANOVA and ASREML in R.

Yield potential was calculated = ((Rainfall (30% October to March) + April to October rainfall – 90 mm evaporation) * 25 kg/ha/mm). Previous October rainfall is generally not included in this calculation however, 2022 was an exceptionally wet season and it would be unwise to ignore it. Barley nitrogen requirement = (yield t/ha * 10% protein * 1.61) / 45% N use efficiency.

Table 2. Agronomic information for trial sites at Redhill and Bute in 2023.

Site	**Redhill**	**Bute**
Seeding date	May 15	May 16
Variety (Seeding rate)	Beast barley 80 kg/ha	Commodus CL barley 75 kg/ha
Starting fertiliser	MAP 100 kg/ha	MAP 100 kg/ha
N applications (Growth stage)	June 26 (GS 14)	June 26 (GS 14)
Harvest date	October 31	November 2

Nitrogen response curves were fit to the yield data for each site as a polynomial function. Predicted grain yield was then used to conduct partial gross margin (PGM) analysis to find the N rate at maximum PGM for each site.

Prices used in the PGM were $700/t for urea and $270/t for BAR1 barley. All treatments met and were assessed as BAR1 grade, despite some treatments reaching malt classification standards (currently Beast and Commodus CL are pending malt accreditation). The N rate at maximum PGM was then compared to historical yield and protein data.

Seasonal conditions

At both Redhill and Bute, the season started well with good seeding rains and a wet June. This was followed by a very dry spring (Figure 3). Well below average rainfall was received through July to October. October rainfall at Redhill was 5 mm and Bute 8.5 mm and this resulted in moisture stress prior to maturity at these sites. However, significant stored moisture was available for the crops throughout the growing season from the wet spring in 2022 (Figure 3).

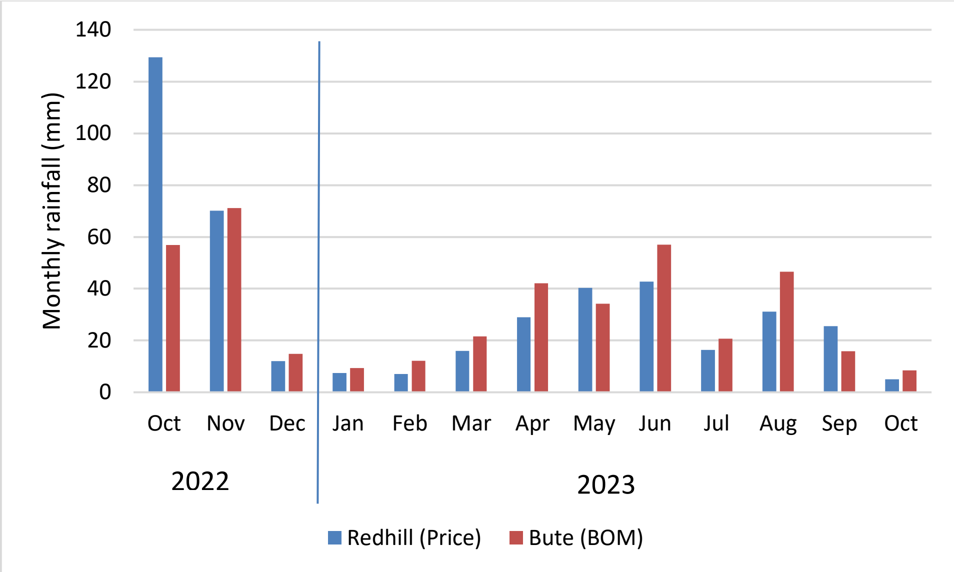

Figure 3. Monthly rainfall for Redhill and Bute from October 2022 to October 2023.

Results and discussion

Exploring the relationship between historical data layers and pre-seeding soil available N

Grain protein from the previous season had a moderate correlation to pre-seeding soil available N (Figure 4). At both the Redhill and Bute sites, as 2022 protein increased, soil available N measured in March the following season also increased. The rate of increase was similar for both sites at an average of 7.5 kg N/ha for each percent protein increase. The Bute sites were more variable and as a result had a weaker correlation compared to Redhill.

The 2022 grain yield and the combination of 2022 grain yield and protein (shown as N removal) did not have the same relationship between sites (Figure 4). At the Bute sites grain yield had a moderate correlation with soil available N compared to no relationship at Redhill. The opposite was observed between the two sites for N removal.

This data suggests grain protein can better describe the variation in soil available N compared to grain yield or N removal.

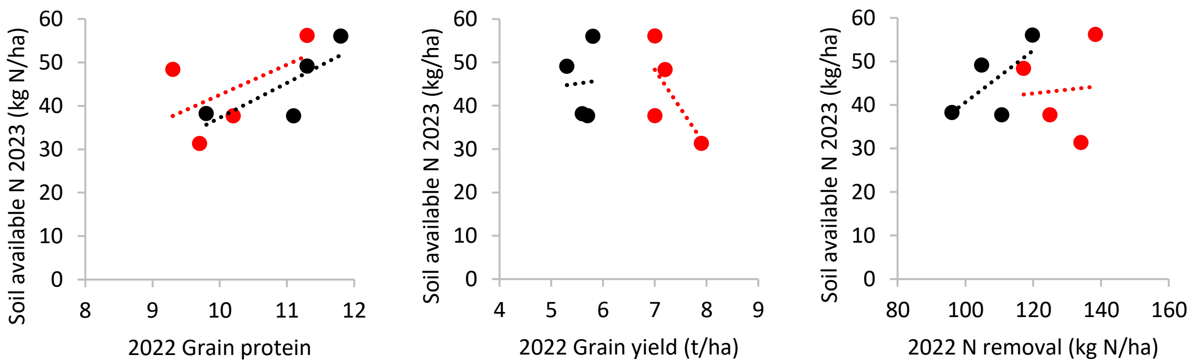

Figure 4. The relationship between 2022 protein (left), grain yield (mid) and N removal (right) and soil available N sampled March 2023 at Redhill (black) and Bute (red).

Protein – Redhill; y = 8.01x - 42.89, R^2 = 0.59, Bute; y = 6.94x - 26.91, R^2 = 0.30

Grain yield – Redhill; y = 1.67x + 35.91, R^2 = 0.001, Bute, y = -18.00x + 174.37, R^2 = 0.49,

N removal – Redhill; y = 0.5952x - 18.909, R^2 = 0.4456, Bute; y = 0.0855x + 32.393, R^2 = 0.0054.

Table 3. Grain yield, quality and N removal for eight N response trials at Redhill and Bute 2023. Within a row, numbers that share a common letter are statistically similar.

N rate (kg/ha)	**0**	**25**	**50**	**75**	**100**	**150**	**200**	***Pr (>F)***
Site 1 – MYLP								
Grain yield (t/ha)	3.4 d	4.0 c	4.4 b	5.0 a	5.0 a	5.3 a	5.3 a	*<0.001*
Protein (%)	8.7 f	9.2 ef	9.6 e	10.5 d	11.7 c	12.9 b	13.9 a	*<0.001*
Screenings (%)	0.3 b	0.2 b	0.2 b	0.2 b	0.2 b	0.3 b	0.6 a	*0.02*
N removal (kg/ha)	53g	65 f	74 e	92 d	102 c	119 b	128 a	*<0.001*
Site 2 – MYMP								
Grain yield (t/ha)	4.0 e	4.4 d	4.7 c	5.1 b	5.2 ab	5.2 ab	5.4 a	*<0.001*
Protein (%)	9.5 e	10.1 e	10.8 d	11.6 c	12.9 b	13.2 b	15.1 a	*<0.001*
Screenings (%)	0.2 b	0.3 b	0.3 b	0.3 b	0.2 b	0.4 b	0.6 a	*0.026*
N removal (kg/ha)	66 f	79 e	90 d	104 c	117 b	121 b	141 a	*<0.001*
Site 3 - MYHP								
Grain yield (t/ha)	3.8 d	4.3 c	4.5 bc	4.8 ab	4.9 a	5.1 a	5.2 a	*<0.001*
Protein (%)	9.8 e	10.1 de	10.9 d	12.0 c	13.1 b	13.6 b	14.7 a	*<0.001*
Screenings (%)	0.3 a	0.2 a	0.2 a	0.3 a	0.3 a	0.3 a	0.5 a	*0.151*
N removal (kg/ha)	64 e	76 de	85 d	101 c	113 bc	122 ab	134 a	*<0.001*
Site 4 – HYHP								
Grain yield (t/ha)	4.1 e	4.7 d	4.8 cd	5.0 bc	5.1 ab	5.3 a	5.1 ab	*<0.001*
Protein (%)	8.9 f	9.7 e	10.0 e	11.1 d	12.1 c	13.4 b	14.8 a	*<0.001*
Screenings (%)	0.6 a	0.3 a	0.2 a	0.3 a	0.5 a	0.5 a	1.0 a	*0.23*
N removal (kg/ha)	65 f	79 e	84 e	97 d	108 c	124 b	132 a	*<0.001*
Site 5 – HYLP								
Grain yield (t/ha)	3.7 d	4.2 c	4.5 b	4.6 ab	4.7 a	4.6 ab	4.5 b	*<0.001*
Protein (%)	8.7 e	9.1 de	9.5 d	10.5 c	10.7 c	12.6 b	14.4 a	*<0.001*
Screenings (%)	2.4 b	1.0 b	1.4 b	2.1 b	2.5 b	5.3 a	7.0 a	*0.002*
N removal (kg/ha)	56 f	67 e	74 d	84 c	89 c	101 b	113 a	*<0.001*
Site 6 – MYLP								
Grain yield (t/ha)	3.9 d	4.3 c	4.8 b	4.7 b	5.0 a	4.6 b	4.6 b	*<0.001*
Protein (%)	7.7 e	8.1 e	9.0 d	9.9 c	10.4 c	12.5 b	14.3 a	*<0.001*
Screenings (%)	0.6 d	0.6 d	0.9 d	2.1 c	2.1 c	4.9 b	8.4 a	*<0.001*
N removal (kg/ha)	52 g	61 f	75 e	81 d	91 c	101 b	115 a	*<0.001*
Site 7 – MYHP								
Grain yield (t/ha)	4.0 bc	4.1 abc	4.3 a	4.3 ab	4.3 a	4.0 c	3.9 c	*<0.001*
Protein (%)	9.7 d	10.5 d	11.9 c	12.2 c	12.5 c	14.6 b	16.0 a	*<0.001*
Screenings (%)	0.9 d	1.4 cd	2.8 bc	3.4 b	4.1 b	10.6 a	10.6 a	*0.151*
N removal (kg/ha)	69 d	75 d	90 c	92 bc	94 bc	102 ab	110 a	*<0.001*
Site 8 – MYMP								
Grain yield (t/ha)	4.1 d	4.5 c	4.7 ab	4.8 a	4.8 a	4.7 ab	4.6 bc	*<0.001*
Protein (%)	9.4 e	9.6 de	10.1 d	11 c	11.6 c	13.4 b	14.4 a	*<0.001*
Screenings (%)	0.9 d	1.0 d	1.4 d	2.5 cd	3.2 c	5.6 b	8.1 a	*<0.001*
N removal (kg/ha)	67 f	76 e	83 d	92 c	98 b	111 a	117 a	*<0.001*

General crop performance across the paddocks

Redhill grain yields were highly responsive to N at all sites, with responses ranging from 1.2 t/ha at Site 4 HYHP to 1.8 t/ha at site 1 MYLP, where maximum yield is compared with nil N applied (Table 3). Maximum barley grain yields were achieved with 75 kg N/ha or 100 kg N/ha across the four trial sites at Redhill. Grain quality was excellent with all samples testing < 1.0% screenings. Grain protein ranged from 8.7% to 14.8% and similar to grain yield was highly responsive to N fertiliser rate.

Maximum grain yields at Bute were slightly lower than at Redhill. The maximum yield at Redhill averaged 5.3 t/ha compared with 4.7 t/ha at Bute. Responses to N were also slightly lower, ranging from 0.3 t/ha at site 7 MYHP to 1.1 t/ha at site 5 HYLP. However, at Bute maximum grain yields were achieved from N fertiliser rates between 50 to 100 kg N/ha depending on the site. The low rainfall in September and October lead to moisture stress and haying off at some sites at high nitrogen rates (Table 3). This resulted in reduced grain yields and increased screenings at the highest N rates.

Grain quality was also more variable across the Bute paddock. The protein levels ranged from 7.7% to 16% and screening levels were higher in some treatments, up to 10.6%. Despite the moisture stress and resulting higher screenings the quality assessments meet BAR1 receival standards from all treatments and sites.

Partial gross margin analysis

Historical protein to predict crop N response

From the first season of results, there is evidence that historical protein can be used to indicate the variability in N demand for the current crop in a given paddock (Figure 5). At Redhill, as the 2022 protein increased the N rate to maximise PGM in 2023 reduced at a rate of 16 kg N/ha for each 1% protein increase. The response was steeper at Bute, where the N rate to maximise PGM reduced by 43 kg N/ha for every 1% increase in historical grain protein.

The absolute N requirement for a given historical protein varied between the two paddocks in 2023. At 10% protein in 2022 the N fertiliser rate required to maximise PGM at Redhill was 125 kg N/ha compared to 61 kg N/ha at Bute. The specific reason for the large difference in optimum N rates remains unclear from one season of results. The Redhill paddock produced higher maximum yields at 5.3t/ha compared with 4.7t/ha, but a 0.6t/ha increase in yield target should not increase optimum N rate by 64kg N/ha.

