2025

HART TRIAL RESULTS

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HART
SA's premier cropping field site

With thanks to the Hart team for photos
within this publication and on the front cover

Research supporters

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Hart 2026 calendar

HART FIELD DAY

September 15

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.

Getting The Crop In

March 11

8am – 12:30pm

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

Winter Walk

July 21

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 20

5pm followed by BBQ

Another informal opportunity to inspect the trial site, this time just prior to harvest. Key researchers and industry representatives are again present in the field to answer your questions.

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

Hart AGM

October 2026

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.

Craig Davis
Roger Kimber
Andre Sabeeney
Stuart Sherriff
Andrew Cootes
Kelvin Tiller
Rob & Dennis Dall
Daniel Neill
James Venning
Matt Dare
Rob & Glen Wandel
Trevor Day
Scott Weckert
Anthony Pfitzner
Glen Wilkinson
Justin, Bradley & Dennis Wundke
Simon Honner
Chris Preston
Peter Baker
Matt Williams
Richard Verner
James Henderson
Wade Hogg
Braydon Keech
Luke Dohnt
Mick Faulkner

We would also like to thank various organisations for the provision of seed and/or products that were trialed in the 2025 research program.

ADAMA
FMC
SARDI Clare
Advanta Seeds
Global Grain Genetics
Agriculture Victoria – field pea breeding program
InterGrain
SARDI Agronomy & Crop Sciences
AGF seeds
Agriculture Victoria – lentil breeding program
LongReach Plant Breeders
Seednet
Agspec
Nufarm
Pacific Seeds
Australian Grain Technologies
Nuseed
Agfert
Barenbrug
Pioneer Seeds
Syngenta
BASF
Plant Science Consulting
Bayer Crop Science
Corteva Agriscience
S & W Seeds
RAGT

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

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

We welcome Tom Gameau and Kenton Porker to this committee in 2026.

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

Glen Wilkinson (Snowtown) .... Chairman, Sponsorship
Ryan Wood (Clare) .... Vice-chairman, Sponsorship
Sandy Haskell (Clare) .... Executive Officer
Dale Callary (Clare)....................... Treasurer
Matt Dare (Marola)........................ Commercial Crop Manager, Sponsorship
Scott Weckert (Blyth) .... Sponsorship, Community Engagement
Andre Sabeeney (Clare) .... Board member
Rob Dall (Kybunga)....................... Board member
Stuart Sherriff (Clare).................... Board member
James Venning (Barunga Gap)..... Board member
Simonne Read (Adelaide)............. Board member
Zack Zweck (Kadina) .... Board member *(from October 2025)*
Simon Honner (Blyth).................... Board member *(to October 2025)*

Hart staff

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(maternity leave from October 2025)
Kaidy Morgan.........Research Lead
Mikaela Tiller..........Research Officer
Emily Newton.........Research Assistant

Sandy Haskell............ Executive Officer
Robyn Howard .... Finance Officer
Simone Lawry .... Admin Officer
Gabrielle Hall .... Media

Site Management

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SARDI, Agronomy Clare:
Patrick Thomas, John Nairn, Navneet Aggarwal, Dylan Bruce, Trevor Lock, Caitlin Parsons and Hugh Drum.

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Or find out more about us…


HART
SA's premier cropping field site
Hart Field Day
September 15, 2026
www.hartfieldsite.org.au

The Hart site

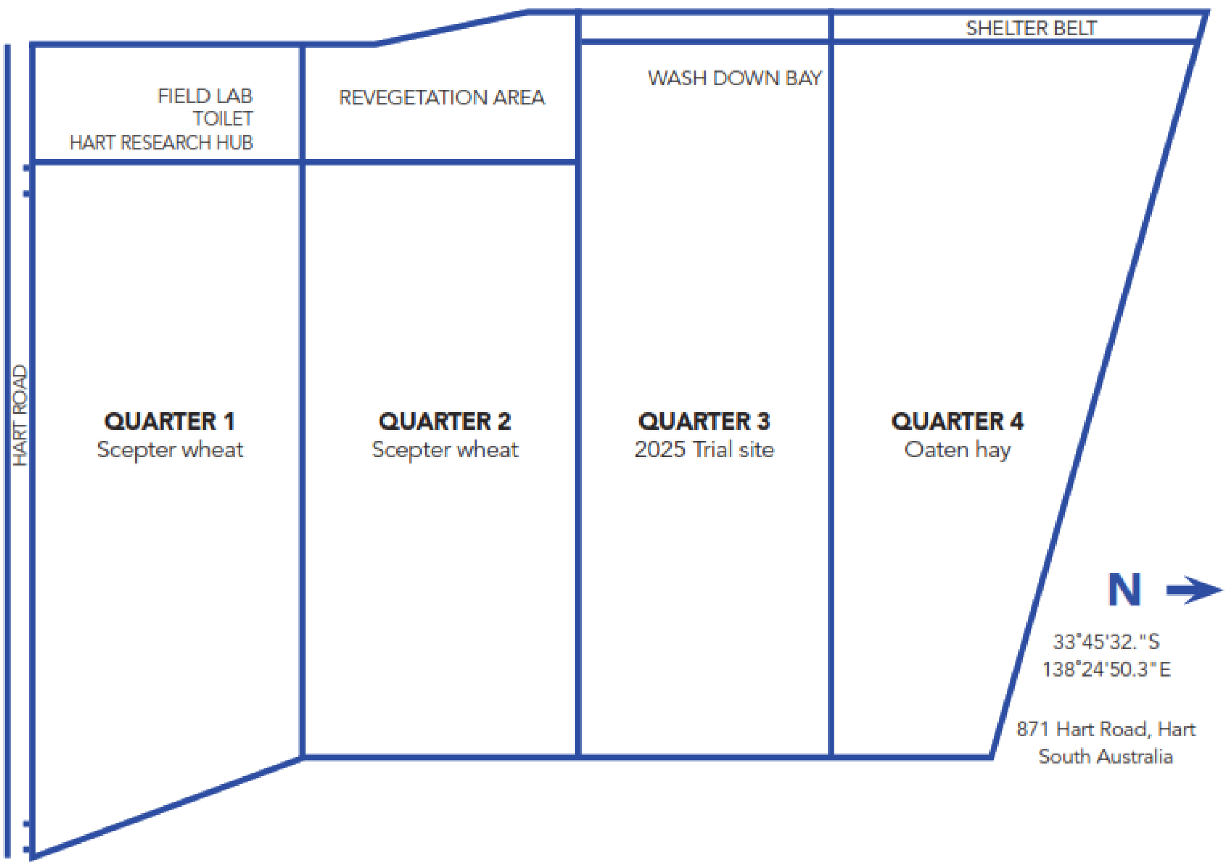
The Hart field site consists of 40 hectares owned by the group.

It is managed as four quarters (shown below) that are rotated each year.

In 2025, our trials were held in Quarter 3.

Quarters 1, 2 and 4 make up our commercial crop:

- Q1 & Q2 were sown to Scepter wheat
- Q4 was sown to oaten hay (to be cut in preparation for the following year's trial site).



Facilities at the Hart site also include:

- Field lab – for workspace and sample processing
- Hart Research Hub – for workshops, events & meetings
- Storage shed
- Washdown bay
- Toilet
- Fully fenced re-vegetation area

Hart commercial crop report

Matt Dare
Commercial Crop Manager, Hart Field-Site Group

The 2025 Hart commercial crop was sown with Scepter wheat in Quarters 1 & 2 of the site. Quarter 4 was sown with oats and cut for hay in preparation for 2026 trials.

The commercial crop was sown dry on May 7 at 90 kg/ha. Fertiliser (23:15) was applied at 70 kg/ha at sowing.

Emergence did not occur until mid-June, following 8.6 mm of rain on May 27.

Pre-emergent herbicide; 118 g/ha Sakura and 2.0 L/ha Triallate, was applied and incorporated by sowing.

Urea was applied at 50 kg/ha on July 24. A top up application was planned but a decision was made not to apply due to minimal stored soil moisture.

A broad leaf herbicide was applied on August 7; 25 ml/ha Priority, 440 ml/ha MCPA LVE570, 60 ml/ha Lontrel Advance and 250 ml/ha Epoxiconazole125 + 0.5% v/v uptake oil.

Harvest was completed on November 20 and resulted in a yield of 2 t/ha, graded at H2 quality.

The Hart Field-Site Group board would like to thank Matt Williams for sowing, spraying, spreading and harvesting the commercial crop this season. We also thank Rob Wandel for sowing, cutting and baling the oats and ADAMA for donating the Priority herbicide used.

Interpretation of statistical data

The results of replicated trials are presented as either the predicted or average (mean) for each of the replicates within a treatment. When analysing data statistically, authors generally use a REML spatial model (Hart method) or ANOVA, respectively.

Here, we describe the internal process used to analyse Hart data in GenStat.

A spatial analysis is conducted using restricted maximum likelihood (REML), incorporating row and column effects to account for spatial variation across the field. Treatment is fitted as a fixed effect. When $p \leq 0.05$, a multiple comparisons test is performed using the Bonferroni test at the 5% significance level. The Bonferroni critical difference (CD) is calculated using the average standard error of difference (SED) from the REML output and the appropriate Bonferroni-adjusted t critical value (calculated in excel using GenStat output). Differences between treatment means greater than the calculated Bonferroni CD are considered statistically significant. Not significant (NS) indicates that there is no difference between the treatments ($p>0.05$).

At a 95% confidence interval if $p \leq 0.05$, we are 95% confident that observed differences in a trial are due to the treatments, and not by chance (5%).

Interpretation of replicated results: an example only

Below we use an example of a replicated wheat variety trial containing both grain yield and quality data (Table 1). Statistically significant differences were found between varieties for both grain yield and protein. The Bonferroni CD for grain yield is 0.40, meaning 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 Calibre is significantly different to all other varieties as it is the only variety followed by a superscript (a). Scepter, Vixen and Ballista 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, variety performance was only significant from another if there was more than 0.9% difference in protein. In the example, Catapult 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 will be displayed as seen in the screenings column below (Table 1).

Table 1. Wheat variety grain yield, protein and screenings from a hypothetical example to illustrate interpretation of p-value and Bonferroni CD. Columns with shaded values show the best performing treatments.

Variety	**Grain yield (t/ha)**	**Protein (%)**	**Screenings (%)**
Catapult	3.50^{c}	10.3^{a}	0.2
Ballista	3.98^{b}	8.4^{b}	1.0
Vixen	3.75^{bc}	9.1^{b}	0.5
Scepter	4.05^{b}	8.9^{b}	0.9
Calibre	4.77^{a}	8.4^{b}	0.4
P-value	**0.002**	**<0.001**	**NS**
Bonferroni CD	**0.40**	**0.9**	

Disclaimer

While all due care has been taken in compiling the information within this manual the Hart Field-Site Group Inc and 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.

The 2025 season at Hart

Mikaela Tiller and Kaidy Morgan
Hart Field-Site Group

With Decile 2 (176 mm) growing season rainfall (GSR) in 2024 and below average summer rainfall that followed in the Mid North region, stored soil moisture was low coming into the 2025 growing season (Figure 1 and 2). The dry conditions and late start increased reliance on late season rainfall to increase yield potential for all crops across the Hart field site.

Seeding commenced at Hart on April 24, with dry sowing of pre-emergent herbicide time of sowing, profitable yield frontiers and dry seeding mitigation trials. Rainfall was minimal and sporadic with a total of 25.8 mm across March and April. The majority of trials were sown dry or delayed, with sowing continuing throughout mid-late May and June. Emergence was first observed on site in mid-June, with the last trial sown on July 7.

Above average rainfall for July (73.4 mm), including the largest rainfall event for the year (July 10 – 23.4 mm), favoured early crop development. No rainfall event during the growing season infiltrated to deeper than 40 cm (Figure 3). Below average rainfall was observed for the remainder of the year.

The dry finish to the season saw harvest commence on November 5 at Hart and conclude on December 5.

Hart received a total of 262.6 mm of annual rainfall (397 mm average) for 2025 and 223 mm of growing season rainfall (GSR) (288 mm average), equivalent to a Decile 3 (30th percentile) growing season when compared to the past 100 years.

Growing conditions across the Mid North in 2025 were variable, with some areas receiving timely rain, which increased yield potential. At Hart however, dry conditions resulted in below average yields and quality.