Fertiliser N requirements are affected by many factors including:

- Grain yield potential, both sites were predicted to have similar barley yield potentials and N requirements of 4.3 t/ha and 153 kg N/ha for Redhill and 4.8 t/ha and 163 kg N/ha for Bute.
- Soil available N pre-seeding was on average, slightly higher at Redhill (38 – 56 kg N/ha) compared to Bute (31 – 56 kg N/ha).
- Soil organic carbon levels (0-10 cm) were generally moderate to low in both paddocks. The Bute paddock is a sandy textured soil with organic carbon levels ranging from 0.9 – 1.0% indicating low potential for soil N mineralisation. At the Redhill paddock, the soil texture is loam to clay loam and the organic carbon values were higher ranging from 1.2 – 1.4% and therefore a higher potential for N mineralisation.

These factors suggest the Redhill site should have had more available N in the soil compared to Bute and therefore a lower N fertiliser requirement. However, the opposite was observed in the field and further investigation is required.

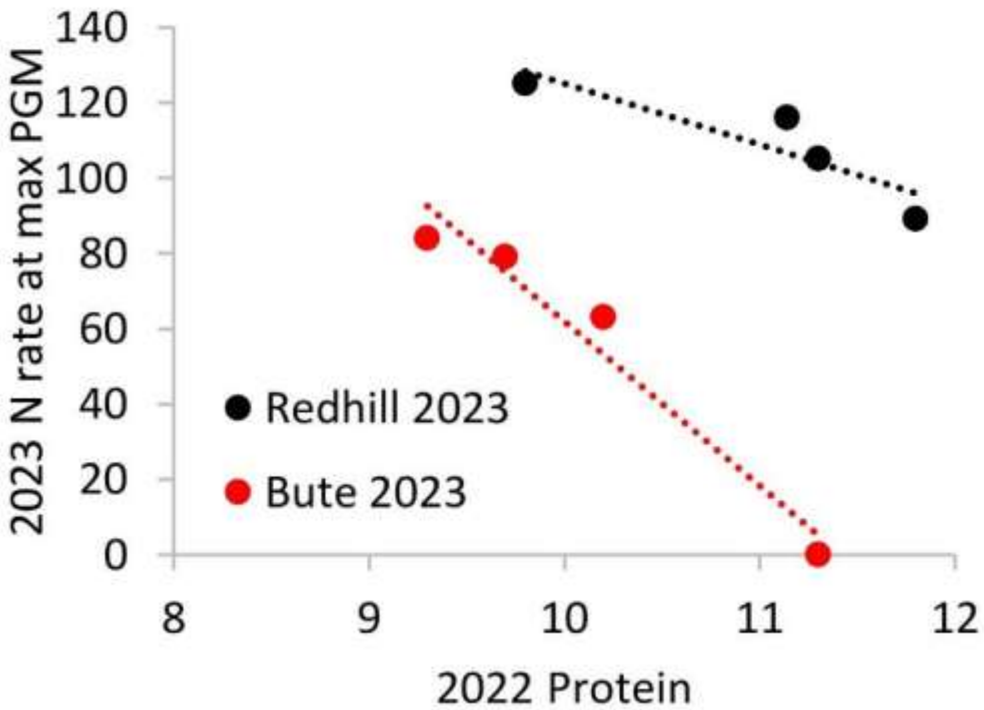

Figure 5. The 2022 protein and N rate required to maximise PGM in 2023 for Redhill and Bute.
Bute - y = -43.7x + 499, R^2 = 0.95, Redhill - y = -16.2x + 287, R^2 = 0.79

<u>Historical nitrogen removal to predict crop N response</u>

Using historical yield and protein data, the crop N removal from 2022 was calculated for each trial site (Table 1). The first season of trials show there is a strong relationship between the 2022 crop N removal and the 2023 fertiliser N requirement (Figure 6) and this relationship was similar for both the Redhill and Bute sites. As 2022 N removal increases, the N demand to achieve maximum PGM in 2023 was reduced. Where 2022 N removal reached 154 kg N/ha, no fertiliser N was required in the 2023 season to maximise PGM. In this instance all N from the following crop is being mined from soil reserves, which over time is expected to deplete organic matter reserves. When N removal reached 107 kg N/ha in 2022, N fertiliser rates that equal replacement were required to maximise PGM in the following season (Figure 6). Below this level of N removal, it was necessary to apply N fertiliser rates higher than removal to achieve maximum PGM. It is also expected applying higher fertiliser N rates than removal will result in an increase in soil available N going forward, as per the rationale behind N banking.

Using this methodology in practice suggests higher N fertiliser rates are required on low protein/low yielding areas of the paddock which may also increase the soil N bank. However, in high yielding/high protein areas of the paddock, soil N will be mined. If this strategy is used long-term it will result in a more spatially even N requirement across the paddock.

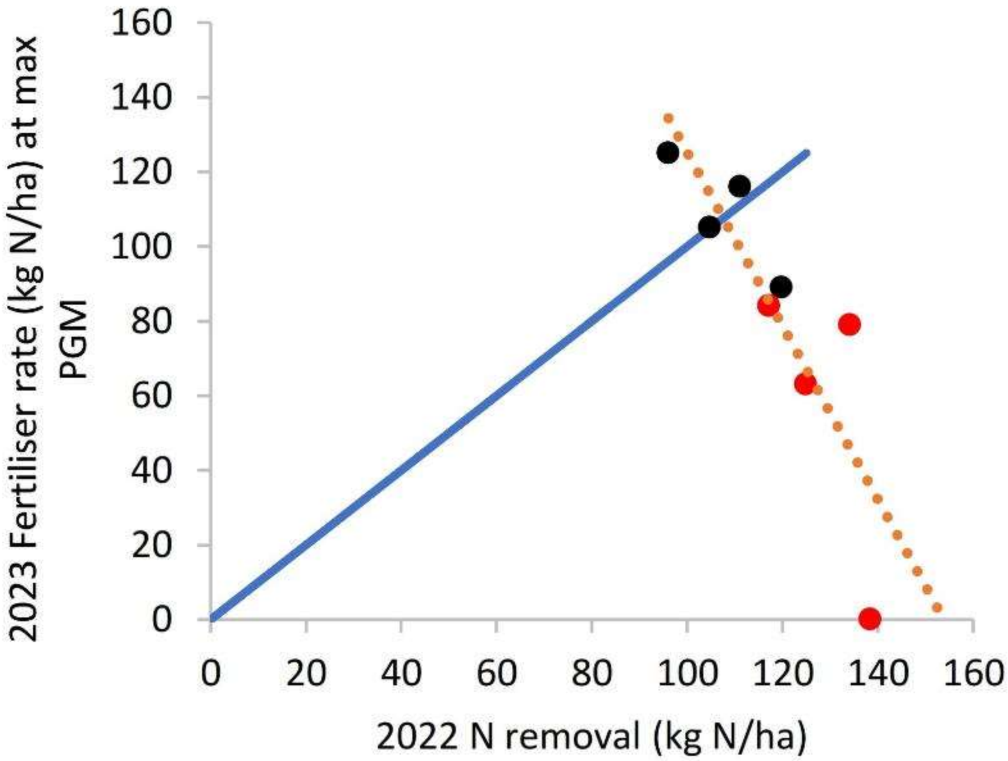

Figure 6. Crop N removal 2022 and N fertilise rate at maximum PGM 2023 for the Redhill (black circles) and Bute (red circles) trial sites, y = -2.32x + 358, R^2 = 0.72, the blue line shows where N removal = N applied.

Conclusions

Grain yield and protein maps collected in 2022 provided useful insight for understanding the variability in N response in the 2023 season. Protein data was more consistent at predicting soil available N and was useful in describing the variability in fertiliser N response in the following crop. The combination of 2022 yield and protein data into N removal produced a similar relationship with fertiliser N requirements for both paddocks. Further research is required across more paddocks and seasons to see if these relationships are maintained across a larger data set.

Acknowledgements

The authors gratefully acknowledge the financial support from SAGIT (TCO 02423) ‘Using grain protein maps to optimise nitrogen fertiliser to paddock scale nitrogen variability’ to conduct this research.

We also acknowledge the following growers Linden & Rob Price and Bill Trengove for hosting the field trials this season.

Two years of testing the nitrogen bank approach at Bute on a sandy soil

Sam Trengove[1], Stuart Sherriff[1], Jordan Bruce[1], Declan Anderson[1], James Hunt[2] and Sarah Noack[1]
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Key findings

- The grain yield of all N management strategies (total N target ranging from 118 – 221 kg N/ha) ranged from 4.91 t/ha to 5.35 t/ha, a difference of 0.44 t/ha, compared to untreated of 3.69 t/ha.
- Higher grain yield in 2023 was related to low grain yield in 2022, and vice versa. Differences in residual moisture are implicated, where lower yielding treatments in 2022 left more unused moisture for use in the 2023 crop compared with the higher yielding treatments in 2022.
- Nitrogen management strategies with total N targets of > 160 kg N/ha were required to build soil N levels (positive N balance) this season.
- Two years of results shows several N strategies were equally profitable (Figure 3), where seven of ten N management strategies tested produced average partial gross margins (PGM) that were within $54/ha of each other over the two seasons.

Why do the trial?

Nitrogen (N) management remains an issue for growers and research has shown N deficiency is considered the biggest single cause of yield gap in Australian wheat. Recently Hunt et al. (2021) developed the concept of N Banks, where enough N is supplied each year to maintain N at a level sufficient to achieve water-limited yield potential in most seasons. In the paddock, this means setting an appropriate N Bank target dictated by annual rainfall and potential yield for each crop location. This approach will require growers to focus more on a longer-term strategy rather than relying on a short-term season by season approach.

'Nitrogen banks' are a strategy for managing N in crop production areas with low environmental losses (leaching, denitrification). Most of the Yorke Peninsula and Mid-North has soils which are free-draining and hold a reasonable amount of water, and therefore, environmental losses of N are low. Exceptions to this are soil types that are prone to waterlogging or very sandy soils which are present in these areas. The advantages of the N Bank approach are that they are simple to calculate, crops are rarely N deficient, and if set at the correct level for the environment, soil organic N is not mined. They also shift the cost of N fertiliser into years following a year of high production, rather than in the year of possible high production.

Nitrogen banks require growers to set a locally relevant target for crop N supply (soil mineral N plus fertiliser N) that is enough to maximise yield in the majority of seasons. Soil mineral N is then measured early in the growing season, and if less than the target N Bank, is topped up to the target value with fertiliser N.

This trial is part of a larger series of experiments in the southern region aiming to compare the productivity (yield, protein), profitability (gross margin, risk) and sustainability (soil organic matter, carbon footprint, N losses) of different management systems over the long term.

How was it done?

Site selection and rainfall

The trial was established 6 km east of Bute, SA in 2022 to evaluate the performance of different N management strategies. Initial soil test results (0-100 cm) from year one are summarised in Table 1. The Bute soil profile is a sand over a sandy loam. The soil pH was slightly acidic in the 0-10 cm moving to neutral and slightly alkaline at depth (Table 1). Soil available phosphorus in the topsoil was high. The site had moderate organic carbon for a sandy soil (0.7%) and low sodicity and salinity.

Soil mineral N pre-seeding in 2022 was 80 kg/ha for the 0-70 cm or 113 kg/ha for 0-100 cm following the previous lentil crop in 2021. In 2023 all plots were sampled for soil mineral N pre-seeding on May 3 (Table 2) to establish any differences among the various N management strategies trialed in season one.

Table 1. Starting soil properties for N Bank trial at Bute, SA sampled in May 2022.

Depth		**0-10 cm**	**10-40 cm**	**40-70 cm**	**70-100 cm**
pH ($CaCl_2$)		6.1	7.9	8.1	8.0
DGT P	µg/L	117			
Organic Carbon	%	0.7			
Conductivity	dS/m	0.09	0.10	0.10	0.11
CEC	cmol/kg	4	17	23	24
ESP	%	0.6	0.3	0.3	0.4

In 2023 Bute received below average growing season rainfall at 225 mm compared to the long-term average rainfall 290 mm (Figure 1). This is a Decile 3 (lowest 30% of rainfall records) for Bute growing season rainfall. The site annual rainfall was 362 mm compared to 391 mm long-term average.

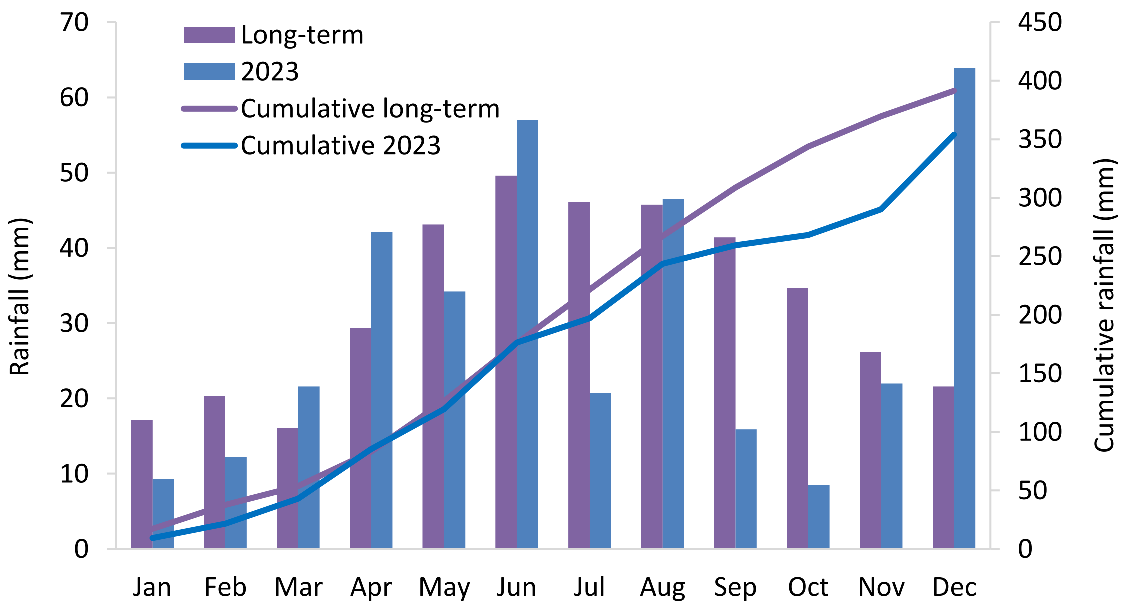

Figure 1. Long-term average and 2023 monthly and cumulative rainfall for N Bank trial at Bute, SA (source: Bute BOM weather station).

Trial design and treatments

The trial was sown to Commodus CL barley at 75 kg/ha on May 16, 2023 following wheat (2022) and lentil (2021). At seeding 130 kg/ha of single superphosphate was applied (no N applied at seeding). The trial was a randomised complete block design and N treatments were applied based on starting soil mineral N results and different N management strategies (Table 2). Three different N management approaches were tested:

- Matching N fertiliser to seasonal yield potential (Yield Prophet® and Yield Prophet Lite, YP)
- Maintaining a base level of fertility using N fertiliser (N Banks)
- District practice

All treatments were compared to a nil N control. Within the Yield Prophet and N Bank systems, there were additional treatments targeting different yield potentials (Table 2). In the Yield Prophet treatment, water limited potential yield was determined at different levels of probability and the amount of N required to achieve these yields applied assuming a requirement of 32 kg N /ha per tonne barley yield. For the N Bank treatments, there were different target levels of N fertility (N Banks). Nitrogen fertiliser rates in these treatments were calculated from the N Bank value (average crop yield potential at Bute 4.0 t/ha = 160 kg N/ha) minus soil profile mineral N measured prior to sowing. All N was applied as urea in a single top-dress application on July 7, 2023 prior to 5 mm of rainfall.

Table 2. Nitrogen management strategies and pre-seeding soil mineral N (May 3, 2023) in the N Bank trial Bute, SA in 2022 and 2023.

Treatment	**Nitrogen applied to wheat 2022**	**Soil mineral nitrogen 2023**	**Nitrogen applied to barley 2023**	**Total N target (soil + fert) 2023**	**Description**
	kg N/ha				
Control	0	44	0	44	No N applied
District Practice	121	59	85	144	Generally based on 32 kg N/tonne barley & average yield target of 4.8 t/ha. However, the rate here was capped at 85 kg N/ha as rates above this in the district are rare.
N Bank Conservative	22	54	81	135	Optimal profit minus 25 kg N/ha
N Bank Optimum Profit	47	51	109	160	Based on the relationship between optimal N Bank and rainfall. This season Decile 5 grain yield of 5 t/ha requires 160 kg N/ha minus starting soil available N
N Bank Optimum Yield	72	54	131	185	Optimal profit plus 25 kg N/ha
*YP BOM	143	65	54	118	Based on BOM season outlook. At the time was predicting a high chance (40%) of below average spring rainfall (decile 1&2). Target potential yield 3.7 t/ha.
YP Decile 1	0	46	72	118	Yield with lowest yielding season finish on record (Decile 1, severe drought). Target potential yield 3.7 t/ha.
YP Decile 2-3	15	73	71	144	Yield with lower yielding quartile season finish (Decile 2-3, moderate drought). Target potential yield 4.5 t/ha.
YP Decile 5	55	46	133	179	Yield with median season finish (Decile 5, 50%, average season). Target potential yield 5.6 t/ha.
YP Decile 7-8	99	52	169	221	Yield with higher yielding quartile season finish (Decile 7-8, favourable season). Target potential yield 6.9 t/ha.

**Yield Prophet Lite was used for yield predictions*

Crop assessments

Crop assessments included GreenSeeker NDVI measured on July 24 and September 1, 2023. Harvest index (HI) cuts were completed at maturity by removing 4 x 0.5 m row at ground level in each plot. Samples were oven dried at 70°C for 48 hours, weighed, threshed and separated into grain and stem /leaf and HI calculated. Grain yield plots were harvested with a plot header on October 27, 2023 and grain yield (t/ha) determined. Grain quality assessment included protein (%) and grain N removal was calculated as the product of grain N content and grain yield multiplied by a protein conversion factor 1.75. Fertiliser recovery N use efficiency (NUE) is the amount of applied fertiliser N recovered in the harvested grain for both trial years. It was calculated as treatment grain N removal minus control grain N removal divided by fertiliser applied (kg N/ha) to the specific treatment. Partial N balance was calculated as fertiliser N minus grain removal.

Results and discussion

Soil mineral nitrogen

The 2023 season pre-seeding soil mineral N levels ranged from 44 kg N/ha to 73 kg N/ha from N rates (ranging from 0 – 143 kg N/ha) applied in 2022. This was a difference in starting soil N of 29 kg N/ha from all N management strategies. There was a poor correlation between last year's fertiliser N rate and soil mineral N which is not commonly expected. This can be explained by above average 2022 spring rainfall resulting in high crop N uptake and negative N balances.

Crop biomass and HI

Crop biomass (measured as NDVI) in late July showed all N treatments had similar NDVI readings averaging 0.69 compared to 0.60 for the untreated control (data not shown). Five weeks later, in early September, NDVI measurements indicated there were only minor differences among the N treatments (Table 3).

Harvest index (HI) is the ratio of grain to total shoot dry matter and is a measure of the crop's reproductive efficiency. In average seasons, the HI is typically 0.3-0.4, compared to drier seasons when the harvest index can be closer to 0.5. Results from the current below average season are in line with this as the majority of N strategies had HI close to 0.5 (Table 3). Over supply of N early in the season can also lead to lower HI because of excessive biomass. This was also observed at Bute with low HI values of 0.41 and 0.44 resulting from the highest total N targets of 221 kg N/ha and 185 kg N/ha.

Grain yield and protein

The grain yield of the different N management strategies (total N target ranging from 118 – 221 kg N/ha) ranged from 4.91 t/ha to 5.35 t/ha, a difference of 0.44 t/ha. Given this small difference it is not surprising there was little variation in grain yield response among the N strategies trialed this season. A number of treatments were high yielding including NB conservative, NB Optimum Profit, YP Decile 1, YP Decile 3, YP Decile 5, NB Optimum Yield and District Practice (Table 3). Interestingly, these tended to be lower yielding treatments the season prior (2022).

Comparison of both seasons of grain yield data shows treatments in 2022 impacted barley yields in 2023. Nitrogen management strategies which had higher grain yields in 2022 were generally followed by lower yields in 2023 (Figure 2). Given NDVI data did not show any clear correlation with starting soil N (i.e. more carry over N from previous high N rates), it suggests this reduction in yield maybe related to soil water. Nitrogen strategies which applied higher fertiliser rates in 2022, stayed greener for longer due the wet spring and potentially used more water. It is this difference in residual water that has had a significant impact on yield this season.

Table 3. GreenSeeker NDVI, harvest index, grain yield (t/ha), protein (%), grain N removal, partial N balance, average fertiliser recovery NUE (2022 & 2023) and partial gross margin ($/ha) from N Bank trial at Bute, SA 2023.

Treatment	Soil mineral N + fertiliser N (kg N/ha)	= Total N (kg N/ha)	NDVI Sept 1	Harvest Index	Grain yield (t/ha)	Protein (%)	Nitrogen removal (kg N/ha)	Average fertiliser recovery (NUE)	Partial N balance (kg N/ha)	Partial gross margin* $/ha
Control	44 + 0	44	0.58 ^{c}	0.51 ^{a}	3.69 ^{e}	7.0 ^{f}	45 ^{g}		-45	1,292
District Practice	59 + 85	144	0.71 ^{b}	0.45 ^{c}	5.04 ^{bcd}	10.6 ^{cd}	94 ^{cde}	41%	-9	1,670
N Bank Conservative	54 + 81	135	0.72 ^{ab}	0.51 ^{a}	5.35 ^{a}	9.1 ^{e}	86 ^{ef}	53%	-4	1,785
N Bank Optimum Profit	51 + 109	160	0.75 ^{ab}	0.47 ^{bc}	5.16 ^{abc}	10.6 ^{cd}	96 ^{bcd}	49%	12	1,689
N Bank Optimum Yield	54 + 131	185	0.77 ^{a}	0.44 ^{cd}	5.08 ^{bcd}	11.9 ^{b}	106 ^{ab}	45%	25	1,635
YP BOM	65 + 54	118	0.75 ^{ab}	0.46 ^{bc}	4.94 ^{cd}	10.1 ^{d}	88 ^{def}	44%	-34	1,671
YP Decile 1	46 + 72	118	0.75 ^{ab}	0.50 ^{ab}	5.27 ^{ab}	8.6 ^{e}	80 ^{f}	48%	-8	1,765
YP Decile 3	73 + 71	144	0.76 ^{ab}	0.52 ^{a}	5.28 ^{ab}	8.6 ^{e}	80 ^{f}	51%	-9	1,770
YP Decile 5	46 + 133	179	0.75 ^{ab}	0.47 ^{bc}	5.25 ^{ab}	11.2 ^{bc}	104 ^{abc}	43%	29	1,693
YP Decile 8	52 + 169	221	0.77 ^{a}	0.41 ^{d}	4.91 ^{d}	12.8 ^{a}	111 ^{a}	39%	58	1,534
		Pr(>F)	<0.001	<0.001	<0.001	<0.001	<0.001			
		LSD (P≤0.05)	0.06	0.04	0.16	0.9	10			

*Partial gross margin was calculated as grain yield x grain price – urea applied (kg /ha) /1000*urea price. Assumed 2023 pricing BAR1 = $350/tonne and urea = $500/tonne.*

Even where no additional N was applied, barley yields were 3.69 t/ha (Table 3). Soil mineral N was low in the control (44 kg N/ha) following high wheat yields in 2022 (Trengove et al. 2022). The N removal results show 45 kg N/ha was removed in the grain. Depleting this supply of N in the long-term is not sustainable.

Fertiliser NUE values reported here are in line with industry values of 30 – 50%. The values presented in Table 3 are the average of both years' fertiliser applications and N removal. They show in general 39 – 51% of the N fertiliser applied was recovered in the grain in the two years of the trial. The fate of the other 49-61% includes the crop residues, soil mineral N and losses to the environment.

Grain protein for all treatments ranged from 7.0 – 12.8% (Table 3). Currently Commodus CL has a maximum delivery grade of feed (no protein limit) however, it is undergoing malt accreditation. Treatments falling outside the protein levels for malt receival standard (9.0 - 12.0%) were the Control, YP Decile 1, YP Decile 3. N Bank Conservative was border line at 9.1%. The highest N strategy this season (YP Decile 8 = 221 kg N/ha) was the only treatment to exceed 12.0%.

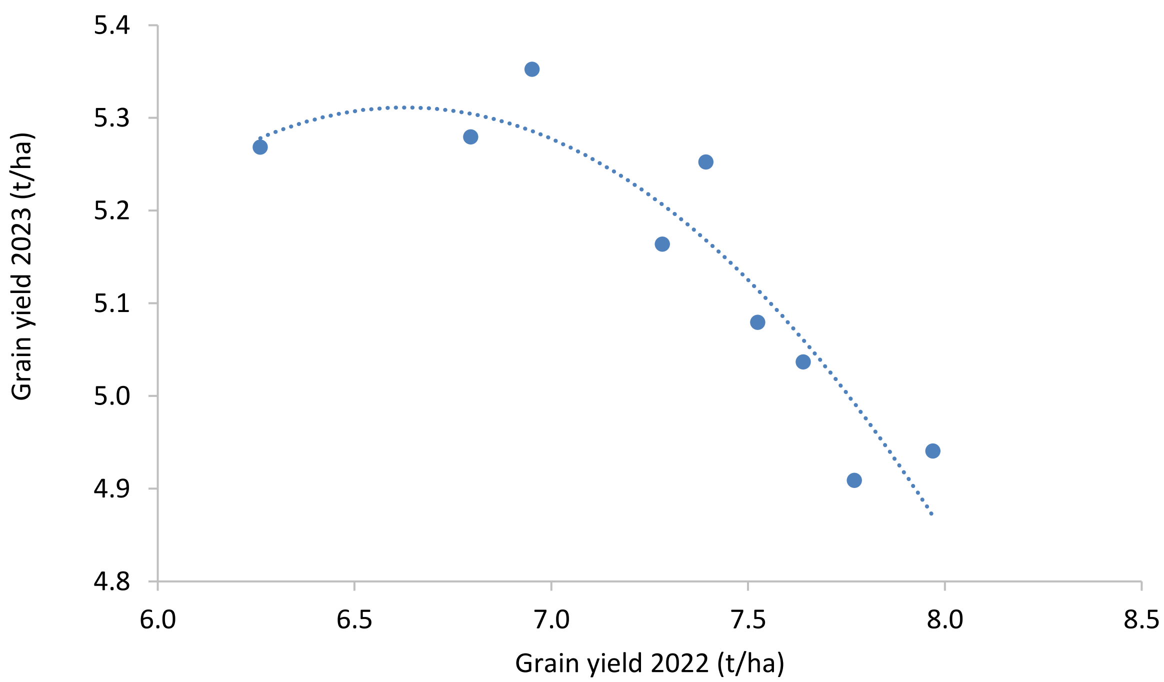

Figure 2. Relationship between wheat grain yield (2022) and barley grain yield (2023) from the various N management strategies, excluding the nil.