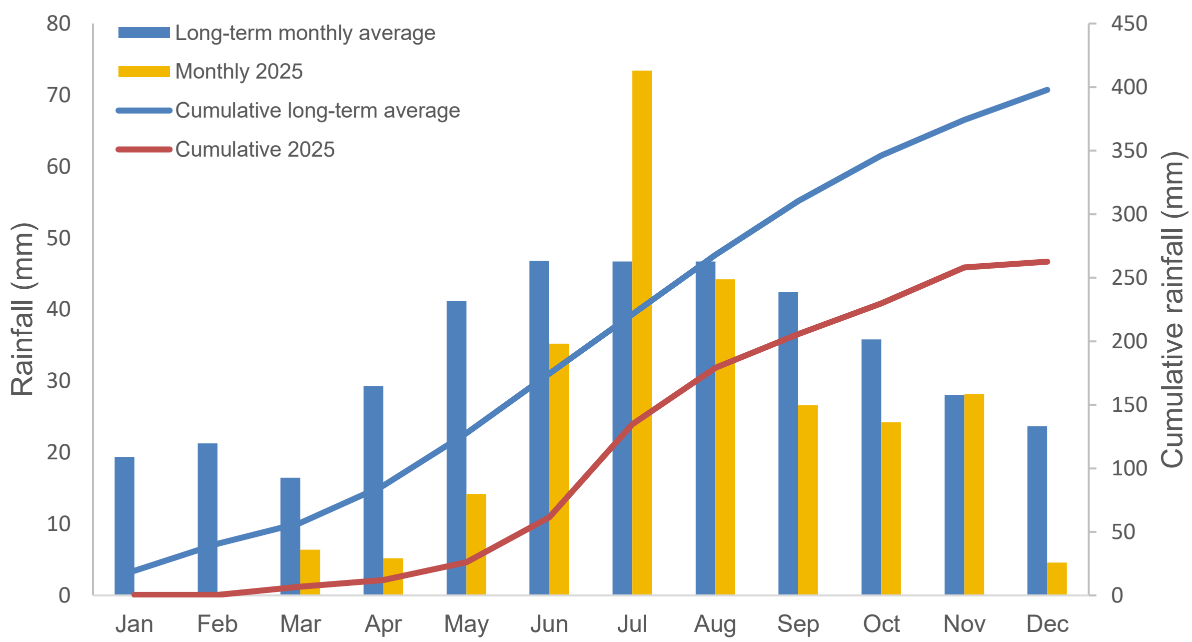


Figure 1. Hart rainfall graph for the 2025 season and long-term average. Lines are displayed to present cumulative rainfall for 2025 (red) and long-term average (blue). Sourced from Mid North Mesonet.

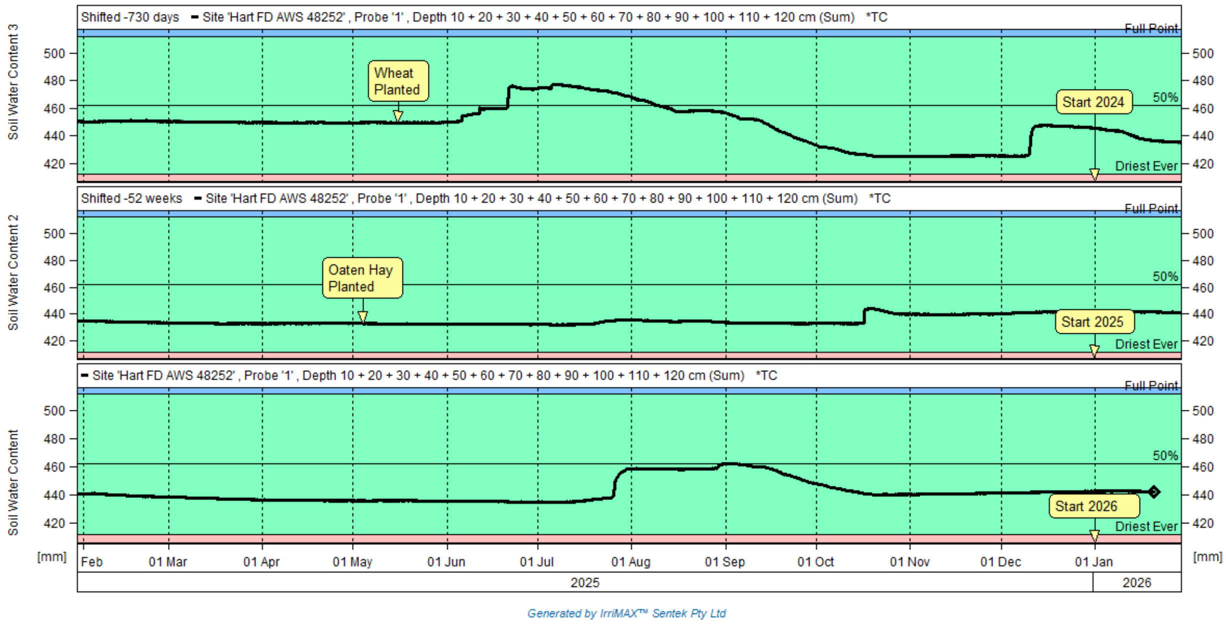


Figure 2. Soil moisture probe summed comparison (120 cm) for 2023 (top), 2024 (middle) and 2025 (bottom) at the Hart field site. Hart soil moisture data is free to view thanks to Agbyte. https://agbyte.com.au/clients/hart/.

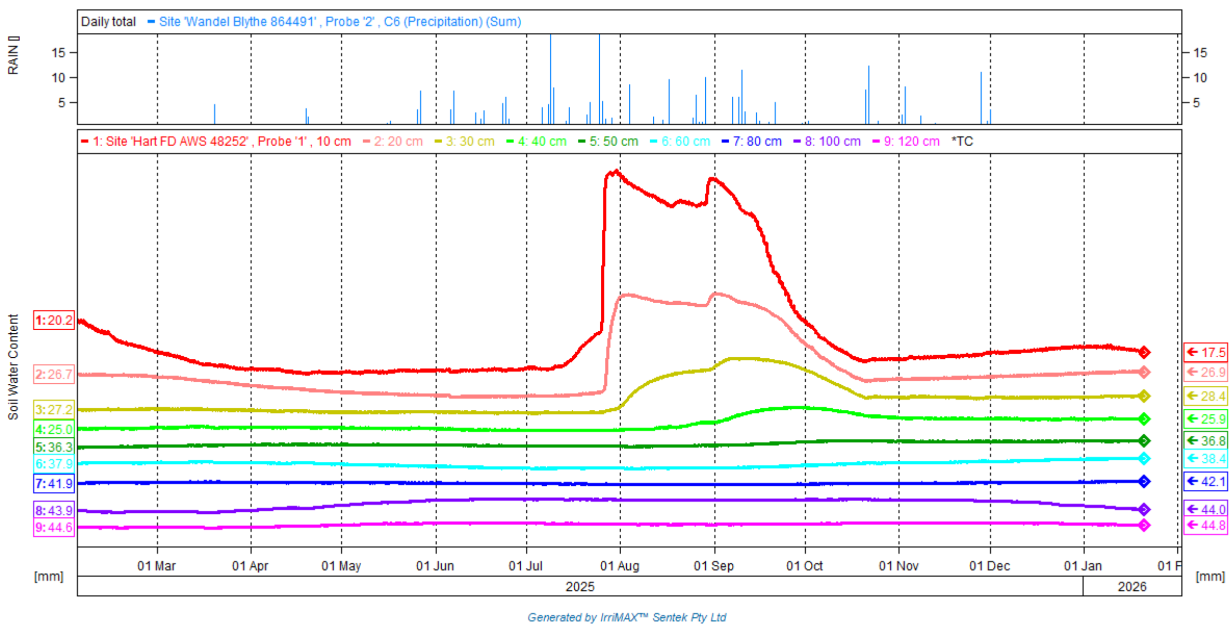


Figure 3. Soil moisture probe stacked sensor for the 2025 growing season at the Hart field site. Hart soil moisture data is free to view thanks to Agbyte: https://agbyte.com.au/clients/hart/

NEW Dale and Murray – main season wheats for SA

DALE PBR

AH Baker – Boy it yields!

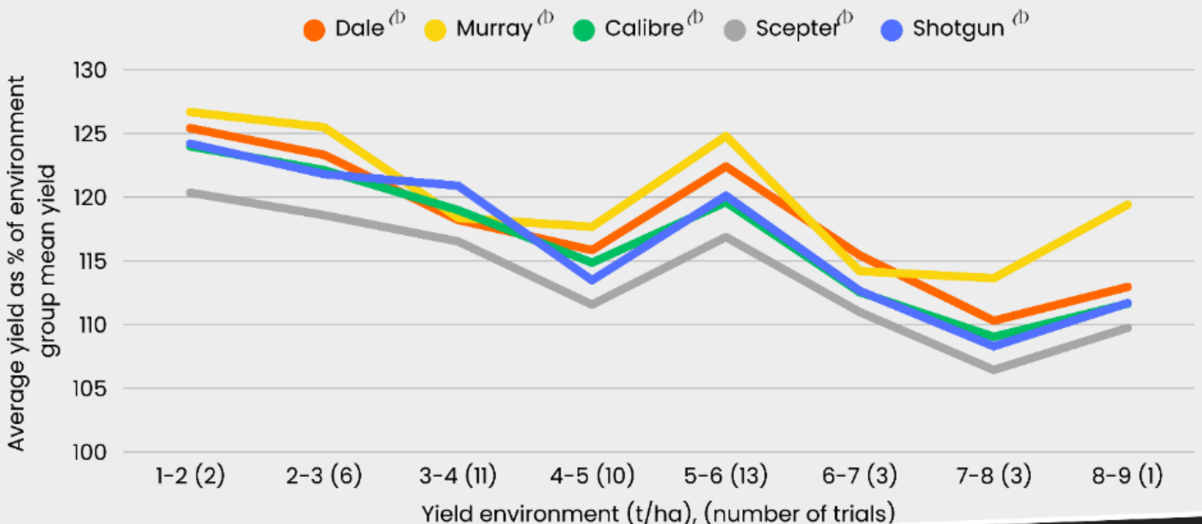
- High yielding AH wheat with consistent performance across SA
- Excellent grain package, particularly good test weight, similar to Scepter
- Good pre-harvest sprouting tolerance, an improvement over RockStar and Vixen
- Seed is available from InterGrain Seedclub Members for the 2026 season

MURRAY PBR

Steam ahead with high yield

- APW wheat suited to medium-high rainfall areas of South Australia
- Medium plant height with strong lodging tolerance
- Disease profile includes good stem rust (MRp) and CCN (MRMSp)
- Good grain quality including excellent test weight and good screenings in medium rainfall environments

2018-25 InterGrain South Australia MET yield performance, represented by yield environment as a % of site mean yield



For more information, contact your local Territory Manager
Darcy Moore
0448 138 944
dmoore@intergrain.com

intergrain.com
Scan the QR code for more information on Dale

Comparison of wheat varieties and summary of nitrogen decisions

Mikaela Tiller and Kaidy Morgan
Hart Field-Site Group

Key findings

- Wheat yields were below average at Hart in 2025, likely due to a combination of low stored soil water, a late season break, below average spring rainfall and Decile 3 (223 mm) growing season rainfall (GSR).
- APW variety Tomahawk CL Plus and AH variety Shotgun yielded highest, achieving 2.05 and 2.01 t/ha, respectively.
- LRPB Dual, AGT-Colt, and Durum varieties Patron, AGT-Banker and Bitalli, met the respective AH or Australian Premium Durum (ADR) receival standards of ≥13% protein, while all other varieties did not meet the threshold.
- Despite relatively low yields, all varieties exhibited test weights greater than the 76 kg/hL minimum receival standard for AH. Average screenings across the trial were 6.0%, however variety averages ranged from 2.9-20.5%.

Aim

To compare the performance of pre-commercial and newly released wheat (*Triticum aestivum*) varieties alongside current commercial variety options in the medium rainfall zone of South Australia.

Methodology

A trial was conducted at Hart, SA in 2025 to investigate wheat varietal performance (Table 1). The trial was established as a randomised complete block design with three replicates of 31 wheat varieties. New lines at Hart in 2025 included AGT-Colt (RAC3254), Packer, AGT-Rio, AGT-Banker (AGTD173) and coded lines; 19Q3H0393, 19G3H0499, IGW6955, L20158-141-15 and LPB21-34503.

The trial was managed through the application of pesticides to ensure an insect, weed and disease-free canopy. Grain yield (t/ha), protein (%), test weight (kg/hL) and screenings (%) were assessed post-harvest. The 2025 growing season was characterised by below average rainfall. The trial was not subject to stress from any other external or environmental factors. Trial data was analysed utilising REML spatial model (Regular Grid) in GenStat 24th Edition. Bonferroni critical difference values (Bonferroni CD) were calculated using average standard error of difference (SED) from the GenStat output and the relevant t critical value calculated in Excel. This number can be used to determine the difference required for a significant effect between treatments.

Table 1. Trial details for 2025 wheat variety comparison at Hart, SA.

Plot size	1.75 x 10 m	**Soil N**	120.4 kg N/ha
Location	Hart, SA	**Fertiliser**	Seeding: MAP (10:22) Zn 1% @ 80 kg/ha
Seeding date	May 23, 2025		
Harvest date	November 28, 2025		July 14: 30 kg N/ha (applied as Easy N)
Previous crop	Bale awnless wheat		
Growing season rainfall	Decile 3 (223 mm)		

Nitrogen discussion

High background N (120 kg N/ha) was observed at Hart in 2025 following Decile 2 GSR and a wheaten hay crop in 2024. In-season N decisions were influenced by considering existing soil organic N, Yield Prophet®, Bureau of Meteorology (BoM) climate outlooks and economics.

Despite being typically highly responsive to N at all decile ranges, high background N indicated that there were only small benefits of additional N, unless growing season rainfall exceeded Decile 3 (Figure 1, Graph A) (Hart Field-Site Group, 2025).

In July, the Bureau predicted 23% chance that July - September rainfall would fall into a Decile 1–4 category and 51% chance of falling into Decile 7–10. Combined, this information estimated that the likelihood of receiving above median (average) rainfall from July–September was 76% which is slightly higher than the long-term odds. To reduce the yield gap between YP_W and YP_N (Figure 1, Graph A), one in-season application of 30 kg N/ha was applied as a foliar application on July 14, taking a somewhat conservative approach considering the dry and late start to the season (Hart Field-Site Group, 2025).