Patrial gross margin and N balances

Comparison of the different systems shows that N Bank Conservative (135 kg N/ha total N) was the most profitable treatment this season (Table 3). This was followed by two other conservative N management strategies achieving similar levels of profit (within $20/ha); YP Decile 3 and YP Decile 1.

The partial N balance from all treatments ranged from negative (mining soil N) 45 kg N/ha to positive (increasing soil mineral N) 58 kg N/ha (Table 3). This season N management strategies with total N targets of 160 to 221 kg N/ha resulted in positive N balances of 12 to 58 kg N/ha. Management strategies with total N targets of 144 kg N/ha or less mined N from the system.

Reviewing two years of results shows several N strategies were equally profitable (Figure 3), where seven of ten N management strategies produced average partial gross margins (PGM) that were within $54/ha of each other. The treatments that fall outside of this group were the annual low input strategies (Nil, YP Decile 1) and annual high input strategy (YP Decile 8). Given the seasons rainfall were Decile 7 in 2022 and Decile 3 in 2023, it is not surprising these treatments have not performed well in both years. In contrast, treatments that respond to the season, or target moderate inputs performed better. This outcome is supported by a previous long-term trial carried out by Hunt et al. (2021) at Curyo, Victoria.

The data from Bute also shows profit is maximised at slightly negative (-30 kg N/ha) partial N balance and gross margin begins to decline at an N balance ±20 kg N/ha from this value. In general, the lower N input strategies that optimise PGM are lower risk and provide a higher return on investment in the short term. Conversely, the higher input strategies that optimise PGM may result in a lower return on investment in the short term (due to a higher cost base) but, longer term will be more sustainable agronomically with neutral to positive N balances (more N applied in fertiliser than removed in grain) indicating soil organic N is not being mined.

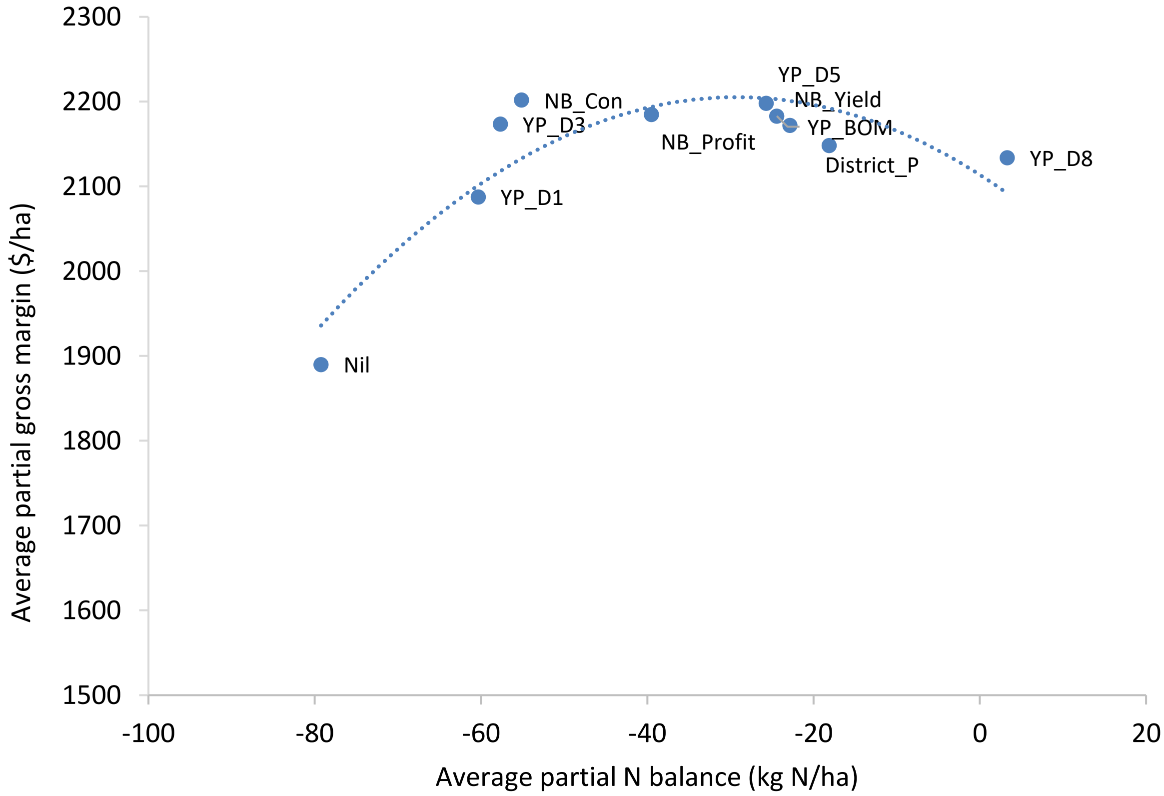

Figure 3. The relationship between average (2022 and 2023) partial N balance and average partial gross margin for the different N treatments trialed at Bute, SA.

Conclusions

This project aims to demonstrate to growers how to reduce the yield gap from N deficiency, increase profit, and stop mining soil organic matter by taking a longer-term view of N management. Below average growing season rainfall resulted in barley grain yields at Bute ranging from 3.69 t/ha to 5.35 t/ha. A number of N management strategies were high yielding including NB Conservative, NB Optimum Profit, YP Decile 1, YP Decile 3 and YP Decile 5, but this was largely linked to production in 2022 where lower yielding treatments in that year performed comparatively better in 2023 and vice versa. Soil water dynamics are important in this interaction.

Reviewing two years of results shows several N strategies were equally profitable. Currently the data shows profit is maximised at a slightly negative (-30 kg N/ha) partial N balance. However, over the longer term, while it is expected these strategies will remain the most profitable, they are likely to have neutral to positive N balances (more N applied in fertiliser than removed in grain) indicating soil organic N is not being mined.

Acknowledgements

The authors gratefully acknowledge the investment from GRDC in both year one (BWD2204002RTX) and year two through the 'RiskWi$e' National Risk Management Initiative (HFG2303-001BGX).

We also thank collaborating trial host grower Bill Trengove.

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Nitrogen banking approach for clay-loam soil in the medium rainfall zone of SA

Rebekah Allen[1], Kaidy Morgan[1] and James Hunt[2]

[1]Hart Field-Site Group, [2]The University of Melbourne

Key findings

- Two contrasting seasons were observed at the N Bank trial site from 2022 – 2023 at Kybunga, SA receiving 552 mm and 407 mm of annual rainfall, respectively.
- In 2022, all nitrogen (N) management treatments resulted in a negative partial N balance (kg N/ha), indicating soil N was mined. This occurred to a smaller extent in 2023, with several treatments in positive N balance (partial N balance ranging from -62.1 to +30.7 kg N/ha).
- Barley yield response to N treatments was moderate (0.77 t/ha difference) with yields ranging from 4.36 – 5.13 t/ha. Several treatments yielded well in 2023 including N Bank Conservative, N Bank Optimum Profit, YP Decile 5 and YP Decile 7 (applied N ranging from 34 – 93 kg N/ha).
- The N Bank conservative treatment (160 kg/ha total N/) was the most profitable treatment at Kybunga in 2023 with a partial gross margin of $1,655.
- Although not the most profitable, cumulative partial N balance (2022 and 2023) shows that YP Decile 8 and N Bank Optimal Yield treatments have reduced mining of soil mineral N, across two good production years at Kybunga, SA.

Background

Nitrogen (N) deficiency is the most significant factor contributing to grain yield gaps within Australian cropping systems, reducing in on-farm profitability (Hunt, 2020). It is suggested that national wheat yields could increase by up to 40% by alleviating N deficiency (Hochman and Horan 2018).

Two strategies can be implemented to manage N application, including traditional nitrogen budgeting which attempts to match N to seasonal yield potential, or strategic nitrogen sequence targets, otherwise known as the nitrogen banking approach (N Banks). Generally, our tactical approach to in-crop N management targets a particular yield or seasonal outcome, using the 40 kg/N per tonne of wheat rule. If we know how much N is available to the crop as soil mineral N, we know how much extra to add. But we also know that if we are unlikely to hit this target, we are going to either under-fertilise and regret being too cautious or over-fertilise and regret being too optimistic (Allen et.al., 2023). The national average for in-crop nitrogen application is currently 45 kg N/ha which is one of the main reasons for the gap between actual and potential yields (Hunt et al., 2022).

Nitrogen banking is a strategy to simplify a management decision and manage N in crop production across areas with low environmental losses, such as leaching and denitrification. The nitrogen banking approach ensures adequate N is applied to maintain levels that can achieve water-limited potential yield (PYw) potential in most seasons (Trengove, 2022). This is a long-term and strategic approach, where an appropriate N Bank target is implemented for crop N supply. This is determined by yield potential and environment at a specific location.

Some of the biggest advantages associated with N banking is that soil organic N is not mined if targets are set correctly. This is important as unused fertiliser maintains the fertility of continuous cropping systems, with crops like wheat only sourcing 30-40% of their nitrogen requirement from fertiliser (Hunt, 2023). This N strategy also moves the cost of nitrogen fertiliser from seasons with a high production potential, into seasons following a high production year (Trengove, 2022).

Methodology

Site selection and rainfall

A trial was established at Kybunga in 2022 as a series of long-term experiments across the southern region, aiming to evaluate the productivity (yield and protein), profitability (gross margin) and sustainability (soil organic matter, carbon and N losses) of long-term N management systems. The Kybunga site is located within the medium rainfall zone of the Mid-North region on a light clay-loam soil type. Soil mineral N levels were high in 2022 (Table 1), following the previous year's field pea crop with a total of 147 kg N/ha (0 – 100 cm). Topsoil pH was neutral (pH 7) at 0 – 10 cm, increasing to alkaline at depth (10 – 100 cm). Phosphorous availability by DGT P was adequate (60.1 µg/L) and salinity slightly high (> 15 dS/m).

Table 1. Soil properties for the Kybunga, SA trial site sampled May 4, 2022.

Soil properties	**Units**	**Depth (cm)**			
		0-10	**10-40**	**40-70**	**70-100**
Available N (nitrate + ammonium)	Kg/ha	50.5	50.4	27.2	18.9
pH (CaCl2)		7	8	8	8
DGT P	µg/L	60.1			
Organic carbon	%	1.3			
Conductivity (salt)	dS/m	0.17	0.19	0.16	0.22
CEC (Cation exchange capacity)	cmol/kg	21.8	33.4	28.2	28.3
ESP (Exchangeable sodium percentage)	%	0.8	0.6	1.1	4.2

The site received above average annual rainfall of 552 mm in 2022, compared to the long-term average of 428 mm (Figure 1). Growing season rainfall (GSR) received was 384 mm (April – October). In 2023, the Kybunga site received below average rainfall of 407 mm, with 275 mm contributing to GSR.

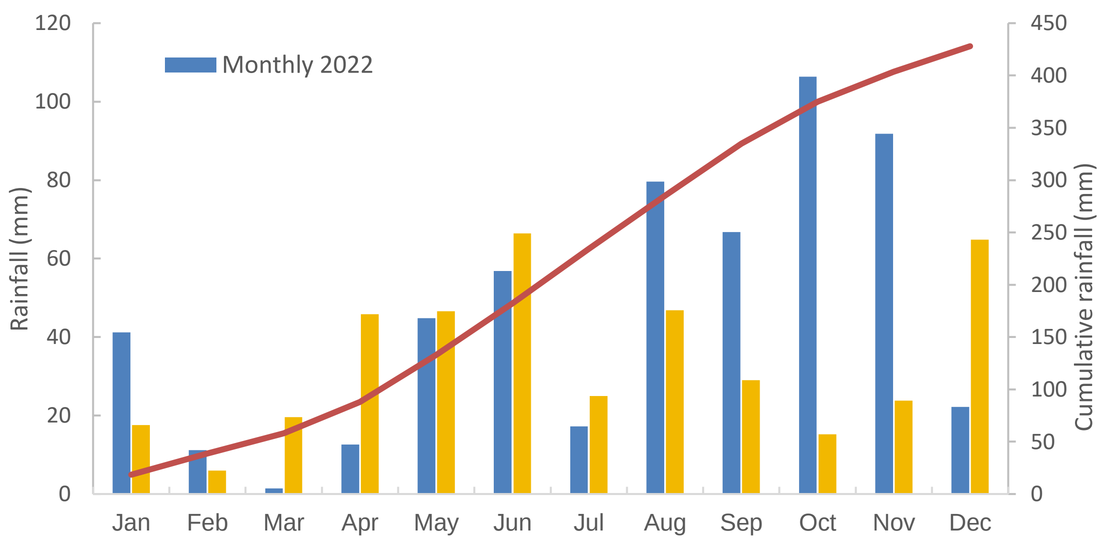

Figure 1. Monthly rainfall at Kybunga trial site for 2022 and 2023 seasons (Source: Kybunga Mesonet). Cumulative long-term average annual rainfall (428 mm) at site is also shown.