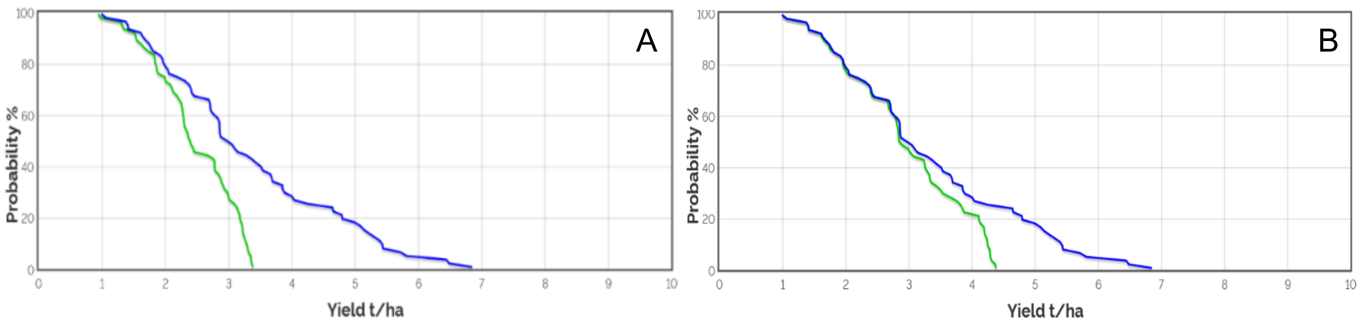


Figure 1: Yield Prophet® Output 1 (Graph A) for the Hart field site on July 10, 2025, for Scepter wheat with no in-crop N applied. This graph shows N responsiveness across all decile outcomes with PY_W ranging from 1-6.9 t/ha. Yield Prophet® Output 2 (Graph B) shows predicted yields after a total of 30kg N/ha was applied at one application timing.

Results and discussion

Grain yield

Minimal summer rain, Decile 2 (176 mm) GSR in 2024, and a late start to the season resulted in increased reliance on late season rainfall to improve crop yield. Above average rainfall for July favoured early crop development, however below average spring rainfall resulted in water stress during reproductive stages, impacting yield potential across all varieties.

Across the wheat variety trial, yields ranged from 1.45-2.05 t/ha with the average yield being 1.68 t/ha. Several Australian Hard (AH) and Australian Prime White (APW) varieties including Shotgun and Vixen performed significantly better than other varieties, however many were statistically equivalent (Table 2). APW variety Tomahawk CL Plus and AH variety Shotgun were the only varieties to achieve yields over 2 t/ha. Tomahawk CL Plus and Shotgun were also ranked in the top five yielding varieties within the National Variety Trial at Pinery and Spalding (GRDC, 2025).

Long-term yield data shows that Calibre, Scepter, Vixen, and Brumby continue to perform well, yielding above the trial average across multiple seasons at Hart (Table 3).

Durum varieties Bitalli, DBA Aurora and Patron yielded similarly (range 1.61-1.66 t/ha) and were ranked in the top five yielding Durum varieties within the National Variety Trial at Pinery (GRDC, 2025).

Grain quality

Wheat grain protein averaged 12.3% across the trial in 2025. Durum varieties Patron, AGT-Banker and Bitalli, and AH varieties LRPB Dual and AGT-Colt, achieved the respective Australian Premium Durum (ADR) or AH receival standards of ≥ 13% protein. All other varieties exhibited a protein between 11.1 and 12.9%, achieving APW1 for protein. Despite being a feed only variety, Wallaroo recorded 13.7% protein and was among the highest performing varieties for protein.

All varieties exhibited test weights greater than 76 kg/hL, with coded line L20158-141-15 achieving 84 kg/hL, which was significantly greater than all other varieties except Durum varieties Patron and AGT-Banker which were statistically equivalent. Screenings ranged from 2.9-20.5% across all varieties at Hart in 2025, with LRPB Anvil CL Plus achieving the lowest screenings of 2.9%, although many varieties were statistically similar. Several varieties exceeded 5% screenings and did not meet H1 or APW1 receival standards, with coded line 19Q3H0393 and Genie exceeding 10% screenings, therefore not meeting AGP1 or SFW1 receival standards.

Summary

Decile 3 (223 mm) GSR at Hart in 2025 affected yield potential and quality across the trial site. High test weight was observed across all varieties, with screenings highly variable dependent on variety. In general, protein was low across all varieties, with only six varieties achieving a protein higher than the 13% minimal receival standard for AH classification.

Photo. Wheat varieties trial at Hart, 2025.

Table 2. Wheat grain yield (t/ha) and quality results in Hart in 2025. Shaded values indicate significant best performing treatments. Any difference between two means greater than the Bonferroni critical difference value is significant at α = 0.05 after Bonferroni correction.

Quality	Variety	Grain yield t/ha	% of site average	Protein %	% of site average	Test weight kg/hL	% of site average	Screenings %	% of site average
AH	AGT-ColtⒹ (RAC3254)	1.61^{a-f}	96	13.4^{ijk}	109	81.3^{f-m}	101	6.3^{b-j}	100
	BoaⒹ	1.67^{b-i}	99	12.1^{c-f}	99	78.6^{a-d}	97	6.9^{e-j}	110
	CalibreⒹ	1.71^{c-i}	102	12.3^{efg}	100	79.8^{c-i}	99	4.0^{a-e}	64
	DaleⒹ	1.72^{d-i}	102	11.5^{abc}	94	81.5^{j-m}	101	4.8^{a-f}	77
	GenieⒹ	1.48^{abc}	88	12.6^{fgh}	103	80.1^{d-j}	99	20.5^{l}	329
	LRPB AnvilⒹ CL Plus	1.55^{a-d}	92	12.1^{c-g}	99	81.1^{f-l}	101	2.9^{a}	47
	LRPB DualⒹ	1.61^{a-f}	96	13.2^{hij}	107	81.3^{g-m}	101	3.5^{a-d}	56
	LRPB MajorⒹ	1.59^{a-e}	95	12.3^{efg}	100	81.1^{f-l}	101	8.3^{ijk}	133
	LRPB MatadorⒹ	1.79^{e-j}	107	12.0^{c-f}	98	80.6^{e-k}	100	9.0^{jk}	145
	PackerⒹ	1.57^{a-e}	94	11.9^{b-f}	97	81.7^{j-m}	101	4.1^{a-e}	66
	RockStarⒹ	1.72^{d-i}	102	11.8^{a-e}	96	80.1^{d-j}	99	5.8^{a-j}	94
	ScepterⒹ	1.71^{d-i}	102	11.8^{a-e}	96	82.1^{klm}	102	4.9^{a-g}	78
	ShotgunⒹ	2.01^{jk}	120	11.2^{ab}	92	81.3^{fh-m}	101	3.5^{a-d}	55
	VixenⒹ	1.87^{gi-k}	111	11.6^{a-d}	94	79.6^{b-g}	99	4.9^{a-h}	79
	H1 receival standard			**>13**		**>76**		**<5**	
APW	AGT-RioⒹ (V15019-88)	1.55^{a-d}	92	12.3^{d-g}	100	79.6^{b-f}	99	7.8^{f-j}	125
	BrumbyⒹ	1.76^{d-i}	104	11.6^{a-e}	95	80.1^{d-j}	99	6.1^{a-j}	98
	DozerⒹ CL Plus	1.53^{a-d}	91	12.3^{c-g}	100	78.1^{abc}	97	7.7^{f-j}	123
	MowhawkⒹ	1.83^{f-k}	109	12.9^{ghi}	105	82.1^{klm}	102	4.1^{a-e}	65
	MurrayⒹ	1.66^{a-h}	99	11.8^{a-e}	96	79.7^{b-h}	99	8.1^{gi-k}	130
	RGT PonsfordⒹ	1.45^{a}	86	12.3^{c-g}	100	77.1^{a}	96	6.1^{a-j}	97
	SoakerⒹ	1.57^{a-d}	93	11.8^{a-e}	96	81.3^{fgi-m}	101	9.0^{jk}	143
	Tomahawk CL PlusⒹ	2.05^{k}	122	11.1^{a}	91	81.9^{klm}	102	3.6^{a-e}	58
	APW1 receival standard			**>10.5**		**>76**		**<5**	
Feed	WallarooⒹ	1.46^{ab}	87	13.7^{jk}	112	82.5^{lm}	102	6.5^{d-j}	103
	SFW1 receival standard			**NA**		**>70**		**<10**	
ADR	AGT-BankerⒹ (AGTD173)	1.66^{a-i}	99	14.1^{k}	115	82.9^{mn}	103	4.6^{a-f}	74
	BitalliⒹ	1.61^{a-e}	96	14.1^{k}	115	81.7^{klm}	101	5.5^{a-i}	88
	PatronⒹ	1.62^{a-f}	97	13.6^{jk}	111	82.5^{lmn}	102	3.1^{ab}	50
Pending quality	19Q3H0393	1.74^{d-i}	103	11.7^{a-e}	96	78.1^{ab}	97	11.0^{k}	176
	19Q3H0499	1.87^{g-k}	111	11.2^{ab}	91	81.2^{f-m}	101	5.7^{a-i}	91
	IGW6955	1.81^{e-j}	108	11.8^{a-e}	96	79.8^{c-i}	99	5.8^{a-j}	94
	L20158-141-15	1.65^{ac-g}	98	12.1^{c-f}	99	84.0^{n}	104	3.2^{abc}	51
	LPB21-34503	1.62^{a-f}	97	12.0^{c-f}	98	79.0^{b-e}	98	6.3^{c-j}	101
	Site Average	**1.68**		**12.3**		**80.7**		**6.2**	
	P-value	**<0.001**		**<0.001**		**<0.001**		**<0.001**	
	Bonferroni CD	**0.23**		**0.73**		**1.69**		**3.25**	

Table 3. Long term wheat variety performance at Hart for 2021–2025 seasons (expressed as a % of trial average).

		% Trial average					Grain yield (t/ha)
Quality	**Variety**	**2021**	**2022**	**2023**	**2024**	**2025**	**2025**
AH	AGT-Coltⓓ (RAC3254)					96	1.61
	Ballistaⓓ	100	108	106	107		
	Boaⓓ				118	99	1.67
	Calibreⓓ	112	99	108	122	102	1.71
	Catapultⓓ	96	105	101	99		
	Daleⓓ (IGW6993)				104	102	1.72
	Devilⓓ		98				
	Genieⓓ			95	63	88	1.48
	Grenade CL Plusⓓ	93	97	96			
	Hammer CL Plusⓓ	108	89	94	116		
	Kingstonⓓ	101	95	106	85		
	LRPB Anvilⓓ CL Plus	105	81	87	115	92	1.55
	LRPB Dualⓓ			99	81	96	1.61
	LRPB Majorⓓ				51	95	1.59
	LRPB Matadorⓓ			104	122	107	1.79
	LRPB Scoutⓓ	86	101	98			
	Packerⓓ					94	1.57
	Reillyⓓ		102	102	127		
	RockStarⓓ	80	107	95	73	102	1.72
	Scepterⓓ	113	100	108	101	102	1.71
	Shotgunⓓ				103	120	2.01
	Sunblade CL Plusⓓ	105	111	114	64		
	Valiantⓓ CL Plus	93	100	95			
	Vixenⓓ	130	96	105	120	111	1.87
APW	AGT-Rioⓓ (V15019-88)					92	1.55
	Brumbyⓓ	115	104	104	103	104	1.76
	Chiefⓓ CL Plus	102	85	95			
	Cutlassⓓ	76					
	Dozerⓓ CL Plus			98	123	91	1.53
	Denisonⓓ	86	110	105			
	LRPB Trojanⓓ	93	105	106			
	Mowhawkⓓ			100	35	109	1.83
	Murrayⓓ (IGW6895)				135	99	1.66
	RGT Ponsfordⓓ					86	1.45
	Sheriff CL Plusⓓ	107	96	89	82		
	Soakerⓓ			99	121	93	1.57
	Tomahawk CL Plusⓓ				129	122	2.05
ASW	Razor CL Plusⓓ	111	94	98			
Feed	Wallarooⓓ					87	1.46
Pending quality	19Q3H0393					103	1.74
	19Q3H0499					111	1.87
	IGW6955					108	1.81
	L20158-141-15					98	1.65
	LPB20-8165				101		
	LPB21-34503					97	1.62
ADR	AGT-Bankerⓓ (AGTD173)					99	1.66
	Bitalliⓓ		106	97		96	1.61
	DBA Auroraⓓ		109	98			
	Patronⓓ		124	98		97	1.62
	Trial average yield t/ha	**2.03**	**4.40**	**3.75**	**0.55**	**1.68**	
	Sowing date	May 3	May 5	May 12	May 14	May 23	
	Apr-Oct rain (mm)	232	355	236	176	223	
	Annual rain (mm)	401	519	355	240	263	

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 Australian Grain Technologies (AGT), InterGrain, LongReach, RAGT and Seednet for providing seed to conduct this trial.

This trial is funded by HART

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Photo. Wheat trials at Hart in 2025.