Trial design and treatments

The trial was sown to Compass barley at 150 plants/m^2 (~80 kg/ha) on May 17, 2023, after Scepter wheat in 2022 (Table 2). The trial was a randomised complete block design, evaluating ten N management strategies (Table 3), based on starting soil mineral N results each season. Across the ten treatments, three core N management approaches were tested:

1. Matching N fertiliser to seasonal yield potential (Yield Prophet®)
2. Target N fertiliser rate to maintain a base level of fertility (Nitrogen banking)
3. District practice (45 kg N/ha)

Yield Prophet® was used to evaluate yield spread as probabilities at Kybunga, based on starting soil water and available N. This determined several treatments across decile outcomes (1 – 8). The amount of N calculated for these treatments was determined by the difference between water limited yield (PYw) and nitrogen limited yield potential (PY_N). The amount of N required to achieve these yields assumed a requirement of 40 kg N /ha per tonne of barley.

An 'optimal profit' N Bank target was selected based on the relationship between average annual rainfall and the minimum N Bank target required to achieve average economic yield. Optimal Yield and Conservative targets were plus and minus 25 kg N/ha from the optimal profit treatment respectively. Nitrogen fertiliser rates in these treatments were calculated from the N Bank value, minus soil profile mineral N measured prior to sowing. All N was applied as urea in a single top-dress application in July, plus 6 kg N/ha was applied through MAP fertiliser at seeding.

Crop measurements included plant counts (plants/m^2) and harvest index (HI) which were conducted at maturity by removing 4 rows x 0.5 m at ground level in each plot. Samples were oven dried at 70°C for 48 hours, weighed, and then threshed to separate grain from stem and leaf, to calculate harvest index (HI). Harvest index is defined by the ratio of grain to total shoot dry matter (leaf and stem) and is a measure of reproductive efficiency.

The trials were harvested to determine grain yield (t/ha) and quality measurements were completed to measure protein (%), screenings (%), test weight (kg/hL) and retention (%) (barley only). Grain N removal was also calculated as a product of grain N content and yield multiplied by a protein conversion factor of 1.75.

All 2022 and 2023 trial data was analysed using a REML spatial model (Regular Grid) in Genstat 23rd edition.

Table 2. Site details for 2022 and 2023 nitrogen banking trial at Kybunga, SA.

2022	**Plot size**	2.0 m x 10.0 m	**Fertiliser**	Seeding: MAP (10:22) + 1% Zn @ 60 kg/ha
	Seeding date	May 28, 2022		
	Crop	Scepter wheat		
	Seed rate	180 plants/m^2	**N application**	July 15, 2022
	Harvest date	December 23, 2022		
2023	**Plot size**	2.0 m x 10.0 m	**Fertiliser**	Seeding: MAP (10:22) + 1% Zn @ 60 kg/ha
	Seeding date	May 17, 2023		
	Crop	Compass barley		
	Seed rate	150 plants/m^2	**N application**	July 26, 2023
	Harvest date	October 27, 2023		

Table 3. Nitrogen treatments evaluated each season in Kybunga N banking trial.

Treatment	Description
Control	No N applied (Nil)
District Practice	Generally based on national average of 45 kg N/ha
N Bank Conservative	Optimal profit minus 25 kg N/ha
N Bank Profit Optimum	Based on the relationship between optimal N Bank and rainfall
N Bank Yield Optimum	Optimal profit plus 25 kg N/ha
***YP BoM**	Based on BoM season outlook at time of application (generally a three-month outlook)
YP Decile 1	Yield with lowest yielding season finish on record (Decile 1, severe drought)
YP Decile 2-3	Yield with lower yielding quartile season finish (Decile 2-3, moderate drought)
YP Decile 5	Yield with median season finish (Decile 5, 50%, average season)
YP Decile 7-8	Yield with higher yielding quartile season finish (Decile 7-8, favourable season)

**YP = Yield Prophet®*

Results and discussion

2022 Results

Nitrogen treatments ranged from 0 – 96 kg N/ha at Kybunga in 2022 (Table 4). District Practice (45 kg N/ha), Decile 1 and Decile 2 – 3 treatments had no in-crop fertiliser applied as sufficient N was available (soil mineral N + seeding N) to produce a 3.8 t/ha wheat crop, based on the 40 kg N per tonne wheat rule. Above average rainfall of 552 mm achieved grain yields ranging from 5.44 – 6.52 t/ha (Table 5), with YP BoM and YP Decile 7 – 8 the highest performing treatments, both targeting above average rainfall seasons (6.2 t/ha PYw). Both treatments met APW1 receival standards (protein <11.5%). All other treatments met ASW1 (protein <10.5%). All treatments had low screenings (3.8%) and high test weight (83.1 kg/hL).

Table 4. Nitrogen treatments and pre-seeding soil mineral N at Kybunga in 2022 and 2023.

	2022		2023			
Treatment	**Applied N (kg/ha)**	**PYw (t/ha)**	**Soil N + starter fert (kg N /ha)**	**Partial N supply (soil + all fert) (kg/ha)**	**PYw (t/ha)**	**Applied N (kg/ha)**
Control	0		86 + 6	92		0
District Practice	0		86 + 6	138		46
N Bank Conservative	8		86 + 6	160		68
N Bank Optimum Profit	33		86 + 6	185		93
N Bank Optimum Yield	58		86 + 6	210		118
YP BoM	96	7.8	86 + 6	236*	7.8*	144*
YP Decile 1	0	2.7	86 + 6	92	2.7	0
YP Decile 3	0	3.9	86 + 6	104	3.9	12
YP Decile 5	40	4.5	86 + 6	126	4.5	34
YP Decile 7	96	5.9	86 + 6	168	5.9	76

**Nitrogen for YP BoM treatment was incorrectly applied and should have been 104 kg N/ha, based on BoM three-month forecast predicting a 46% chance of Decile 2 – 3.*

Table 5. Grain yield (t/ha), partial gross margin and partial N balance (kg N/ha) for all N management strategies at Kybunga in 2022. Partial N balance is calculated as grain N removal – N fertiliser applied.

Treatment	**Grain yield (t/ha)**	**Partial gross margin ($/ha)**	**Partial N balance (kg N/ha)**
Control	5.50[ab]	2,036	-92.7
District Practice	5.76[bcd]	2,131	-98.5
N Bank Conservative	5.66[abc]	2,074	-86.9
N Bank Optimum Profit	5.87[cd]	2,084	-68.1
N Bank Optimum Yield	6.02[d]	2,076	-49.5
YP BoM	6.52[e]	2,227	-25.5
YP Decile 1	5.44[a]	2,012	-91.6
YP Decile 3	5.61[abc]	2,075	-94.5
YP Decile 5	6.03[d]	2,125	-63.1
YP Decile 7	6.51[e]	2,223	-23.6

2023 results

Soil mineral nitrogen

Following a high production year for wheat in 2022, pre-seeding soil mineral N was similar across all treatments with a site average of 80 kg N/ha at Kybunga in 2023. Nitrogen rates applied to treatments varied, ranging from 0 – 236 kg N/ha (Table 4).

Crop HI, grain yield and protein

Harvest index (HI) as a ratio of grain to total shoot dry matter was similar for all treatments at Kybunga in 2023 with a site average of 0.49 (P=0.075). Harvest index values of 0.5 can be expected in a well-managed barley crop.

Barley yield response to varying N treatments was moderate (0.77 t/ha difference) with yields ranging from 4.36 – 5.13 t/ha (Table 6). Several treatments yielded well in 2023 including N Bank Conservative, N Bank Optimum Profit, YP Decile 5 and YP Decile 7. In control and Decile 1 treatments where no N was applied, barley yields achieved 4.36 – 4.37 t/ha, respectively. Grain N removal results show that 60 – 62 kg N/ha was removed, mining soil N. Barley protein ranged from 7.2 – 12.9% across N management strategies. District practice (45 kg N/ha) and N Bank Conservative (160 kg N/ha) met MALT 2 receival standards (screenings >7% to meet Malt 1) with protein levels ranging from 9.6 – 9.9%.

Similar trends were observed across reduced N management strategies with improved screenings, retention and test weight across the control, and Decile 1 – 5 treatments. Screenings ranged from 14.1 – 22.6% in high N management strategies, however all treatments had similar grain to shoot ratios when harvest index was measured. This may result from higher N treatments producing greater biomass or tiller number in comparison to lower N treatments, however coupled with a drier season, these higher yielding treatments resulted in overall reduced grain weight. Similar observations were noted in previous nitrogen experiments across NSW (Bellata and Narrabri), showing that increasing N application rates significantly increased grain screening levels (Daniel et.al., 2016).

The error in N application in 2023 to the YP BoM treatment (46% chance of Decile 2 – 3) increased applied N to 144 N/ha (> Decile 7). Although lower yielding than best performing treatments, it still achieved 5.01 t/ha. Protein also exceeded 12%, failing to meet malt specifications.

Partial gross margin and N balance

A comparison of various N management systems at Kybunga in 2023, shows that the N Bank Conservative (160 kg N/ha total N) was the most profitable treatment with a partial gross margin of $1,655. Similar results were also observed at Bute, SA in 2023 (Trengove et.al., 2023). Nitrogen management strategies achieving similar levels of profit (within $100/ha) were District Practice and YP Decile 5.

The N management strategy with the lowest partial gross margin in 2023 was the control treatment, achieving $1,372/ha (-$283 compared to N Bank conservative). A two-year partial gross margin (Figure 3) shows that YP Decile 7 has been the most profitable N treatment overall to date, this is likely a reflection of the favourable season carrying over from 2022, where this treatment capitalised from a high production year with sufficient N to exceed PYw of 6.2 t/ha.

Partial N balances (grain N removal – N fertiliser applied) at Kybunga ranged from -62 to +31 kg N/ha. This shows that all N management strategies mined soil N from the system in 2023. This result shows N management strategies with total N targets of ≥ 210 kg N/ha resulted in positive N balances of 12.7 – 30.7 kg N/ha. Cumulative partial N balance (2022 and 2023) displayed in Figure 3 show that YP Decile 7 and N Bank Optimal Yield have reduced mining of soil mineral N.

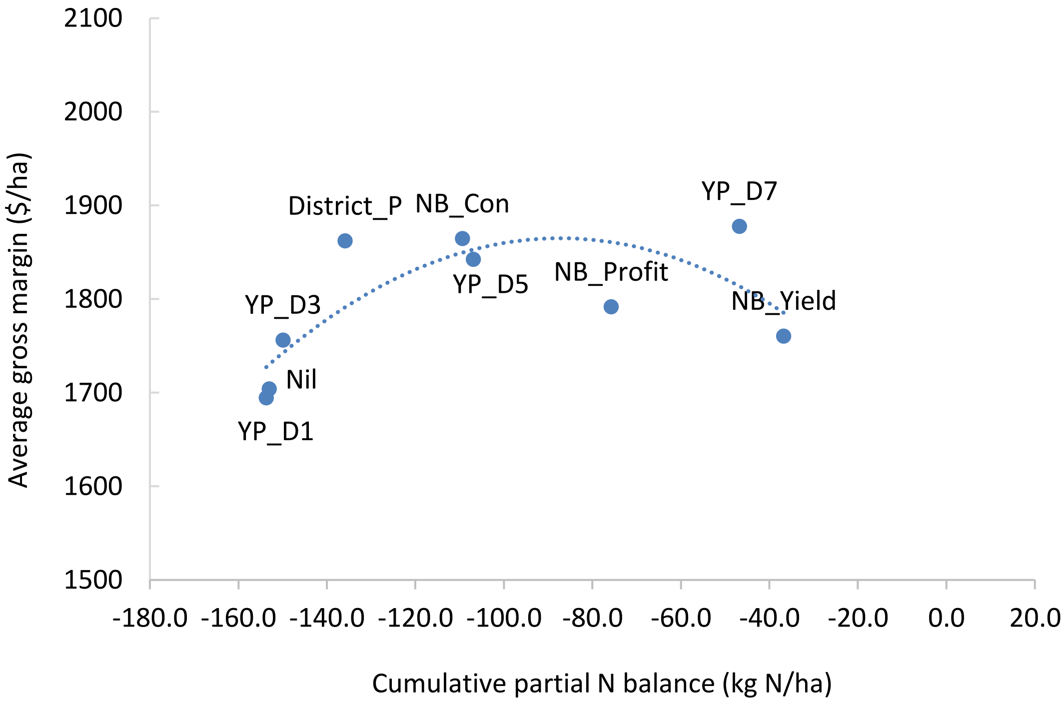

Figure 3. The relationship between average (2022 and 2023) partial N balance and average partial gross margin for N treatments trialed at Kybunga. YP BoM treatment has been excluded from this data set.

Table 6. Grain yield (t/ha), protein (%), screenings (%), test weight (kg/hL), retention (%) grain N removal, partial N balance and partial gross margin ($/ha) for N bank trial at Kybunga, SA 2023. Shaded values represent the best performing treatments in each column.

Treatment	Applied N fertiliser (kg N/ha)	Grain yield (t/ha)	Protein (%)	Screenings (%)	Retention (%)	Test weight (kg/hL)	Grain N removal (kg N/ha)	Partial N balance (kg N/ha)	Cumulative partial N balance (kg N/ha)	Average partial gross margin* $/ha
Control	0	4.36[a]	7.9[a]	3.8[a]	96.3[f]	70.5[ef]	60.4[a]	-60.4	-153.1	1,704
District Practice	46	4.98[c]	9.6[d]	9.7[b]	89.1[d]	69.6[de]	83.5[d]	-37.4	-135.9	1,862
N Bank Conservative	68	5.24[d]	9.9[d]	10.0[b]	88.0[d]	69.1[cd]	90.6[e]	-22.5	-109.4	1,865
N Bank Optimum Profit	93	5.08[cd]	11.3[e]	17.2[cd]	81.1[b]	68.3[bc]	100.8[f]	-7.6	-75.7	1,792
N Bank Optimum Yield	118	4.99[c]	12.1[f]	18.4[d]	79.4[b]	67.8[ab]	105.3[g]	12.7	-36.8	1,760
YP BoM	144	5.01[c]	12.9[g]	22.6[e]	75.7[a]	67.3[a]	113.1[h]	30.7		
YP Decile 1	0	4.37[a]	8.1[ab]	4.8[a]	95.2[ef]	70.7[f]	62.3[a]	-62.1	-153.7	1,694
YP Decile 3	12	4.61[b]	8.4[bc]	6.2[a]	93.6[e]	70.2[ef]	67.5[b]	-55.5	-149.9	1,756
YP Decile 5	34	5.07[cd]	8.8[c]	5.8[a]	93.4[e]	70.6[ef]	77.7[c]	-43.8	-106.9	1,842
YP Decile 7	76	5.13[cd]	11.1[e]	14.1[c]	83.6[c]	68.2[ab]	99.0[f]	-23.1	-46.7	1,878
Malt 1 receival standards			**9 – 12**	**7.0**	**>70**	**>65**				
BAR 1 receival standards			**NA**	**15**	**NA**	**>62.5**				
P value		**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**			

**Partial gross margin shown is calculated as an average across 2022 and 2023 seasons (grain yield x grain price – urea applied (kg /ha) /1000*urea price). Assumed 2022 pricing: APW1 = $380/t, ASW1 = $370/t and urea = $1200/tonne. Assumed 2023 pricing: Malt 2= $330/t, BAR1 = $315/t, and urea = $500/tonne.*

Summary

By implementing a strategic and longer-term approach to N management, growers can reduce N deficiency and prevent the mining of soil organic N.

A high production year in 2022 saw high N treatments (YP BoM and Decile 7) yield exceptionally well, achieving grain yields above 6.5 t/ha. All treatments had a negative partial N balance showing that soils were mined of organic N, this was reduced in high N treatments (-23.6 to -25.5) as a larger amount of N was available from fertiliser application. In 2023, several treatments yielded well including N Bank Conservative, N Bank Optimum Profit, YP Decile 5 and YP Decile 7 in an average season (275 mm GSR). Although higher yields were gained, increased N application increased screenings (%) reducing overall grain quality and receival grade. Treatments with slightly lower N application (YP Decile 5 = 34 kg N/ha) also had protein < 9%.

When reviewing cumulative results for 2022 and 2023 seasons, it is evident that District Practice (45 kg N/ha) and N Bank Conservative have been the most profitable N management strategies to date, however they do have a high negative partial N balance > 100 kg N/ha, showing soil N balances are still getting mined. Nitrogen Bank Optimum Yield and YP Decile 7 are the closest treatments to a neutral N balance of -36.8 and -46.7, respectively. It is expected that over time, more neutral to positive N balances will be observed throughout this trial.

Acknowledgements

The authors would like to acknowledge GRDC investment 'RiskWi$e' (the National Risk Management Initiative) (HFG2303-001BGX)' for financially supporting this project.

Trial host, growers Rob and Dennis Dall, are gratefully acknowledged for their support.

In addition, we also thank collaborating research partners.

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Useful resources

Year 1 results of NGN Nitrogen banking trials in Southern region (2023):
https://www.farmtrials.com.au/trial/34426

Evaluating the importance of sowing rate, depth and time of sowing on emergence and yield – wheat and canola

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Key findings

- Despite observed differences in establishment between times of sowing (TOS) for wheat and canola, early sown crops resulted in higher yields due to improved water use efficiency (WUE) for biomass and grain production at Hart.
- With a dry subsoil there was no benefit of deep sowing canola or wheat. In general, similar yields were achieved from shallow and standard sowing depths.
- Increasing sowing rates to compensate for anticipated lower establishment did not increase yields of canola and wheat in most cases.
- Preliminary data from Hart suggests that soil moisture at sowing may be an indicator of plant establishment (%), with an approximate 2% reduction in establishment noticed for every 1% decline in soil moisture for both wheat and canola, regardless of TOS.

Background

An increase in the average farm size and variation in autumn rainfall means that it is becoming increasingly important for farmers to sow earlier in the season without significantly reducing production potential (Flohr et al. 2021). Despite recent cultivar development improving resilience to drought stress, significant risks remain when dry sowing. Poor establishment and uneven crop development associated with dry sowing, particularly into marginal soil moisture, may lead to significant issues such as poor weed control and a reduction in crop productivity.

Simulation modelling of the effects of dry sowing has suggested potential yield benefits of up to 35% compared to delayed sowing in wet conditions (Fletcher et. al. 2015). The greatest benefits were noticed at locations with lower annual rainfall, heavier soils and where there was a large cropping program (Fletcher et. al. 2015). By testing the impact of sowing depth on plant establishment in dry conditions, the risks associated with dry sowing can be quantified. In order to combat potential yield losses associated with poor establishment in dry conditions, the efficiency of increasing sowing rates was explored.

In 2023, trials were sown at three sites across the Mid-North of SA; Hart, Giles Corner and Bute. Trial objectives investigated techniques to improve the effectiveness of dry or early sowing by quantifying effects of sowing depth and rate on plant establishment, growth and yield under varying soil moisture conditions and times of sowing.

Methodology

Five replicated trials were sown across three sites; a calcareous clay-loam at Hart, dark grey vertosol at Giles Corner and a loam to clay-loam soil at Bute. At each site, crops were sown at three or four sowing dates between late April and early June, with three sowing depths and two or three plant densities. Sowing rates for Hart targeted 100%, 125% and 150% of the standard sowing rate. For canola, these rates were 45, 56 and 68 plants/m^2 respectively, and for wheat the rates were 180, 225 and 270 plants/m^2. Similar rates were targeted at Bute and Giles Corner sites (Table 1).

All trials were sown with a knife-point press wheel system. The same seeder was used at both Hart and Giles Corner sites, however very low bulk density of the vertosol soil at Giles Corner resulted in seeder wheels sinking. Tynes also caused variability in depth at Giles Corner due to soil clods. Clods are often present in high clay content soils and can range from 1-30 cm in size and caused a relatively large spread of seeding depth across the wheat trial. The canola trial at Giles Corner was sown on a bean stubble and had a slightly lower clay content compared to the wheat, which was reflected in more stable depths.

The number of plants/m^2 was measured to determine the effect of treatment on establishment. Soil moisture in the top 10 cm was recorded at sowing and monitored until final emergence of all TOS. Normalised Difference Vegetation Index (NDVI) was also measured frequently after emergence to track plant growth (higher NDVI values indicate less exposed soil and greener vegetation). Additionally, timing of key phenological events (e.g., flowering) were recorded for all plots to determine potential treatment effects on plant development. Data was analysed using REML spatial model (Regular Grid) in Genstat 23rd edition.

Table 1. Trial details for the three sites at Hart, Giles Corner and Bute.

Crop type	Hart	Giles Corner	Bute
Rockstar wheat	**TOS 1:** April 27 **TOS 2:** May 5 **TOS 3:** June 2 **Depth** 10 mm, 40 mm, > 50 mm **Sowing rates** 180, 225, 270 plants/m^2	**TOS 1:** April 21 **TOS 2:** May 5 **TOS 3:** June 2 **Depth** 20 mm, 35 mm 70 mm **Sowing rates** 180, 240 plants/m^2	**TOS 1:** April 21 **TOS 2:** May 5 **TOS 3:** May 19 **Depth** 35 mm, 46 mm, 56 mm **Sowing rates** 180, 270 plants/m^2
Enforcer CT canola	**TOS 1:** April 21 **TOS 2:** May 5 **TOS 3:** June 2 **TOS 4:** June 20 **Depth** 10 mm, 20 mm, 30 mm **Sowing rate** 45, 56, 68 plants/m^2	**TOS 1:** April 21 **TOS 2:** May 5 **TOS 3:** June 2 **Depth** 10 mm, 20 mm, 50 mm **Sowing rate** 50, 70 plants/m^2	

Results

Hart

Time of sowing

Plant establishment (%) differences were observed between all TOS at Hart in 2023 (Table 2).

Establishment results were consistent for wheat and canola, with sowing on June 2 (TOS 3) recording the highest establishment counts (plants/m^2). Crops sown on May 5 (TOS 2) into marginal soil moisture with little follow up rain recorded the lowest plant establishment.

Average plant establishment for canola (TOS 1 – 4) was 54%, 32%, 89% and 71% respectively. The corresponding values for wheat were 75%, 64% and 84%. This shows that plant establishment of canola was more sensitive to TOS and soil moisture at seeding than wheat. Although similar trends were noticed, canola had higher variation across TOS for plant establishment (%) than wheat (Figure 1). Establishment and soil moisture at seeding for both wheat and canola suggests a decrease of approximately 2% in establishment for every 1% decrease in soil moisture at sowing time at Hart, highlighting that soil moisture at sowing is a key indicator of plant establishment, regardless of time of sowing (Figure 1).

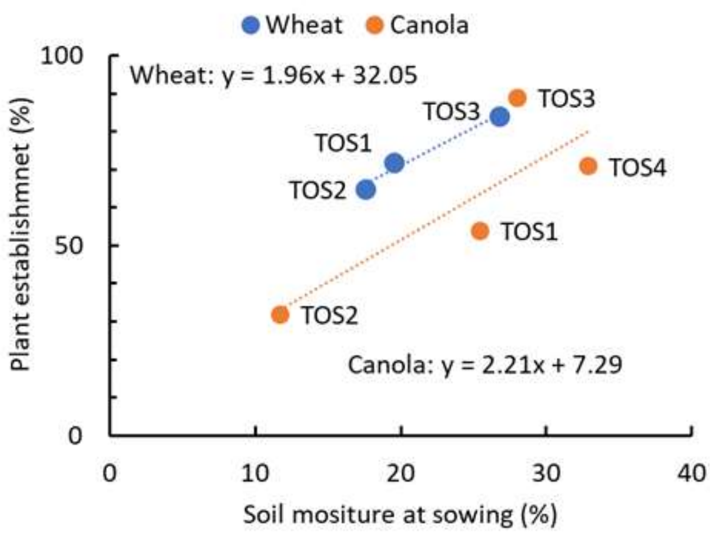

Figure 1. Plant establishment (%) and soil moisture (%) at sowing for each wheat and canola TOS.

Time of sowing had significant effects on grain yield in wheat and canola at Hart In 2023. In wheat and canola, the highest grain yields were achieved with the earliest sowing date (Figure 2 & 3).

TOS 1 shallow and standard sown wheat treatments performed best, averaging 4.3 and 4.4 t/ha respectively, while canola TOS 1 recorded the highest yield at 2.16 t/ha.

Table 2. Treatment effects on plant establishment (plants/m^2) and establishment % for both wheat and canola. Significant differences in plant establishment between treatments are indicated by different letters after plant count (plants/m^2). Shaded values indicate the treatments with the highest plant establishment.

Effects of sowing date			Effects of sowing depth			Effects of sowing rate		
CANOLA								
Sowing date	**Plants /m^2**	**Establishment %**	**Depth mm**	**Plants /m^2**	**Establishment %**	**Rate /m^2**	**Plants /m^2**	**Establishment %**
April 21 (TOS 1)	30^{b}	54	**10**	40^{b}	71	**45**	28^{a}	62
May 5 (TOS 2)	18^{a}	32	**20**	37^{b}	66	**56**	37^{b}	66
June 2 (TOS 3)	50^{d}	89	**30**	27^{a}	48	**68**	39^{b}	57
June 20 (TOS 4)	40^{c}	71						
WHEAT								
Sowing date	**Plants /m^2**	**Establishment %**	**Depth mm**	**Plants /m^2**	**Establishment %**	**Rate /m^2**	**Plants /m^2**	**Establishment %**
April 27 (TOS 1)	168^{b}	75	**10**	190^{b}	84	**180**	136^{a}	75
May 5 (TOS 2)	145^{a}	64	**40**	172^{b}	76	**225**	168^{b}	75
June 2 (TOS 3)	190^{c}	84	**55**	142^{a}	63	**270**	202^{c}	75

Photo: Hart regional intern, Kaidy Morgan, presenting at the 2023 Hart Field Day.