Comparison of barley varieties

Mikaela Tiller and Kaidy Morgan
Hart Field-Site Group

Key findings

- The average barley yield observed at Hart in 2025 was 2.37 t/ha, with yields ranging from 1.44-2.92 t/ha.
- As a result of high protein, screenings and low-test weight, no varieties met Malt 1 receival standards at Hart in 2025. Coded line SCA25-Y006 (19Y027S-003) was the only variety to meet BAR1 receival standards across all quality metrics.
- All varieties exceeded the maximum receival standard threshold of 12% protein for Malt 1, with the site average being 15.8%. High protein likely resulted from high soil N and water stress during grain fill.
- Below average spring rainfall likely contributed to high screenings ranging from 11.5-40.1% and low retention ranging from 11.0-52.7% across all varieties.

Aim

To compare the performance of pre-commercial and newly released barley (*Hordeum vulgare*) varieties alongside current commercial variety options in the medium rainfall zone of South Australia**.**

Methodology

A trial was conducted at Hart, SA in 2025 to investigate barley varietal performance (Table 1). The trial was established as a randomised complete block design with three replicates of 29 barley varieties including new varietal lines AGT Bunyip IA (AGTB0530), RGT Atlantis (RP22054) and Rocket CL (IGB22023T), and coded lines: RGT-RP19034 and RGT-RP21011.

The trial was managed through the application of pesticides to ensure an insect, weed and disease-free canopy. Grain yield (t/ha), protein (%), test weight (kg/hL), screenings (%) and retention (%) were assessed post-harvest. The 2025 growing season was characterised by below average rainfall. The trial was not subject to stress from any other external or environmental factors. Trial data was analysed utilising REML spatial model (Regular Grid) in GenStat 24th Edition. Bonferroni critical difference values (Bonferroni CD) were calculated using average standard error of difference (SED) from the GenStat output and the relevant t critical value calculated in Excel. This number can be used to determine the difference required for a significant effect between treatments.

Table 1. Trial details for 2025 barley variety comparison at Hart, SA.

Plot size	1.75 x 10 m	**Soil N**	120.4 kg N/ha
Location	Hart, SA	**Fertiliser**	Seeding: MAP (10:22) Zn 1% @ 80 kg/ha
Seeding date	May 23, 2025		
Harvest date	November 7, 2025		July 14: 30 kg N/ha (applied as Easy N)
Previous crop	Bale awnless wheat		
Growing season rainfall	Decile 3 (223 mm)		

Results and discussion

Grain yield

Following Decile 2 rainfall in 2024 and a late start to the 2025 growing season, 73.4 mm of rain received in July favoured early crop development. Despite good early crop growth, below average rainfall was seen for the remainder of the 2025 growing season, limiting yield potential during reproductive stages. The average barley yield observed at Hart in 2025 was 2.37 t/ha, with yields ranging from 1.44-2.92 t/ha (Table 2). Many varieties yielded similarly, with a difference of 0.55 t/ha required for a significant yield result between varieties.

Feed varieties Beast, Combat and Granite CL produced 2.92, 2.82 and 2.75 t/ha respectively. Long-term yield data shows Beast and Combat continue to perform well, often yielding above the trial average across multiple seasons at Hart. Granite CL has performed well but requires further evaluation across a range of seasons (Table 3). Beast and Combat were also ranked in the top five yielding varieties within the National Variety Trial at Salter Springs and Crystal Brook (GRDC, 2025).

Malt varieties Compass, Laperouse and Maximus CL yielded 2.78, 2.80 and 2.72 t/ha respectively. Although long-term yield data for Malt varieties trialed at Hart remains variable, Compass, Laperouse and Maximus CL have performed well over the past two seasons, consistently yielding above the trial average (Table 3). Pending malt varieties AGT Bunyip IA (AGTB0530) and Rocket CL (IGB22023T) also performed well, achieving yields of 2.80 and 2.81 t/ha, respectively.

Grain quality

All barley varieties recorded protein that exceeded the maximum receival standard threshold of 12% for Malt 1. Nitrogen availability and water stress leading into grain fill were likely contributing factors to high protein in 2025, potentially causing a “haying off” effect through the utilisation of moisture and nutrient resources early, prematurely ending grain fill (Kirkegaard et al, 2001).

RGT Asteroid (RP14033) and RGT-RP19034 were the only varieties to exceed the 65 kg/hL test weight minimum for Malt 1, however achieved feed only for all other quality parameters. Many varieties did not meet the receival standards for BAR1, exhibiting a test weight of less than 62.5 kg/hL. Combat achieved the lowest test weight at 57.8 kg/hL.

All varieties exhibited high screenings ranging from 11.5-40.1% and low retention ranging from 11.0-52.7%. Beast, SCA25-Y006 (19Y027S-003) and Rocket CL (IGB22023T) were the only varieties where screenings did not exceed the maximum threshold of 15% for BAR1 receival standards. As expected, when considering screenings results, Beast, SCA25-Y006 (19Y027S-003) and Rocket CL (IGB22023T) also exhibited the highest retention at 52.7, 50.5 and 49.8%, respectively.

Summary

A Decile 3 (223 mm) GSR at Hart in 2025 affected yield and quality across the trial site. The average barley yield observed was 2.37 t/ha with yield ranging from 1.44-2.92 t/ha. As a result of high protein and screenings and low-test weight, no varieties met Malt 1 receival standards. Coded line SCA25-Y006 was the only variety to meet BAR1 receival standards across all quality metrics.

Table 2. Barley grain yield (t/ha) and quality results at Hart in 2025. Shaded values in each column indicate best performing treatments. Any difference between two means greater than the Bonferroni critical difference value is significant at α = 0.05 after Bonferroni correction.

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
Malt	Commodusⓓ CL	2.51^{e-h}	106	15.0^{a-d}	95	63.5^{bcd}	103	19.7^{a-d}	79	34.5^{a-f}	120
	Compassⓓ	2.79^{gh}	117	15.0^{abc}	95	63.1^{bcd}	102	15.5^{ab}	62	35.9^{b-f}	125
	Cyclopsⓓ	2.59^{fgh}	109	15.3^{a-e}	97	59.2^{ab}	96	25.3^{a-f}	102	24.0^{ab}	83
	Laperouseⓓ	2.80^{gh}	118	15.2^{a-d}	96	64.3^{cd}	104	19.0^{abc}	77	30.2^{a-f}	105
	Maximusⓓ CL	2.72^{gh}	115	15.7^{a-e}	100	63.0^{bcd}	102	24.0^{a-f}	97	29.3^{a-e}	101
	Neoⓓ CL	1.92^{a-e}	81	15.1^{a-d}	96	58.2^{ab}	94	40.1^{df}	162	20.2^{ab}	70
	RGT Planetⓓ	1.86^{a-d}	78	17.4^{efg}	110	61.7^{a-d}	100	26.4^{a-f}	106	18.5^{ab}	64
	Spartacus CLⓓ	2.51^{fgh}	106	16.3^{b-f}	103	61.8^{a-d}	100	35.3^{c-f}	142	18.4^{ab}	64
Malt 1 Receival Standards				**9-12**		**>65**		**<7**		**>70**	
Feed	Beastⓓ	2.92^{h}	123	15.3^{a-d}	97	61.7^{a-d}	100	11.6^{a}	47	52.7^{cf}	183
	Bigfoot CLⓓ	2.68^{gh}	113	15.7^{a-e}	100	60.6^{abc}	98	21.0^{a-d}	85	32.5^{a-f}	113
	Combatⓓ	2.82^{h}	119	13.9^{a}	88	57.8^{a}	93	21.2^{a-d}	85	29.0^{a-d}	100
	Graniteⓓ CL	2.75^{gh}	116	15.0^{ab}	93	59.1^{ab}	96	33.0^{b-f}	133	18.5^{ab}	64
	Minotaurⓓ	2.41^{d-h}	102	15.3^{a-d}	97	63.3^{bcd}	102	30.1^{a-f}	121	18.9^{ab}	66
	PegasusAXⓓ	2.27^{c-g}	96	17.1^{d-g}	109	62.5^{bcd}	101	34.1^{b-f}	137	11.1^{a}	38
	Spinnakerⓓ	2.08^{b-f}	88	15.7^{a-e}	100	59.5^{ab}	96	36.9^{def}	149	18.0^{ab}	62
BAR1 Receival Standards				**NA**		**>62.5**		**<15**		**NA**	
Pending malt accreditation	AGT Bunyip IAⓓ (AGTB0530)	2.80^{gh}	118	14.9^{abc}	94	64.2^{cd}	104	19.8^{a-d}	80	28.9^{abc}	100
	RGT Atlantisⓓ (RP22054)	1.49^{a}	63	17.8^{fg}	113	62.3^{a-d}	101	29.0^{a-f}	117	29.6^{a-e}	103
	Rocketⓓ CL (IGB22023T)	2.81^{gh}	119	14.3^{ab}	90	59.6^{ab}	96	14.5^{a}	58	49.8^{c-f}	173
	Titan AXⓓ	2.52^{fgh}	106	15.1^{a-d}	96	62.7^{bcd}	101	22.4^{a-f}	90	34.4^{b-f}	119
Under evaluation	RGT Asteroid (RP14033)	1.44^{a}	61	18.9^{g}	120	65.2^{cd}	105	21.8^{a-e}	88	36.7^{b-f}	127
	RGT-RP19034	1.70^{abc}	71	18.0^{fg}	113	66.1^{d}	107	29.0^{a-f}	117	24.7^{ab}	86
	RGT-RP21011	1.68^{ab}	71	17.0^{c-g}	108	61.7^{a-d}	100	29.3^{a-f}	118	17.3^{ab}	60
	SCA25-Y006 19Y027S-003	2.53^{fgh}	107	14.2^{ab}	90	63.1^{bcd}	102	11.8^{a}	48	50.5^{cef}	175
	Site average	**2.37**		**15.8**		**61.9**		**24.8**		**28.9**	
	P-value	**<0.001**		**<0.001**		**<0.001**		**<0.001**		**<0.001**	
	Bonferroni CD	**0.55**		**2.02**		**4.88**		**19.18**		**22.81**	

Table 3. Long-term barley variety performance at Hart for 2021–2025 seasons (expressed as a % of trial average).

Quality	Variety	2021	2022	2023	2024	2025	Grain yield (t/ha) 2025
		% Trial average					
Malt	CommodusⓅ CL	100	95	97	78	106	2.51
	CompassⓅ	112	90	101	113	117	2.78
	CyclopsⓅ	103	101	96	89	109	2.59
	LaperouseⓅ	112	87	94	102	118	2.80
	LeabrookⓅ	107	96	98			
	MaximusⓅ CL	96	91	93	188	115	2.72
	NeoⓅ CL				70	81	1.92
	RGT PlanetⓅ	86	119	100	80	78	1.86
	Spartacus CLⓅ	83	91	94	136	106	2.51
	ZenaⓅ CL		117	98			
Feed	BeastⓅ	111	96	105	129	123	2.92
	Bigfoot CLⓅ				105	113	2.68
	CombatⓅ		112	110	139	119	2.82
	FathomⓅ	107	101				
	GraniteⓅ CL				129	116	2.75
	MinotaurⓅ	101	107	106	129	102	2.41
	PegasusAXⓅ				115	96	2.27
	RosalindⓅ	105	101	102			
	SpinnakerⓅ			98	58	88	2.08
Pending malt accreditation	AGT Bunyip IAⓅ (AGTB0530)					118	2.80
	RGT AtlantisⓅ (RP22054)					63	1.49
	RocketⓅ CL (IGB22023T)					119	2.81
	Titan AXⓅ		96	102	82	106	2.52
Under evaluation	AGTB0532				99		
	RGT Asteroid (RP14033)				47	61	1.44
	RGT Orbiter				47		
	RGT-RP19034					71	1.70
	RGT-RP21011					71	1.68
	SCA25-Y006 19Y027S-003				63	107	2.53
	Trial average yield (t/ha)	**2.61**	**5.99**	**4.66**	**0.69**	**2.37**	
	Sowing date	May 3	May 5	May 12	May 13	May 23	
	April-Oct (mm)	232	355	236	176	223	
	Annual rainfall (mm)	401	519	355	240	263	

Acknowledgements

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This trial is funded by HART SA's premier cropping field site

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Photo. Barley varieties session at the 2025 Hart Field Day.

Comparison of lentil and field pea varieties

Mikaela Tiller and Kaidy Morgan
Hart Field-Site Group

Key findings

- Sowing outside of the preferred lentil and field pea sowing window, followed by below average spring rainfall, resulted in water stress during reproductive stages, impacting yield across both crop types.
- Lentil yields ranged from 0.63-1.60 t/ha with PBA Highland XT achieving the highest yield.
- All field pea varieties yielded similarly at Hart in 2025, averaging 1.08 t/ha.
- National Variety Trial (NVT) yield averages at Riverton for lentils were 3.06 t/ha and field peas were 2.67 t/ha, significantly greater than what was achieved at Hart.

Aim

To compare the performance of pre-commercial and newly released lentil (*Lens culinaris*) and field pea (*Pisum sativum*) varieties alongside current commercial variety options in the medium rainfall zone of South Australia**.**

Methodology

Two trials were established at Hart, SA in 2025 to investigate lentil and field pea varietal performance (Table 1). The trials were randomised complete block with three replicates. Twelve lentil varieties including two pre-commercial lines ALB2422 and ALB2424 and 14 field pea varieties including pre-commercial lines APB2401, APB2403 and APB2501 were evaluated.

The trial was managed through the application of pesticides to ensure an insect, weed and disease-free canopy. Lentil yields were variable across the 2025 trial site due to the combined effect of soil constraints, pre-emergent herbicide damage and dry conditions (Decile 3, 223 mm). The residual standard deviation (residual SD), representing unexplained variation between plots, was 0.34 t/ha. This should be considered when interpreting grain yield results provided.

Trial data was analysed utilising REML spatial model (Regular Grid) in GenStat 24th Edition. Bonferroni critical difference values (Bonferroni CD) were calculated using average standard error of difference (SED) from the GenStat output and the relevant t critical value calculated in Excel. This number can be used to determine the difference required for a significant effect between treatments.

Table 1. Trial details for 2025 lentil and field pea variety comparison at Hart, SA.

Plot size	1.75 x 10 m	**Soil N**	120.4 kg N/ha
Location	Hart, SA	**Fertiliser**	Seeding: MAP (10:22) Zn 1% @ 80 kg/ha
Seeding date	June 20, 2025		
Harvest date	November 5, 2025		
Previous crop	Bale awnless wheat (hay)		
Growing season rainfall	Decile 3 (223 mm)		

Results and discussion

Lentil grain yield

At Hart in 2025 lentil yields ranged from 0.63-1.60 t/ha with the average yield being 1.02 t/ha. Late emergence, followed by below average spring rainfall resulted in water stress during reproductive stages, impacting yield across all varieties. PBA Highland XT yielded higher than all varieties, other than PBA Hallmark XT and GIA Thunder which were statistically equivalent (Table 2).

Long-term yield data shows that GIA Thunder and PBA Jumbo 2 continue to perform well, yielding above the trial average across multiple seasons at Hart (Table 6). In 2025, GIA Thunder was ranked in the top three yielding varieties within the National Variety Trial at Owen and Riverton (National Variety Trials, 2025). PBA Hallmark XT and PBA Highland XT also continue to perform well, exceeding the average site yield the last two years by at least 30% (Table 3).

Growing conditions in 2025 across the Mid North were variable, with some areas receiving timely rain which increased yield potential. This was evident in the varying results in the National Variety Trials (NVT), where average lentil yield at Riverton was 3.06 t/ha, Crystal Brook was 2.21 t/ha and Owen was 1.35 t/ha, all greater than the average yield at Hart (1.02 t/ha) (GRDC, 2025).

Table 2. Grain yield (t/ha) and maturity characteristics (= unknown maturity) of lentil varieties at Hart in 2025. Lentil maturity characteristics sourced from 2026 South Australian Crop Sowing Guide. Shaded values in each column indicate best performing treatments. Any difference between two means greater than the Bonferroni critical difference value is significant at α = 0.05 after Bonferroni correction.*

Lentil variety	Maturity	Grain yield (t/ha)
GIA MetroФ	Mid-late	0.63^{a}
GIA SireФ	Mid	0.64^{a}
ALB Dane Ф (ALB2321)	Mid-late	0.80^{ab}
ALB2424	*	0.91^{abc}
ALB2422	*	0.94^{abc}
ALB TerrierФ	Mid	1.00^{abc}
GIA ColomboФ (GIA2301L)	Mid	1.04^{abc}
PBA Jumbo2Ф	Mid	1.04^{abc}
GIA LightningФ	Mid	1.05^{abc}
GIA ThunderФ	Mid	1.29^{bcd}
PBA Hallmark XTФ	Mid	1.31^{cd}
PBA Highland XTФ	Early-mid	1.59^{d}
Average grain yield (t/ha)		**1.02**
P-value (≤0.05)		**<0.001**
Bonferroni CD		**0.52**

Table 3. Long-term yield data for lentil varieties at Hart 2021-2025.

% of trial average						Grain yield (t/ha)
Variety	**2021**	**2022**	**2023**	**2024**	**2025**	**2025**
ALB2422					92	0.94
ALB2424					89	0.91
ALB Daneᶲ (ALB2321)					79	0.80
ALB Terrierᶲ		111	111	52	98	1.00
GIA Colomboᶲ (GIA2301L)				89	102	1.04
GIA2302L				111		
GIA2303L				89		
GIA Leaderᶲ	103	105	99	52		
GIA Lightningᶲ		105	105	111	103	1.05
GIA Metroᶲ		80	81	74	62	0.63
GIA Sireᶲ		80	92	66	62	0.64
GIA Thunderᶲ	113	123	110	118	126	1.29
PBA Blitz		90	100			
PBA Boltᶲ		90	104			
PBA Hallmark XTᶲ	97	99	97	148	129	1.31
PBA Highland XTᶲ	99	104	100	148	156	1.59
PBA Hurricane XTᶲ	95	105	93	118		
PBA Jumbo2ᶲ	110	108	105	108	102	1.04
PBA Kelpieᶲ XT	82	94	103	118		
Average grain yield (t/ha)	**1.62**	**1.30**	**5.42**	**0.14**	**1.02**	
Sowing date	May 18	May 18	June 9	June 5	June 20	
April - Oct (mm)	355	232	355	176	223	
Annual rainfall (mm)	503	401	519	240	263	

Field pea yield

There were no significant differences in yield observed between any varieties at Hart in 2025. Yields ranged from 0.97-1.28 t/ha with an average of 1.08 t/ha (Table 5). Long-term yield data shows that Kaspa and PBA Butler continue to perform well, often yielding above the trial average across multiple seasons at Hart (Table 6).

Varying results in the field pea National Variety Trials were also observed, with the average yield at Riverton being 2.67 t/ha and 1.83 t/ha at Willamulka, both exceeding Hart's average yield. Similarly to Hart, APB Bondi was in the top three performing varieties within the NVT at Riverton. PBA Taylor performed well, achieving the highest yield at Riverton, 3.13 t/ha, and within the top two varieties at Willamulka, achieving the same yield as the top variety Kaspa, 2.04 t/ha (GRDC, 2025).

Table 5. Field pea grain yield (t/ha) results from Hart in 2025.

Variety name	Grain yield (t/ha)
PBA Gunyah⟑	0.97
PBA Oura⟑	0.97
GIA Kastar⟑	0.99
APB2501	1.03
GIA Ourstar⟑	1.03
GIA2203P	1.05
PBA Butler⟑	1.05
PBA Taylor⟑	1.06
PBA Wharton⟑	1.06
APB2401	1.07
Kaspa	1.11
APB Bondi⟑	1.16
PBA Pearl	1.24
APB2403	1.28
Average grain yield (t/ha)	**1.08**
P-value	**NS**

Photo. Field pea plots at Hart in 2025.

Table 6. Long-term yield data for field pea varieties at Hart 2021-2025.

	% of trial average					Grain yield (t/ha)
Variety	**2021**	**2022**	**2023**	**2024**	**2025**	**2025**
APB2401				105	99	1.07
APB2402				95		
APB2403					119	1.28
APB2501					96	1.03
APB Bondiⓓ				113	108	1.16
Kaspa	113	106	102	98	103	1.11
GIA2202P		110	95			
GIA2203P			101	113	98	1.05
GIA Kastarⓓ	88	86	99	93	92	0.99
GIA Ourstarⓓ	93	84	85	101	96	1.03
PBA Butlerⓓ	108	112	101	92	98	1.05
PBA Gunyahⓓ		93	99	97	90	0.97
PBA Ouraⓓ		101	99	102	90	0.97
PBA Pearl		106	103		115	1.24
PBA Percy		99	98			
PBA Taylorⓓ		105	110	85	98	1.06
PBA Whartonⓓ	98	99	109	107	98	1.06
Average grain yield (t/ha)	**1.38**	**1.61**	**3.63**	**0.77**	**1.08**	
Sowing date	May 18	May 18	June 9	June 5	June 20	
April - Oct (mm)	355	232	355	176	223	
Annual rainfall (mm)	503	401	519	240	263	

Summary

Decile 3 (223 mm) GSR at Hart in 2025 affected yield and quality across the trial site. In general, lentil and field pea yields were low, with an average of 1.02 and 1.08 t/ha, respectively. The highest yielding lentil was PBA Highland XT (1.59 t/ha) and field pea was pre-commercial line APB2403 (1.28 t/ha), although all field pea varieties yielded similarly.

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This trial is funded by

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Evaluating mixed species pastures in the Mid North

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Key findings

- Cereals were the most reliable and productive crop type in 2025, with barley varieties leading both early and later (post-grazing) season dry matter.
- Brassicas offered high dry matter potential but were more variable; tillage radish and forage brassicas performed well early, while Puna chicory consistently had low dry matter.
- Ryegrass varieties produced moderate early feed but increased later in the season. Pasture legumes were low yielding early and variable later; vetches, medics, clover and trigonella improved with time but generally remained lower than cereals and ryegrass in 2025.
- Mixed-species treatments provided consistent dry matter, often matching the best single species crops, highlighting their value for providing feed across the season.
- Feed quality and other benefits from pasture legumes and mixed-species (e.g. residual water and soil nitrogen) are still being assessed for 2025.

Introduction

Selecting and managing pastures effectively can be challenging, especially when trying to optimise production and livestock performance across different environments. In response to this challenge, two mixed-species pasture demonstration sites have been established in different environments in the Mid North of South Australia, at Hart and Farrell Flat. The specific objectives of the mixed-species pasture trials were to:

- Optimise pasture production across different environments and production zones.
- Evaluate pasture options for their ability to produce biomass and feed quality during key periods of the season when feed gaps occur.
- Demonstrate weed and disease management benefits, nitrogen fixation, and soil water conservation, which may improve crop yield in following seasons.

Methodology

Two trials were established at Hart and Farrell Flat, SA to evaluate a range of pasture systems for their suitability to the Mid North region (Table 1). The trials assessed a range of crop types standalone or in a mixture with other species, including cereals, ryegrass, brassicas and legumes (Table 2 and 3). Initial soil available nitrogen was 120 kg N/ha at Hart with -2.1 mm plant available water (PAW) and at Farrell Flat there was 146.1 mm of PAW and 132 kg N/ha. Urea (47 kg N/ha) was applied in July at each trial site to ensure pasture production was not limited by nitrogen.

Pasture species were assessed as sole crops to quantify their production potential and forage quality without the confounding effects of mixed-species competition. Pasture mixtures were developed from the individual species to balance dry matter production, seasonal feed supply, feed quality and herbicide options, with the aim of identifying the best pasture options for growers and advisers.

Table 1. Trial details for 2025 mixed-pasture species trial at Hart and Farrell Flat.

	Hart	Farrell Flat
Seeding date	June 20, 2025	June 18, 2025
Grazing date	September 1, 2025	September 2, 2025
2025 annual rainfall	263 mm	297 mm
Growing season rainfall	223 mm	253 mm
Soil available nitrogen	120.4 kg N/ha	132 kg N/ha
Plant available water (PAW)	-2.1 mm	146.1

Table 2. Crop type and specific varieties under evaluation in the Hart and Farrell Flat, 2025 trial.

Crop type	Variety	Farrell Flat seeding rates (kg/ha)	Hart seeding rates (kg/ha)
Cereal	Commodus CL barley		70
	Express forage oats	70	
	Forester oats	70	50
	Magnate forage barley	70	70
	Mowhawk wheat	100	100
	Neo CL barley	70	
	Newton barley	70	70
	Titan AX barley	70	
Ryegrass	Dazzler ryegrass	20	20
	Prodigy ryegrass	20	
Brassica	Blue Gorilla forage brassica	5	
	Captain CL canola	2	
	Greenland forage brassica	5	5
	RGT Hybra forage brassica	5	
	Puna chicory	6	6
	Retained winter canola	5	5
	Tillage radish	5	5
Pasture legume	AGF Balansa clover	4	4
	Benetas vetch	40	
	Jester SU barrel medic		5
	Timok vetch	40	40
	Trigonella	5	5

Table 3. Mixtures evaluated in the Hart and Farrell Flat, 2025 trials.

Hart	
Mixture and seeding rate	**Total (kg/ha)**
Timok vetch 40 kg/ha + Magnate barley 40 kg/ha + Trigonella 2 kg/ha	82
Retained winter canola 3 kg/ha + Commodus barley 40 kg/ha	43
Timok vetch 40 kg/ha + Greenland forage brassica 3 kg/ha	43
AGF WinterMax - Vampire ryecorn 30%, oats 36%, tillage radish 10%, Crimson clover 8% and tetraploid annual Italian ryegrass 16%	50
Farrell Flat	
Mixture and seeding rate	**Total (kg/ha)**
Titan barley 40 kg/ha + Benetas vetch 40 kg/ha + retained winter canola 2 kg/ha	82
Greenland Forage Brassica 3 kg/ha + Benetas vetch 40 kg/ha	43
Prodigy ryegrass 40 kg/ha + AGF balansa clover 40 kg/ha + Forester oats 2 kg/ha	82
AGF WinterMax - Vampire ryecorn 30%, oats 36%, tillage radish 10%, Crimson clover 8% and tetraploid annual Italian ryegrass 16%	50

During the season dry matter and feed quality was assessed at two times; early September (pre-grazing and mid-October (post-grazing). Grazing was simulated by mowing half of the plot area while, still allowing sufficient leaf area for crop recovery. Residual soil moisture and soil available nitrogen on selected treatments were analysed at the end of the season to identify additional rotational benefits of the different crop species. However, only dry matter results were available at the time this report was prepared.