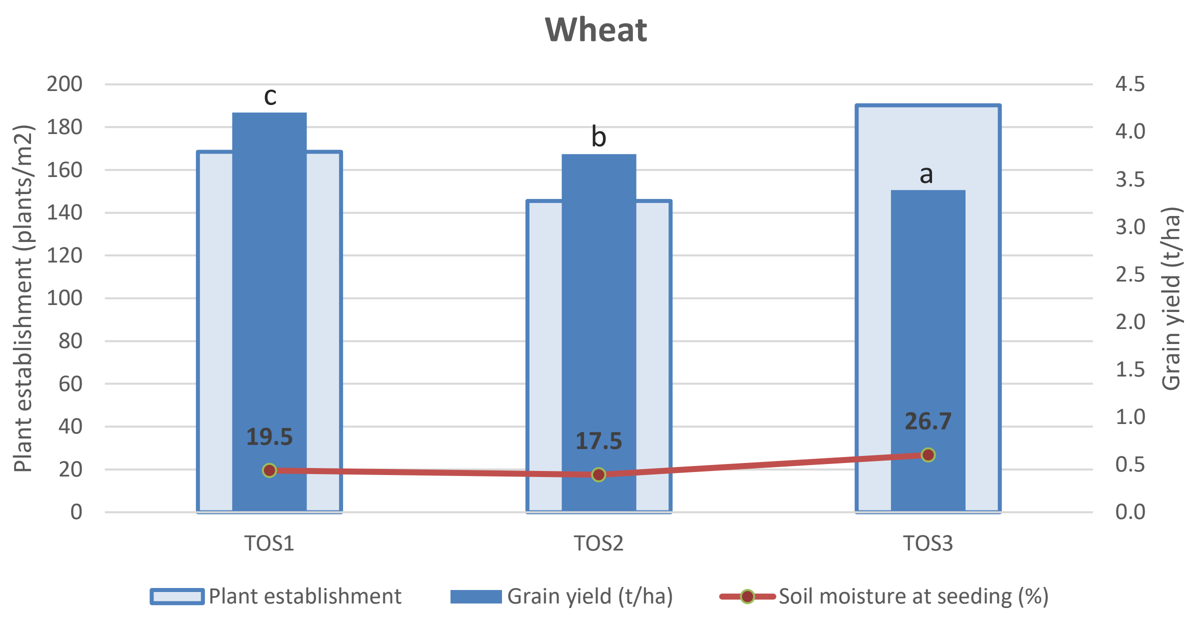

Figure 2. Plant establishment (plants/m^2), grain yield (t/ha) and soil moisture % (displayed) at seeding for wheat TOS at Hart. Time of sowing (TOS) with the same letter above yield are not significantly different.

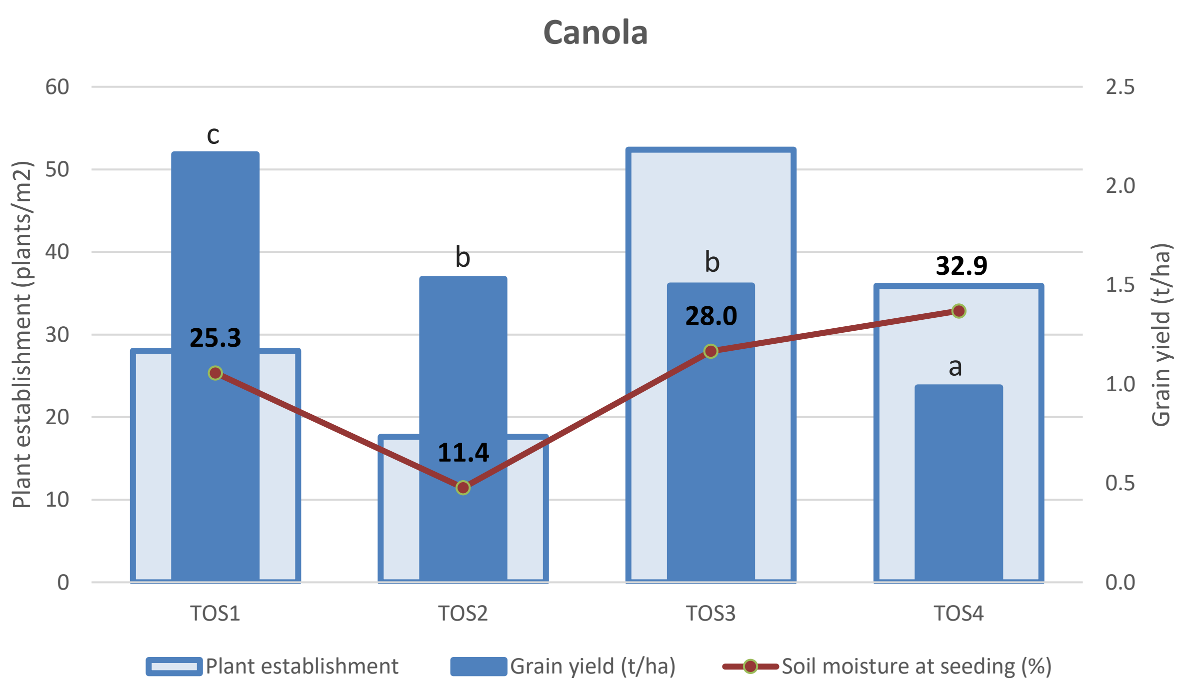

Figure 3. Plant establishment (plants/m2), grain yield (t/ha) and soil moisture % (displayed) at seeding for canola TOS at Hart. Time of sowing (TOS) with the same letter above yield are not significantly different.

Table 3. Time of sowing effect on 50% flowering date for canola at Hart.

TOS	50% flowering date
April 27	August 31
May 5	September 11
June 2	September 25

Sowing depth

Deep sowing reduced plant establishment for both wheat and canola, with shallow sown treatments achieving approximately 20% higher establishment than deep sowing for both crop types. (Table 2).

Sowing depth influenced wheat yield with shallow sown treatments yielding higher than standard and deep. Plant establishment for canola ranged from 27 - 40 plants/m^2 across three depths, however the ability of canola plants to branch out and fill space resulted in no yield differences despite variation in establishment (Figures 4a and 4b).

Sowing rate

Sowing at the standard rate resulted in the lowest plant density for both canola (target 45 plants/m^2) and wheat (target 180 plants /m^2), achieving 28 and 136 plants/m2, respectively (Table 2). Seeding rates targeting 125% and 150% increased plants/m^2, however there was no yield benefit from a higher plant density, either in canola or wheat. Despite differences in plants/m^2 for sowing rates, establishment % of both wheat and canola remained relatively consistent at 75% for wheat and 57% – 66% for canola.

These results suggest that increasing sowing rate above grower standard practice may improve crop establishment, but this does not result in grain yield increases.

Grain quality

Oil content for all canola treatments was high, with both TOS 2 and TOS 4 exceeding 42%, therefore receiving oil content premiums (Table 5). Although TOS 1 had the highest yield, it had a lower oil content than TOS 4 which yielded only 0.99 t/ha. This may indicate a relationship between oil content and grain yield in dry spring conditions. Previous studies have found a positive link between yield (t/ha) and oil content (%), however this was not evident in this trial (McBeath et. al., 2020).

Differences in wheat grain protein (%) were small and ranged from 10.1% to 10.7% (Table 6). Protein for TOS 1 and 2 was below the 10.5% minimum for APW1 receival standards, while TOS 3 recorded 10.7% protein and therefore met APW1 protein receival standards.

Test weight for all wheat treatments exceeded 76 kg/hL, ranging from 82.8 to 85.1 kg/hL, therefore meeting maximum receival standards (Table 6).

Limited rainfall in the second half of the growing season resulted in high screenings for all treatments, however a trend between TOS and screenings was noticed (Table 6). Earlier sown treatments that were better able to utilise early GSR had lower screenings than later sown treatments where season length and therefore access to early season rainfall was limited.

Flowering dates were impacted by TOS, with canola 50% flowering date ranging from August 11 to September 18 (Table 3). Wheat 50% flowering date ranged from August 31 to September 25 across three TOS (Table 4). The extended flowering window of TOS 1 wheat and canola prior to water and heat stress towards the end of the season is likely a contributing factor for higher yields and reduced screenings from early sown treatments.

Time of sowing had a larger effect on wheat protein, screenings and test weight than sowing depth and sowing rate, with TOS 1 performing best for both screenings and test weight (Table 6).

Table 4. Time of sowing effect on 50% flowering date for wheat at Hart.

TOS	50% flowering date
April 21	August 11
May 5	August 31
June 2	September 11
June 20	September 18

Table 5. Oil content in comparison to yield data for canola TOS trial at Hart in 2023. Significant differences in oil content and yield are indicated by different letters. Shaded values indicate the best performing TOS.

TOS	Oil content (%)	Yield (t/ha)
April 21	41.9^{b}	2.16^{c}
May 5	42.2^{b}	1.53^{b}
June 2	41.1^{a}	1.50^{b}
June 20	44.5^{c}	0.99^{a}

Table 6. Quality data for the wheat trial at Hart in 2023. Significant differences in quality between TOS, depth and sowing rate are indicated by different lettering. Shaded values indicate the best performing treatments.

Treatment	Grain Protein (%)	Screenings (%)	Test Weight (kg/hL)
April 27	10.4^{b}	4.6^{a}	85.1^{c}
May 5	10.1^{a}	6.4^{b}	84.1^{b}
June 2	10.7^{c}	7.4^{c}	82.8^{a}
10 mm	10.5^{b}	6.6^{b}	83.7^{a}
40 mm	10.3^{a}	5.8^{a}	84.2^{b}
55 mm	10.4^{ab}	5.9^{a}	84.1^{b}
180/m^2	10.4	6.3^{b}	83.9^{a}
225/m^2	10.4	6.12^{b}	84.0^{ab}
270/m^2	10.4	5.7^{a}	84.3^{b}

Figure 4 (a,b). These images show the differences in canola development between TOS at Hart. Figure 4a was taken in August, with Figure 4b taken one month later.

Results from other sites

At Giles Corner, canola establishment was lowest (approx. 60%) at the first two sowing dates (April 21 and May 5) compared to June 2 date (80%). However, despite the low establishment, yields were highest at the first two sowing times, while delaying sowing until June 2 resulted in a yield penalty of 20%. Increasing sowing rate had no effect on yield, except when canola was sown deep at 50 mm. At each time of sowing, varying sowing rates and depths to alter plant establishment had little to no effect on canola yield.

In the wheat trial, establishment with sowing on April 21 and May 5 was 55% and 45% respectively and increased to 87% when sown on June 2. These differences reflected the rainfall and soil moisture at sowing. Sowing at 70 mm reduced establishment to 44% compared to 80% with 20 mm sowing depth. The response to time of sowing depended on the sowing depth (Table 7). When sown at 20 mm, yields declined with later sowing, whereas when sown at 35 mm or 70 mm the lowest yields occurred with sowing on May 5, when the emergence was lowest due to dry conductions.

Yield reductions of delaying sowing from April 21 to May 5 were 5% at 20 mm, 9% at 35 mm and 16% at 70 mm. There was only a single significant fall of rain in the two weeks following sowing on May 5 and the shallow sowing may have been better able to utilise this moisture for faster germination and establishment. Compared to canola, wheat was more responsive to changes in plant density.

Established plant densities ranged from approximately 50 plants/m^2 up to 225 plants/m^2 and yield responded to increased plant density up to about 125 plants/m^2. Increasing the sowing rate by a third from 180 seeds/m^2 to 240 seeds/m^2 resulted in a 6% yield increase.

Table 7. The effects of sowing depth on the grain yield of wheat at Giles Corner. Grain yields followed by the same letter are not significantly different. Shaded values indicate the best performing treatments.

	Grain yield (t/ha)		
Sowing date	**Depth**		
	20 mm	**35 mm**	**70 mm**
April 21	6.99^{a}	6.47^{abc}	5.81^{d}
May 5	6.67^{ab}	5.90^{cd}	4.89^{e}
June 2	6.19^{bcd}	6.36^{a-d}	5.99^{bcd}

At Bute, the average wheat establishment was 74%, but ranged from 48% – 100% among individual treatments. Establishment varied little across TOS and the most consistent effect was a reduction in establishment with deep sowing and an increase in plants/m2 with a higher sowing rate.

Table 8. The effects of sowing date on the grain yield of wheat at Bute. Grain yields followed by the same letter are not significantly different. Shaded values indicate the best performing treatments.

Sowing date	Grain yield (t/ha)
April 21	1.83^{b}
May 5	2.26^{a}
May 19	1.89^{b}

Time of sowing and sowing depth affected wheat grain yield at Bute in 2023.

The highest yields were achieved at the second TOS with the first and last sowing dates producing equivalent yields (Table 8). A significant frost event on September 9 caused damage to wheat at Bute, with the April 21 sown treatment affected more than later sowing dates. Frost damage to the early sown crop may be a factor contributing to lower yields when compared to the May 5 sowing.

There was a small (5%) but significant reduction in grain yield when wheat was sown at 53 mm with no difference between 35 mm and 46 mm sowing depths. Despite a wide range in crop establishment among the treatments, there was no significant effect of sowing rate on yield.

Summary

Despite lower establishment from late-April to early-May sowing in wheat and canola at Hart and canola at Giles Corner, these sowing times produced the highest yields due to better utilisation of earlier growing season rainfall for biomass production. Wheat at Giles Corner and Bute was less sensitive to time of sowing in 2024.

Deep sowing showed no benefit in either plant establishment or yield. This is most likely because soil moisture was still low at the deepest sowing depth. Sowing deep into dry soil to promote germination and improve establishment may be a risky tactic.

Increasing sowing rates to compensate for anticipated reductions in crop establishment from sowing into dry soil did not improve yields in most experiments and using standard recommended sowing rates may be adequate.

Further investigation into the relationship between soil moisture at sowing, crop establishment and yield potential will be explored in future years of this project. This trial is in its first of two seasons and final results will be published following the conclusion of the project to provide a more comprehensive investigation across multiple seasons and sites.

Acknowledgements

We would like to acknowledge the SA Drought Hub and South Australian Grains Industry Trust (SAGIT) for their financial contributions to conduct these trials.