The results were analysed using ASREML and Biometry Assist (Nielsen et al. 2026) Tukey's Honest Significant Difference (HSD) test which compares all possible pairs of means and identifies any difference between two means that is greater than the expected standard error.

Results and discussion

Early dry matter production – single species

At Hart, early September dry matter production was highest in cereal and brassica species (Table 4). Commodus CL and Magnate barley, along with tillage radish, produced the greatest early biomass. Greenland forage brassica also performed strongly (2107 kg DM/ha), as did the retained winter canola. Forester oats, Newton barley, Mowhawk wheat and Dazzler ryegrass produced moderate dry matter relative to the full range of treatments (ranging 1409-1935 kg DM/ha).

At Farrell Flat, dry matter production at the first sampling was generally lower than at Hart, and differences were observed in the relative performance of standalone species (Table 4). Cereals again provided the most reliable early biomass, with Magnate barley, an awnless forage variety, producing 2012 kg DM/ha. Both spring barley varieties Titan AX and Neo CL and the winter barley Newton were also high yielding, producing between 1500 and 1700 kg DM/ha. Consistent across both sites, Mowhawk wheat and Forester oats produced significantly lower dry matter than the best-performing cereal treatments. Mowhawk wheat is a quick-maturing winter variety with a vernalisation requirement, and early season dry matter can be lower compared with spring varieties when all sown in mid to late June. However, this reduced early growth is generally offset by the longer vegetative growth period of winter wheats, which allows more time for dry matter accumulation before stem elongation (GS30). In contrast, a reduction in early dry matter production was not observed for the winter barley variety Newton.

Brassica dry matter production at Farrell Flat was more variable compared to Hart. Forage varieties RGT Hybra, Greenland and Blue Gorilla and tillage radish all performed well, producing approximately 1600 kg DM/ha. In comparison, both winter canola treatments (retained seed and Captain) produced lower dry matter. Ryegrass varieties produced dry matter levels comparable to the cereal and brassica treatments at this site.

Pasture legumes produced low early dry matter at both sites (<963 kg DM/ha at Hart and <556 kg DM/ha at Farrell Flat). Chicory (brassica) also produced very low dry matter at both sites (89–395 kg DM/ha), indicating limited contribution to early feed supply. There were no significant differences in dry matter production among the legume pasture species or chicory at this sampling time. This is consistent with outcomes from previous trials (Nietschke and Smith, 2024) at Farrell Flat and Giles Corner which showed pasture legume species produced low early dry matter.

Early dry matter production – species mixtures

All species mixtures produced high early dry matter at Hart, averaging 2758 kg/ha (Table 4). There were no significant differences among the mixtures, and dry matter production was comparable to that of the highest yielding cereal treatments. At Farrell Flat, AGF WinterMax was the highest yielding mixture, producing 2149 kg DM/ha which was comparable to the best performing cereal and brassica treatments. All remaining mixtures were competitive with the 'mid to lower range' single-species treatments.

Table 4. Dry matter weights for all treatments in early September at Hart and Farrell Flat, 2025. Results were analysed using Tukey's test, and single-species treatments and mixtures were analysed separately at each site. Shaded values indicate best performing treatments.

Crop type	Variety	Farrell Flat Dry matter Sept 1 (kg/ha)	Hart Dry matter Sept 2 (kg/ha)
Cereal	Commodus CL barley		2512^{ef}
	Express forage oats	1308^{def}	
	Forester oats	1351^{def}	1935de
	Magnate forage barley	2012^{g}	2573^{ef}
	Mowhawk wheat	966^{bcd}	1540^{cd}
	Neo CL barley	1721^{fg}	
	Newton barley	1497^{d-g}	1626^{d}
	Titan AX barley	1504^{d-g}	
Ryegrass	Dazzler ryegrass	1352^{def}	1409^{bcd}
	Prodigy ryegrass	1568^{efg}	
Brassica	Blue Gorilla forage brassica	1584^{efg}	
	Captain CL canola	1095^{cde}	
	Greenland forage brassica	1482^{d-g}	2107de
	RGT Hybra forage brassica	1722^{fg}	
	Puna chicory	89^{a}	395^{a}
	Retained winter canola	1167^{def}	1440^{cd}
	Tillage radish	1680^{fg}	3105^{f}
Pasture legume	AGF Balansa clover	400^{ab}	466^{a}
	Benetas vetch	427^{ab}	
	Jester SU barrel medic		963^{abc}
	Timok vetch	556^{abc}	818^{abc}
	Trigonella	176^{a}	546^{ab}
		P<0.01	**P<0.01**
Mixtures	Benetas vetch + Greenland Forage brassica	825^{a}	
	Prodigy ryegrass + AGF Balansa clover + Forester oats	1190^{a}	
	Timok vetch + Greenland forage brassica		2851
	Timok vetch + Magnate barley + Trigonella		2690
	AGF WinterMax	2149^{b}	2866
	Retained winter canola + Commodus barley		2625
	Titan barley + Benetas vetch + retained winter canola	941^{a}	
		P<0.01	**NS**

Late season (post-grazing) dry matter production – single species

By the second sampling time, crops at Farrell Flat had produced higher dry matter than Hart across all treatments (Table 5). Drought stress had started to impact the Hart trial by this sampling time. This was not observed to the same extent at Farrell Flat, where higher rainfall was received during the growing season. While total dry matter production differed between sites, similar patterns were observed across crop types. Cereals (wheat and barley) consistently provided the most reliable biomass of all crops trialed. Oat varieties were more variable, at times matching the yields of wheat and barley but in other cases producing slightly lower dry matter. Ryegrass varieties also produced comparatively high dry matter at this sampling time, ranging from 2792 to 3976 kg/ha.

At the later sampling time, brassicas generally produced moderate dry matter at both sites, with little variation observed among the varieties trialed. The only exception was Puna chicory which consistently had very low dry matter at around 400 kg DM/ha. Pasture legumes showed a clear improvement at the later sampling time for both sites. At Hart, a number of pasture legumes were as high yielding as cereal and ryegrass options.

Late season (post-grazing) dry matter production – species mixtures

All mixtures at Hart and Farrell Flat produced moderate to high dry matter, averaging 3608 kg/ha and 1984 kg/ha, respectively. There were no or only minor differences between the mixtures at each site. The results show that in many cases, mixing the sole species assessed in these trials is a viable strategy to maximise fodder production across the season, while also improving pasture quality and livestock performance. While the feed quality results from this season are pending, this approach has been demonstrated in previous trial seasons (Nietschke and Smith, 2024) and helps fill key feed gaps, with cereals and brassicas providing early-season feed and other species, such as legumes (and brassicas), contributing higher-quality forage later in the season as some cereal species/varieties mature and decline in feed quality.

When creating species mixtures, it is important to balance the seeding rates of the individual components, as there is the risk of one or more species outcompeting the others. The current trials, together with previous field research (Nietschke and Smith, 2024), provide guidance on appropriate seeding rates that can form the basis of discussions for individual farms. Commercially available seed blends, such as AGF WinterMax, also offer a pre-mixed option with comparable dry matter production. In this blend, species ratios have been optimised, which was evident in the plots where all species were present and none appeared to outcompete. This approach allows growers to sow mixed-pastures without the added complexity of blending seed or adjusting individual seeding rates.

Table 5. Dry matter weights for all treatments at Hart and Farrell Flat, October 2025 in the 'grazed' plots. Results were analysed using Tukey's test, and single-species treatments and mixtures were analysed separately at each site. Shaded values indicate best performing treatments.

Crop type	Variety	Farrell Flat Dry matter Oct 14 (kg/ha)	Hart Dry matter Oct 9 (kg/ha)
Cereal	Commodus CL barley		2288^{b-f}
	Express forage oats	3321^{cde}	
	Forester oats	3609^{def}	1660^{bcd}
	Magnate forage barley	5273^{ef}	2201^{b-f}
	Mowhawk wheat	4585^{def}	2573^{c-f}
	Neo CL barley	5449^{f}	
	Newton barley	5628^{f}	2997^{f}
	Titan AX barley	5378^{ef}	
Ryegrass	Dazzler ryegrass	3973^{c-f}	2792^{ef}
	Prodigy ryegrass	3616^{c-f}	
Brassica	Blue Gorilla forage brassica	3325^{cde}	
	Captain CL canola	2948^{bcd}	
	Greenland forage brassica	2960^{bcd}	1740^{b-e}
	RGT Hybra forage brassica	2948^{bcd}	
	Puna chicory	428^{a}	399^{a}
	Retained winter canola	2637^{a-d}	1495^{abc}
	Tillage radish	2636^{a-d}	1873^{b-f}
Pasture legume	AGF Balansa clover	2128^{abc}	1350^{ab}
	Benetas vetch	2285^{abc}	
	Jester SU barrel medic		2776^{def}
	Timok vetch	2583^{bcd}	2419^{b-f}
	Trigonella	1061^{ab}	1828^{b-e}
		P<0.01	**P<0.01**
Mixtures	Benetas vetch + Greenland Forage brassica	2924^{a}	
	Prodigy ryegrass + AGF Balansa clover + Forester oats	3125^{ab}	
	Timok vetch + Greenland forage brassica		1822
	Timok vetch + Magnate barley + Trigonella		2279
	AGF WinterMax	3892^{ab}	1700
	Retained winter canola + Commodus barley		2134
	Titan barley + Benetas vetch + retained winter canola	4489^{b}	
		P<0.01	**NS**

Trigonella

Prodigy ryegrass + Balansa clover + Forester oats

Magnate barley

Benetas vetch

Prodigy ryegrass

Retained winter canola

Figure 1. Photos of selected treatments at Farrell Flat taken on September 26, 2025. The rear half of each plot shown had been 'grazed' in early September.

Summary

Overall, while drought reduced yields in 2025, especially at Hart, the relative performance of species and mixtures remained consistent. Across both Farrell Flat and Hart, cereals consistently provided the most reliable source of early and later season dry matter, with barley varieties generally outperforming wheat and oats. Brassicas offered competitive early feed but were more variable, while ryegrass and legumes contributed less early-on but improved later in the season, particularly ryegrass and vetch.

A range of species mixtures performed well, often matching single-species options and providing consistent feed across varying seasonal conditions. Looking at research from 2022–2025, mixtures are most effective when cereals and brassicas supply reliable early-season feed, while legumes and some brassicas deliver higher-quality forage later as cereals mature and feed quality declines.

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Setting crops up to achieve yield potential

Kenton Porker[1] and Kaidy Morgan[2] on behalf of the PYF project team

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Key findings

- Species is a major risk and profit lever. Barley offers greater yield upside when emerged early and aligned with the environment but also carries greater downside risk, particularly for grain quality, when establishment is delayed or nitrogen is misaligned. Wheat is generally more stable across sowing dates and nitrogen strategies.
- You cannot fix crop structure late. Late nitrogen or favourable spring rainfall cannot fully compensate for insufficient canopy development earlier in the season. Crops must be structurally set up before the critical period to convert seasonal upside into grain yield.

Introduction

Profitable Yield Frontiers (PYF)

One of the challenging aspects of agronomy is making early-season decisions when the outcome of the season is still unknown. Sowing time, crop choice, plant density and early nitrogen strategy all shape yield potential well before confidence in rainfall improves. The GRDC Profitable Yield Frontiers (CSP2404-020RTX) is built around this practical challenge. PYF focuses on identifying early decisions that most consistently position crops to achieve a high proportion of their water-limited yield potential to capture upside when seasons turn favourable.

In cereals, yield potential is largely determined during the critical period (CP), from late stem elongation to flowering. Grain number is the main driver of yield and depends on crop growth rate during this window, the duration of the window, and how effectively biomass is allocated to reproduction. However, crop performance during the CP is heavily influenced by earlier decisions. Canopy development, radiation interception, nitrogen status and soil water supply all determine whether the crop has the structural capacity to respond when favourable conditions occur.

The central question becomes, how can we set crops up to convert favourable spring conditions into grain without overspending, and or structurally limiting the crop?

Methodology

Two trials were conducted to examine how early decisions influence critical period performance. At Hart in 2025, plant available water at sowing was low (18 mm).

Soil mineral nitrogen for the trial site was moderate to high, with approximately 92 kg N/ha in the 0–60 cm profile and 110 kg N/ha in the 0–100 cm profile.

Trial 1

Compared contrasting wheat and barley cultivars across two sowing dates in side-by-side factorial. Crops were sown on April 24 (irrigated to ensure establishment), and sown again on May 28, emerging with the June break. This had an overlay of conservative and aggressive N strategies applied early the same as low and high early N in Table 1.

Trial 2

Sown on May 28 and emerged with the break, this trial focused on wheat and examined plant density treated with three nitrogen strategies (Table 1). Three establishment scenarios were created: a suboptimal stand (<50 plants/m²) and a standard stand (~150 plants/m²), along with an increased radiation use treatment (with effectively zero row spacing). We also applied an additional 40 mm of water at flag leaf to capture upside.

Table 1. N strategies at Hart in 2025.

Nitrogen strategy	Total N applied (kg N/ha)	Timing of application	Seasonal target
Low Early N	0	No additional N applied	Conservative (Decile 2 scenario)
High Early N	70	Split across 4 leaf and mid tillering	Aspirational (Decile 8 higher yield target)
Deferred N	70	Single application at flag leaf	Tactical in-season strategy

Results and discussion

Trial 1: Preliminary results

Across treatments, canopy size entering the critical period and grain number was the dominant driver of yield. Despite large canopy differences (Figure 1), small but significant yield responses were measured. Where plant density was suboptimal, rainfed yields were constrained (1.69–1.82 t/ha). Although additional water and nitrogen increased yield, the absolute ceiling remained limited by canopy. Even with deferred nitrogen and supplementary water, small canopies lacked the capacity to fully convert added resources into grain number (Table 2).