We would also like to thank our research partners, Mid North High Rainfall Zone (MNHRZ), Trengove Consulting and the various growers hosting these trials on-farm.

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Evaluating the importance of sowing rate and time of sowing on emergence and yield - lentils

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Key findings

- Despite all times of sowing (TOS) having high starting soil moisture (21 – 30%), TOS influenced lentil establishment (plants/m^2), with reduced plant numbers observed at later sowing times (TOS 3).
- Lentil grain yields achieved from late April (TOS 1) and early June (TOS 2) sowing dates were similar, however a 13% yield reduction was observed when sown in late June (TOS 3).
- Increasing seed densities above 120 plants/m^2 did not improve lentil grain yield (t/ha).

Background

In recent years, lentil production in Australia has increased significantly with over 525,000 tonnes produced in 2022 (Maphosa et.al., 2023). Although the cropping area of lentils is much smaller than wheat, it is a high value crop and remains a common inclusion within farming systems where climatic conditions are suitable. The Mid-North of South Australia is one of the largest lentil producing areas in the nation, meaning that constraints limiting production should be prioritised and explored (Maphosa et.al., 2023).

As a result of increased farm size and inconsistent autumn rainfall, many farmers are opting to sow dry, or earlier in the growing season to ensure seeding programs are completed in a timely manner, in some cases improving crop access to early moisture and early establishment prior to cold conditions (Flohr et al., 2021).

Recently, new research across the Mid-North of SA has investigated early sown pulses including lentil and faba bean as a frost avoidance tool, in addition to other agronomic opportunities aiming to improve pulse yield in areas outside high production zones (Roberts et.al., 2023). A lentil trial at Hart, SA in 2023 investigated techniques aiming to improve the effectiveness of dry or early sowing, complimenting current and past research. The effects of sowing rate on plant establishment, crop growth and grain yield under varying conditions and times of sowing (TOS) were explored.

Methodology

A split-plot trial was implemented at Hart to investigate the effect of time of sowing (TOS) and seeding rate on lentil establishment, crop biomass and grain yield. Lentil variety GIA Thunder was sown at three TOS, ranging from April 27 to June 20 (Table 1), at three sowing rates. Sowing rates targeted 120, 150 and 180 plants/m2, equivalent to 100%, 125% and 150% of the standard sowing density respectively.

Table 1. Site details for 2023 lentil TOS trial at Hart, SA.

Plot size	1.75 m X 10.0 m	**Fertiliser**	Seeding: MAP Zn 1% @ 80kg/ha
Seeding date (TOS 1)	April 27, 2023		
Seeding date (TOS 2)	June 2, 2023		
Seeding date (TOS 3)	June 20, 2023		
Harvest date	November 2, 2023		
Previous crop	Mulgara oaten hay		

The number of plants/m^2 was measured to determine the effect of TOS and sowing rate on establishment. Soil moisture in the top 10 cm was also recorded at sowing and monitored until emergence for each TOS was complete. Normalised Difference Vegetation Index (NDVI) was measured frequently after emergence to track plant growth (higher NDVI values indicate less exposed soil and greener vegetation). Additionally, the timing of key phenological events (e.g., flowering) was recorded for all plots to determine potential treatment effects on plant development. Data was analysed using a REML spatial model (Regular Grid), in Genstat 23rd edition.

Season and rainfall

The first TOS was on April 27, one week after a 20 mm rain event observed across a four-day period. At this time, soil moisture in the top 10 cm was 21.1%, the lowest of all three TOS (Figure 1). The TOS 1 lentils emerged early May after only 6 mm of follow up rain. Rainfall continued to be marginal until May 26 when the site received 16 mm rain. Soil moisture at TOS 2 (June 2) was 27.5%. The late sowing time (TOS 3) was completed on June 20, when soil moisture was 30.4%.

June recorded above average rainfall (68 mm), however the remaining months of the growing season received below average rainfall. Early TOS were able to utilise the significant June rainfall for growth, however TOS 3 was still emerging at this time.

Dry spring conditions resulted in a quick finish for all TOS. Despite the variation in sowing time, desiccation dates and harvest dates were the same for all three treatments. The dry finish to the season shortened the season length of late sown crops.

Results

Time of sowing

Lentil establishment (plants/m^2) was influenced by TOS and was highest at TOS 1 (April 27) and TOS 2 (June 2) (Table 2). When sowing was delayed until late June (TOS 3), lentil establishment was reduced by up to 14%, although soil moisture (%) was similar at each TOS (Figure 1). Average plant establishment for TOS 1 – 3 was 82%, 87% and 73% respectively.

Lentil grain yield was reduced from sowing late (TOS 3 on June 20), however there was no significant difference in yield between TOS 1 and 2 (Figure 1). Time of sowing 1 and 2 lentils were able to use earlier rainfall to establish, increasing their growing season length. Additionally, TOS 1 and TOS 2 lentils flowered up to two weeks earlier than TOS 3 (Figure 2) and had a longer period to set pods in cool conditions, prior to water and heat stress later in the season, likely contributing to higher grain yields.

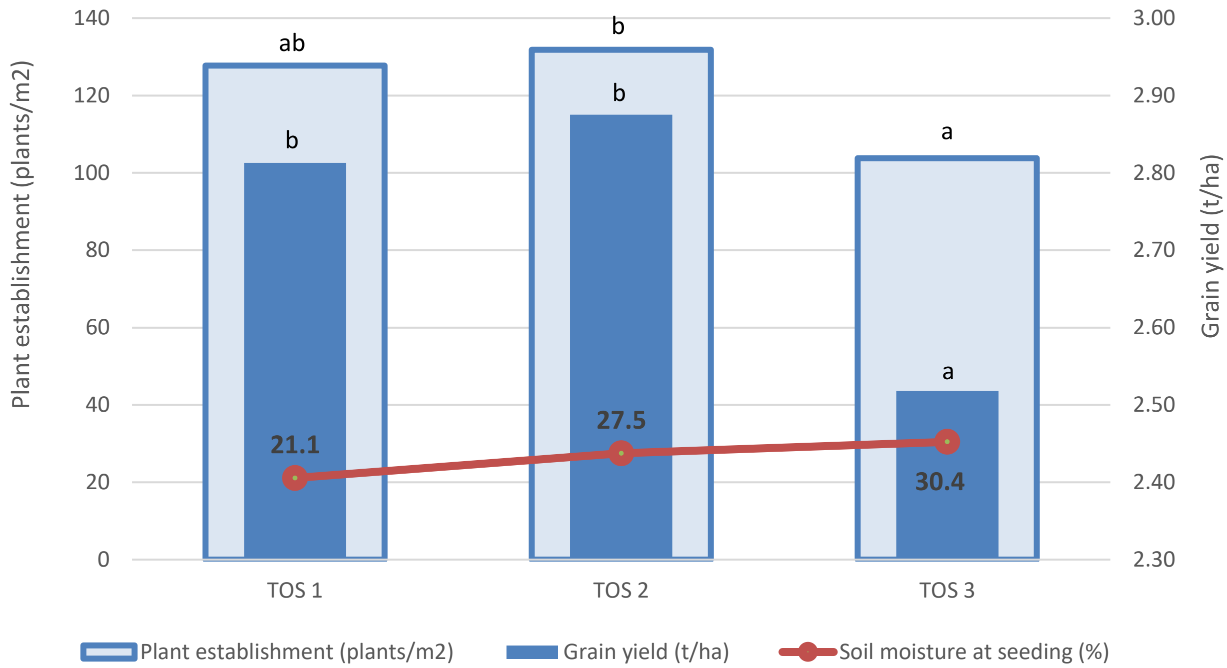

Figure 1. Plant establishment (plants/m²), grain yield (t/ha) and soil moisture at seeding (%) for lentil TOS at Hart. Plant establishment ( ) or grain yield ( ) for each TOS with the same letter are not significantly different.

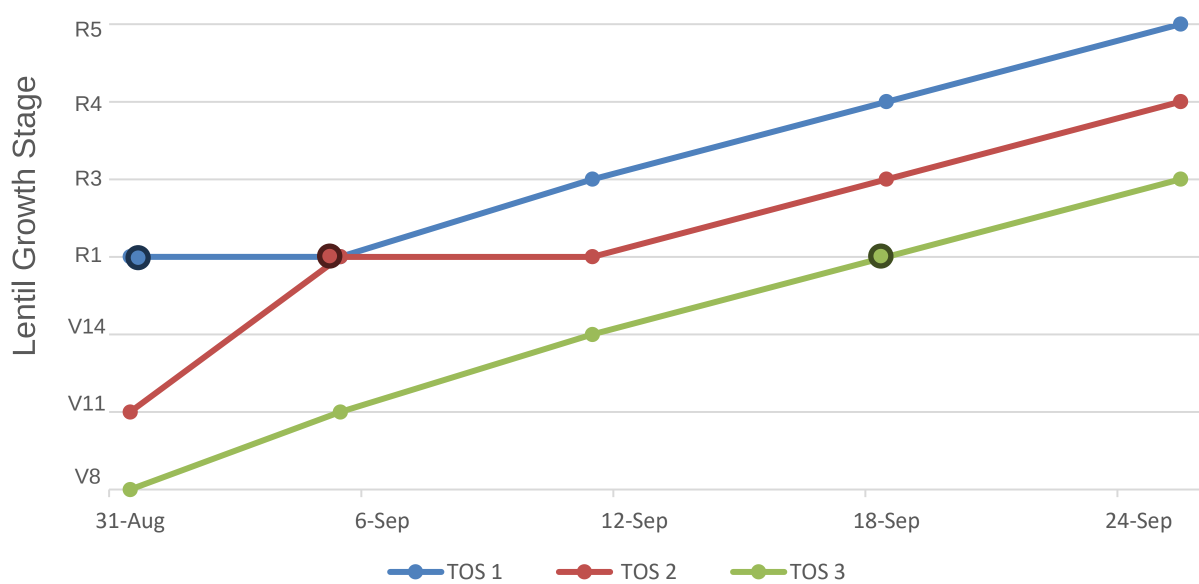

Figure 2. Growth stages for lentil TOS trial at Hart. Large, coloured circles indicate the date of first bloom for all TOS.

Yield reductions in lentil crops sown on June 20 likely resulted from a shortened growing season and exposure to higher temperatures and water stress during critical periods of growth later in the season. In similar 2023 trials with canola and wheat, delayed sowing resulted in improved emergence due to higher soil moisture levels (Morgan et. al., 2023), however later sowing dates showed a negative effect on lentil emergence. Recent studies conducted by NSW Department of Primary Industries found optimum sowing dates for lentils to be between late April and mid-May, with yield penalties noticed outside of this window (Maphosa et.al., 2023). The Hart trial found no yield difference between late April and early June sowing in 2023, however sowing on June 20 resulted in a 13% yield reduction when compared to earlier sowing.

Table 2. Treatment effects on plant establishment (plants/m²) for lentil. Significant differences in plant establishment between treatments are indicated by different letters after plant count (plants/m²). Shaded values indicate the treatments with the highest plant establishment.

Effects of sowing date			Effects of sowing rate		
Sowing date	**Plants/m²**	**Establishment %**	**Sowing rate**	**Plants/m²**	**Establishment %**
April 27 (TOS 1)	123ab	82	**120/m²**	101a	84
June 2 (TOS 2)	131b	87	**150/m²**	119b	79
June 20 (TOS 3)	109a	73	**180/m²**	143c	79

Sowing rate

The standard sowing rate targeting 120 plants/m² recorded the lowest plant establishment (Table 2), however this treatment had the highest level of crop establishment (84%) compared to sowing rates targeting 150 and 180 plants/m² (79% establishment). Sowing rates targeting 180 plants/m² recorded the highest plant density, achieving 143 plants/m². Despite sowing rate influencing plant establishment, this did not translate to differences in crop yield. Results at Hart in 2023 show that no yield benefits were observed by increasing lentil sowing rate above standard practice.

Grain weight

Grain weight of lentils was negatively affected by early sowing in 2023 (Table 3). This may result from an extended reproductive window, increasing crop branching and seed set, reducing individual seed weight due to a dry spring finish. Delayed maturity time of lentils sown on June 20 (Figure 2) likely reduced yield potential as a result of below average rainfall during reproductive stages, resulting in larger individual seed weight despite lower yields.

Table 3. Time of sowing effect on 1000 grain weight (g) for lentils. Significant differences in grain weight are indicated by different letters. Shaded value indicates best performing treatment.

TOS	1000 Grain weight (g)
April 27	32.5a
June 2	36.4b
June 20	38.3c

Summary

No yield gains were observed by increasing seeding rates of lentil above 120 plants/m² target (101 plants/m² achieved). Similar to wheat and canola, earlier sowing also resulted in higher yields for lentils, regardless of sowing rate (Morgan et, al., 2023). Delaying sowing until late June reduced both plant establishment and yield. Sowing in late April and early June provided opportunities for lentils to access early season rainfall for biomass production. Further investigation into the relationship between soil moisture at sowing, crop establishment and yield potential will be explored in future years of this project.

Acknowledgements

We would like to acknowledge the SA Drought Hub and South Australian Grains Industry Trust (SAGIT) for their financial contributions to conduct these trials.

We would also like to acknowledge our research partners Mid-North High Rainfall Zone (MNHRZ), Northern Sustainable Soils and Trengove Consulting.

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Photo: Lentil time of sowing trial at Hart, 2023.