Table 2. Rainfed yield (t/ha) and additional yield response to +40 mm water applied at flag leaf (shown in parentheses), Hart 2025. Confidence interval (CI) = 0.23 t/ha.

Wheat plant density configuration	Low Early N	High Early N	Tactical Deferred N
Suboptimal (<50 plants/m²)	1.73 (+0.30)	1.82 (+0.40)	1.69 (+0.68)
Standard (~150 plants/m²)	2.10 (+0.68)	1.94 (+0.84)	2.13 (+0.85)

By contrast, the standard (and zero) plant density treatment established a larger canopy prior to the CP and consistently achieved higher base yields (1.94–2.13 t/ha). Yield responses to the additional 40 mm of water were larger and more reliable (+0.68 to +0.85 t/ha), particularly under high and deferred nitrogen. These crops had the structural capacity to intercept radiation and better sustain growth during the CP.

The key message is that late inputs cannot fully compensate for insufficient canopy development earlier in the season. Crops must be adequately set up before the CP to translate favourable spring conditions into grain yield.

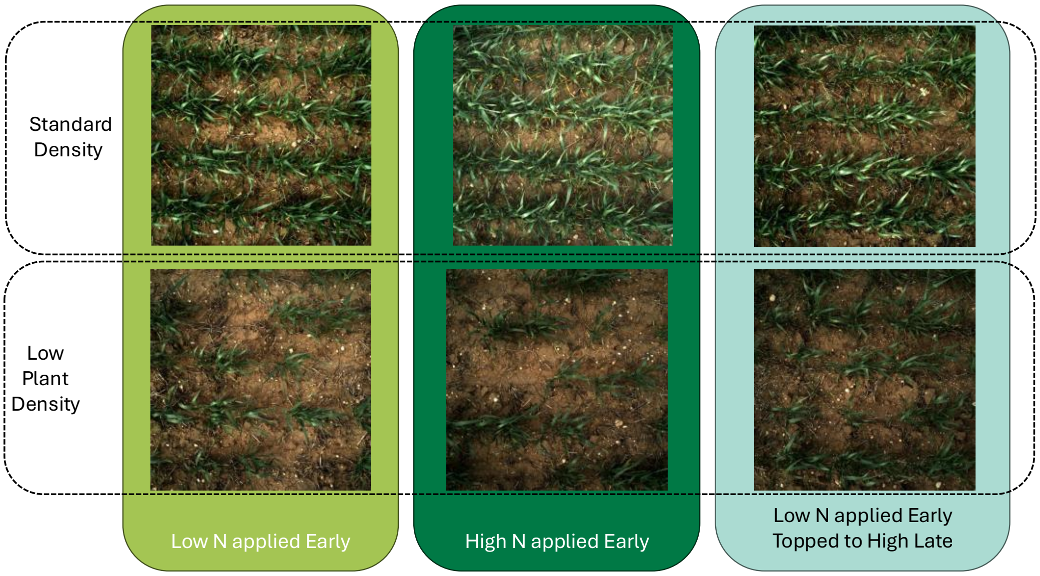

Figure 1. Graphical view of the Shotgun wheat entering the critical period on August 8.

Trial 2: Species is emerging as a major lever for yield and risk management

The highest yielding treatment at this site was early-emerged Bigfoot under a low N strategy (4.16 t/ha). In this seasonal context, maximising yield did not require aggressive nitrogen input. This has clear implications for managing nitrogen risk differently between crop types (Figure 2).

Species choice relative to emergence timing is proving to be one of the biggest levers growers and advisers have for managing both yield potential and seasonal risk. Across sites, early-sown barley delivered clear upside in moderate to high yielding environments.

At Hart, the April 28 germination and low nitrogen barley treatments yielded higher than wheat by a substantial margin. Bigfoot CL achieved 4.16 t/ha, Neo CL 3.77 t/ha and AGTB1010 (winter barley) 3.58 t/ha. In contrast, wheat yielded 2.65 t/ha (Shotgun), 2.42 t/ha (Mowhawk winter wheat) and 2.24 t/ha (AGT Colt). Only early emergence opportunity barley has been shown to have a clear yield advantage.

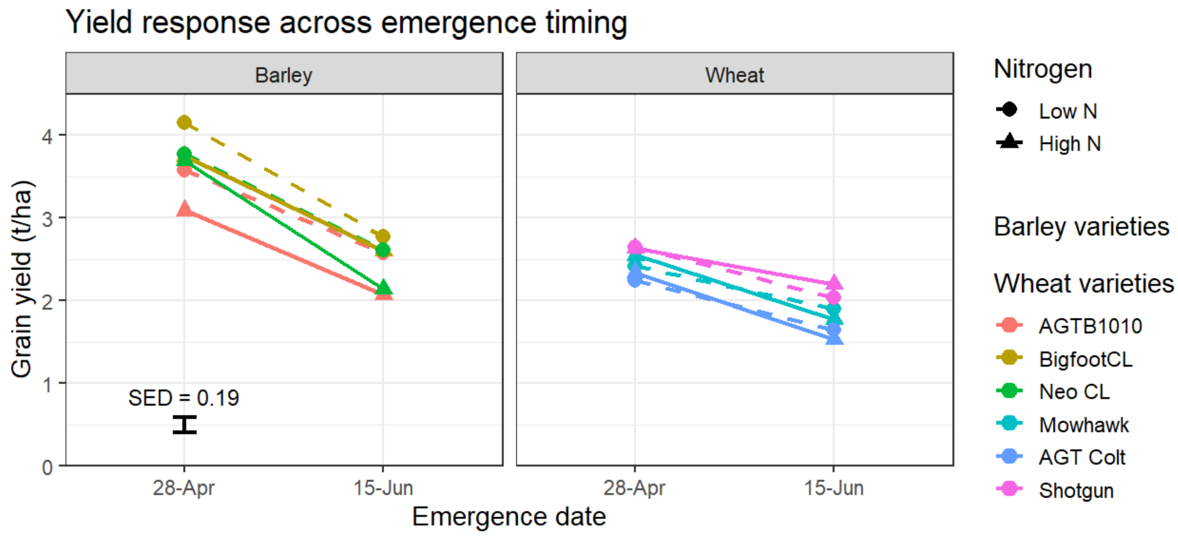

Figure 2. Grain yield (t/ha) of wheat and barley cultivars under two emergence timings (28-Apr and 15-Jun) and two nitrogen strategies (Low N = dashed lines; High N = solid lines). Panels are separated by species.

Despite the yield benefits from early emergence, barley also showed greater sensitivity to delayed emergence. When emergence shifted to June 15 (later break), Bigfoot declined from 4.16 to 2.77 t/ha and Neo CL from 3.77 to 2.61 t/ha. Wheat declines across the same window were smaller (for example, Shotgun declined from 2.65 to 2.04 t/ha). This highlights a strong environment × species interaction that has implications for management.

Barley also appeared more sensitive to nitrogen strategy. Under early sowing, high nitrogen reduced yield in several barley cultivars (e.g. Bigfoot declined from 4.16 to 3.74 t/ha). Wheat responses were more stable across nitrogen strategies. There is some evidence that higher nitrogen under later sowing accelerated yield decline in both species, but the magnitude of these interactions was consistently greater in barley.

Grain quality responses reinforce the trade-off

The yield trade-off in barley becomes even more pronounced when grain quality is considered (Figure 3). Small grain screenings showed a strong sowing date × nitrogen × species interaction. High nitrogen substantially increased screenings in barley, particularly under delayed emergence. For example, Neo CL screenings increased from 9.7% under low N to 24.7% (+15%) under high N when emergence occurred on June 15 and Bigfoot increased from 9.0% to 21.4% (+12%).

These are biologically and economically significant quality penalties. In contrast, wheat cultivars showed smaller and more stable nitrogen responses, typically less than 5% increase in screenings across sowing dates. These results indicate that barley carries greater quality risk under high nitrogen and delayed establishment. Barley offers greater yield upside when emerged early and well aligned with environment, but also greater downside risk, particularly for quality when establishment is delayed or nitrogen is misaligned.

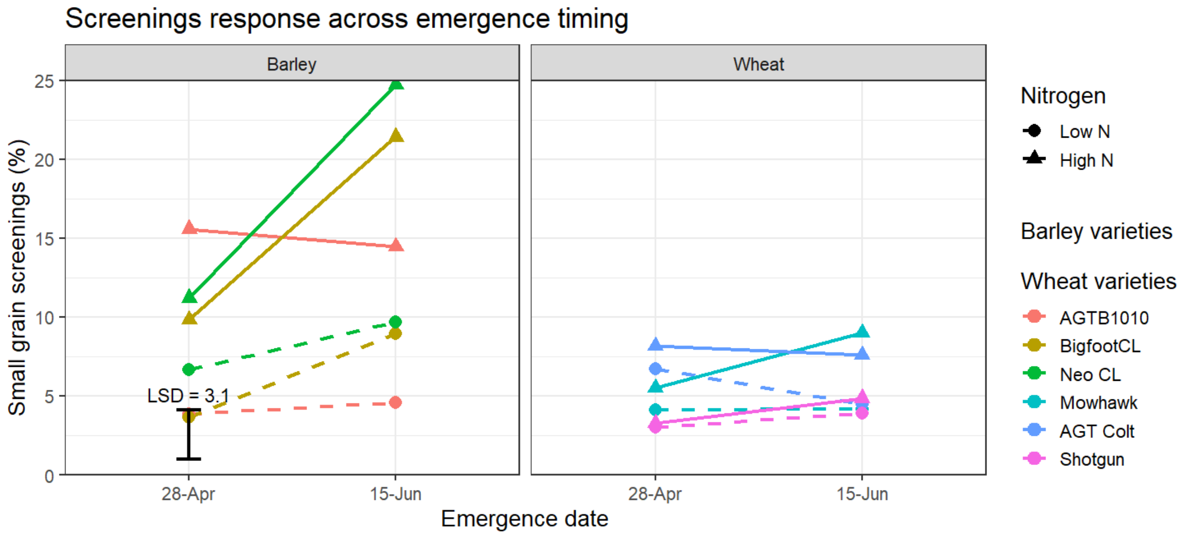

Figure 3. Small grain screenings (%) of wheat and barley cultivars under two emergence timings (28-Apr and 15-Jun) and two nitrogen strategies (Low N = dashed lines; High N = solid lines). Barley exhibited substantially larger increases in screenings under high nitrogen, particularly under delayed emergence, indicating stronger nitrogen-induced quality penalties relative to wheat.

Summary

Yield potential is largely set before flowering. Early decisions, sowing timing, species, plant density and nitrogen, determine whether crops enter the critical period with the structure needed to respond. Barley offers more upside when established early and is well aligned with environment but carries greater yield and quality risk if establishment is delayed or nitrogen is over supplied and this coincides with water stress. Wheat is generally more stable. The physiological reasons for this are being studied.

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Legume and oilseed herbicide tolerance

Hart Field-Site Group

Aim

This demonstration had two primary objectives. The first was to evaluate the crop safety of canola and legume species when exposed to a range of herbicide products, application timings, and rates. The second was to assess the effectiveness of these herbicides in controlling volunteer canola and legume varieties that may require management either within the subsequent season's crop or prior to its establishment.

Observations from 2025 may differ from expected results that would otherwise be seen in more favorable conditions.

Methodology

The 2025 legume and oilseed herbicide tolerance trial was established as a demonstration and arranged as a non-replicated matrix (Table 1). Sixteen varieties were sown in strips representing seven crop types: canola, faba bean, field pea, chickpea, lentil, vetch and barrel medic. A total of 45 herbicide treatments were applied across all 16 crops at different timings. The trial was sown on July 3 into a drying soil profile, with 10.6 mm of rainfall recorded in the seven days leading up to sowing.

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

Plot size	2.2 m x 2.0 m	**Fertiliser**	Seeding: MAP (10:22) + Zn 1% @ 80 kg/ha
Location	Hart, SA		
Seeding date	June 27, 2025	**GSR***	Decile 3 (223 mm)
		Soil type	Clay loam

**GSR = Growing season rainfall*

Application timings:

1. Incorporated by sowing (IBS) — June 27
2. Post-seeding pre-emergent (PSPE) — June 27
3. Early post-emergent (3-4 node) — August 6
4. Post-emergent (5-6 node) — August 19
5. Knockdown & spikes (5-6 node) — August 19

Treatments were visually assessed and scored (Table 2) for herbicide effects approximately six weeks after each application from August to October (Tables 3 & 4).

Table 2. Crop damage ratings and descriptions used for visual assessment of legume and oilseed herbicide tolerance demonstration.

Rating	Crop damage	Explanatory notes
1	No effect	No herbicide effect evident.
2	Slight effect	Some slight or temporary damage, reduced crop vigour and growth. Discoloration, distortion and/or stunting negligible.
3	Moderate effect	Moderate damage with recovery likely expected in most, if not all cases. Can include moderate discolouration, distortion and/or stunting.
4	Irreversible effect	Majority of plants irreversibly damaged. Some discoloration, necrosis and distortion severe.
5	Severe effect	Severe - very severe damage. Majority of plants are dead with the remainder showing distortion or necrosis.
6	Death	Death of plants. Some crop residue may remain but complete loss of plant/and or crop.

Some herbicides used in this demonstration are not registered for the crops to which they were applied, so it is essential to consult product labels before use. In 2025, several treatments produced unexpected differences in crop tolerance. These results should be interpreted with caution, as herbicide performance can vary between seasons and depends heavily on factors such as soil type and weather conditions at the time of application. This trial was not replicated, and all observations are based on a single visual assessment.

Crop safety

Because conditions were exceptionally dry for more than six months prior to the June sowing period, the performance of pre-emergent herbicides was not fully representative of outcomes expected under more typical seasonal conditions.

Crop responses to IBS treatments were generally slight to moderate. Lentils exhibited minimal sensitivity to most treatments, with the exception of Jumbo 2, which showed irreversible injury in response to Terrain Flow.

Ultro® applied at 1700 g/ha was one of safest across all applied IBS treatments for the crops it is registered in. In 2023, 2024 and 2025 seasons, Ultro provided no effect to slight crop effect on canola and medic, however this use is off-label and is not recommended.

Pyroxasulfone and Overwatch applied IBS had significantly less effect on most varieties this year than in 2024.

Voraxor, evaluated as a new treatment, produced lower than anticipated crop damage ratings across most varieties. Substantial variability was observed among canola and lentil varieties, with some canola lines ranging from no visible effect to moderate injury; similar patterns were noted in lentils. Voraxor is not currently registered for pre-sowing application in canola or pulse crops.

PSPE applications provided lower levels of crop safety than IBS treatments, as expected. Crop effects from diuron, simazine, and metribuzin were less pronounced compared with observations from some previous seasons.

Crop control

Crop control at the 5-6 node timing was lower than previous years for Velocity and Talinor. Florasulam and Paradigm gave the most consistent control of the post emergent treatments which was not unexpected. These treatments did offer poor control of the SU tolerant medic, this is likely due to the MOA being a Group 2 herbicide, which SU chemistry also falls under.

Galaxy with LVE MCPA treatments did not adequately control faba bean or pea varieties, and this aligns well with the label recommendations where other herbicides need to be included for full control at this stage.

Knockdown and spikes

Paraquat at 400 mL/ha with Voraxor at 200 mL/ha offered the most consistent control across all pulse and oilseed varieties. With the exception of GIA Ourstar field peas, Kingsford and Timok vetch, all other varieties were controlled.

Paraquat standalone treatments performed very poorly at both the 400 mL/ha and 900 mL/ha rates as would be expected. The best result was seen on HyTTec Trophy canola with the 800 mL/ha rate causing death.

Low rates of paraquat (400 mL/ha), Sharpen, Terrad'or and Voraxor did not control the vetch. Glufosinate at 4 L/ha although not registered gave control of the medic varieties, Timok vetch, chickpeas, faba beans and field peas.

Photo: A drone view of the herbicide tolerance trial at Hart in 2025.

Table 3. Crop damage ratings for the legume and oilseed herbicide tolerance trial at Hart in 2025.

Trial layout – CROP SAFETY

CROP SAFETY				Canola				Bean		Pea		C/pea	Lentil			Vetch		Medic	
	Timing	Treatment	Rate	HyTTec Trophy	PY421C	Nuseed Raptor	InVigor LR 4540P	PBA Bendoc	PBA Samira	PBA Wharton	GIA Ourstar	Genesis090	Jumbo 2	GIA Thunder	GIA Metro	Kingsford	Timok	Jester SU	Sultan SU
1	IBS | June 27	**NIL**		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2		Pyroxasulfone (850 g/kg)	118 g	1	1	1	2	1	1	1	2	2	2	1	1	1	1	1	1
3		Boxer Gold	2500 mL	2	1	2	2	1	1	1	1	2	1	1	1	1	1	2	1
4		Propyzamide	1000 mL	2	1	2	1	1	2	1	1	1	1	1	1	1	1	1	1
5		Tenet	1800 mL	2	2	2	1	1	1	2	2	1	1	1	1	1	1	1	2
6		Ultro	1700 g	1	2	1	1	1	2	1	2	1	1	1	1	1	1	1	1
7		Reflex	1000 mL	2	2	1	2	1	2	2	1	2	1	1	1	1	1	1	2
8		Luximax	500 mL	1	2	2	2	1	1	1	1	2	1	1	1	1	1	1	2
9		Overwatch	1250 mL	2	1	2	1	1	1	2	1	2	1	1	1	1	1	1	1
10		Sentry	50 g	2	1	3	4	2	2	1	1	2	1	1	1	1	1	1	1
11		Mateno Complete	1000 mL	3	3	4	4	3	3	2	2	2	1	1	2	1	1	3	2
12		Terrain Flow	190 mL	3	2	3	2	1	1	2	2	1	4	1	2	2	2	4	4
13		Voraxor	200 mL	2	3	1	2	1	2	No data	1	1	3	1	1	1	1	2	3
14	PSPE | June 27	**NIL**		1	1	1	1	1	1		1	1	1	1	1	1	1	1	1
15		Diuron (900 g/kg)	825 g	5	3	4	3	1	1	1	1	1	1	1	1	1	1	5	2
16		Reflex	1250 mL	6	5	5	4	2	2	1	1	1	2	2	3	1	1	5	5
17		Simazine (900 g/kg)	825 g	1	5	4	4	2	2	1	1	1	2	2	2	1	1	6	6
18		Metribuzin (750 g/kg)	280 g	2	6	6	6	2	2	1	1	1	2	2	1	3	2	6	4
19		Brodal Options	100 mL	4	5	5	6	3	3	2	2	3	2	1	1	2	1	3	2
20		Terbuthylazine (875 g/kg)	1000 g	2	5	5	5	1	2	1	1	1	3	3	3	2	1	6	6
21		Balance + Simazine	100 g + 830 g	5	6	5	6	2	2	1	2	1	4	4	4	3	3	6	6
22	3-4 Node | August 6	**NIL**		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
23		Metribuzin (750 g/kg)	280 g	1	5	5	6	2	2	1	1	2	2	2	1	3	3	2	2
24		Broadstrike + Wetter 1000	25 g + 0.2%	6	1	5	6	1	3	2	1	1	1	1	2	4	3	1	1
25		Thistrol Gold + Cando	2000 mL + 0.5%	6	5	6	6	2	2	2	2	1	2	2	2	4	3	2	1
26		Ecopar Forte + Wetter 1000	400 mL + 0.2%	4	4	4	4	2	2	3	3	1	3	3	3	1	1	2	2
27		Brodal Options + MCPA Amine 750	125 mL + 125 mL	3	3	2	2	2	3	1	1	1	1	1	1	2	3	1	2
28		Terbutryn (500 g/L)	600 mL	1	2	1	2	3	3	1	1	1	1	1	1	1	2	1	2

Table 4. Crop damage ratings for the legume and oilseed herbicide tolerance trial at Hart in 2025.

Trial layout – CROP CONTROL

				Canola				Bean		Pea		C/pea	Lentil			Vetch		Medic	
		CROP CONTROL		HyTTec Trophy	PY421C	Nuseed Raptor	InVigor LR 4540P	PBA Bendoc	PBA Samira	PBA Wharton	GIA Ourstar	Genesis090	Jumbo 2	GIA Thunder	GIA Metro	Kingsford	Timok	Jester SU	Sultan SU
	Timing	**Treatment**	**Rate**																
1	5 - 6 node | August 19	**NIL**		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2		Lontrel Advanced	150 mL	2	1	1	1	6	6	5	6	6	6	6	6	6	6	6	6
3		Metsulfuron Methyl (600 g/kg) + MCPA LVE + Wetter 1000	5 g + 500 ml + 0.1%	6	5	6	6	5	5	6	4	6	6	2	3	6	2	2	2
4		Velocity + Hasten	670 mL + 1.0%	6	5	5	6	5	5	6	5	2	3	3	3	2	2	4	5
5		Talinor + Hasten	750 mL + 1 %	6	5	6	6	6	5	6	5	3	5	4	4	3	5	5	6
6		Infinity Ultra + Hasten	110 mL + 1%	5	3	4	4	3	4	4	5	2	4	3	3	2	1	3	3
7		Frequency + MCPA LVE + Hasten	200 mL + 500 ml + 1%	6	6	6	6	4	3	3	3	1	2	2	4	5	3	4	4
8		Galaxy + MCPA LVE + Hasten	335 mL + 500 ml + 1%	5	5	5	6	4	4	4	4	2	6	5	6	4	2	4	3
9		**NIL**		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
10		Florasulam (200 g/L) + Uptake	25 mL + 0.5%	6	4	6	6	6	6	6	5	6	6	5	5	6	5	3	2
11		Paradigm + Uptake	25 g + 0.5%	6	5	6	6	5	6	5	5	6	6	5	5	6	4	3	3
12		Quadrant	1000 mL	5	5	4	5	3	3	2	2	2	2	2	2	1	1	1	1
13	Knockdown & spikes | August 19	**NIL**		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
14		Paraquat + MSO	800 mL + 1%	6	5	5	5	2	2	2	3	2	1	1	1	1	1	1	1
15		Paraquat + MSO	400 mL + 1%	4	3	3	3	1	2	1	2	3	1	1	1	1	1	1	1
16		Paraquat + Sharpen + MSO	400 mL + 34 g + 1%	6	6	6	6	5	5	5	5	5	5	4	4	2	2	4	4
17		Paraquat + Terrad'or + MSO	400 mL + 40 g + 1%	6	6	6	6	5	6	5	4	5	5	6	5	3	2	5	5
18		Paraquat + Voraxor + MSO	400 mL + 100 mL + 1%	6	6	6	6	5	6	5	4	5	5	5	5	3	4	6	6
19		Paraquat + Voraxor + MSO	400 mL + 200 mL + 1%	6	6	6	6	6	6	6	5	6	6	6	6	4	5	6	6
20		Glufosinate 200 + AMS	2000 mL + 3%	3	3	2	1	5	5	5	5	5	4	2	2	1	3	5	5
21		Glufosinate 200 + AMS	4000 mL + 3%	5	5	5	1	4	6	6	6	6	6	5	5	5	6	6	6
22		Paraquat + Amitrole 250	800 ml + 2000 mL	3	3	3	5	6	5	2	1	2	3	3	3	1	1	5	2
23		Amitrole 250	4000 mL	4	4	4	5	6	6	2	3	5	5	5	5	4	6	6	3

Combinations of crop rotations and herbicides for effective management of brome grass (Snowtown, SA)

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Key findings

- In this trial report, the term 'break' refers to the year in which the selected crop × herbicide combinations are expected to effectively prevent brome grass seed production.
- Brome grass plant density in the no-break system (S1) in 2025 was close to 300 plants/m^2, which reduced wheat yield by more than 1000 kg/ha compared to the single year break systems, which were also sown to wheat in 2025.
- A single year break in brome grass seed set tends to be inadequate for long-term brome grass population management. This was also seen in the trial at Snowtown, where brome grass panicle density in the one-year break systems (S2 and S3) increased by 40 to 50-fold from 2024 to 2025.
- Management systems with a 2-year or 3-year break in brome grass seed set maintained low brome grass panicle density (0 to 3.4 panicles/m^2) in 2025.
- Even though brome grass panicle density in the three systems with lentils in 2025 (S4, S5, S7) was very similar (0 to 2 panicles/m^2), Metro lentil grain yield was 500 kg/ha lower than GIA Thunder lentils. Such a high level of fitness penalty in metribuzin tolerant Metro lentils is consistent with the results from previous research and will reduce its on-farm adoption.
- In System 6 (3-year break), brome grass was effectively controlled in 2024 in lentils and in canola in 2025. In this system brome grass produced only 3 panicles/m^2 in 2025 and canola performed well to produce grain yield of 1500 kg/ha. Therefore, inclusion of canola in the rotation would be a profitable option for brome grass management.

Introduction

Brome grass is currently ranked the second worst weed in grain crops in Australia, causing annual revenue loss of $42 million (Ouzman et al. 2025). Brome grass is difficult to effectively control with pre-emergent herbicides currently registered for use in cereal crops. Development of herbicide tolerant cereal varieties has increased herbicide options available for growers to effectively manage brome grass in the cereal phase of rotations. Integration of herbicide tolerant cereals with break crops such as pulses and canola offers opportunities to effectively deplete brome seedbank and manage its populations. It is important to demonstrate to growers the effectiveness of carefully considered combinations of cropping sequences and herbicide options for the management of brome grass in different agroecological environments.

This study aims to identify rotations and herbicide programs that effectively suppress brome grass populations and minimise seedbank replenishment while maintaining crop productivity.

Methodology

A three-year field trial was established in a randomised complete block design on a commercial farm near Snowtown in the Mid North of SA. This farm has a sandy loam soil which is favoured by brome grass and the participating grower reported difficulty in managing this brome grass population even though it has not yet evolved resistance to any herbicide group.

The trial was sown with an experimental no-till cone seeder with 25 cm row spacing and seeding width of 1.5 m (Table 1). There was a single seeder run per plot, and the plots were 12 m long. There was one buffer plot of Tomahawk CL wheat between all experimental plots to minimise the risk of herbicide spray drift and the dispersal of weed seeds to neighbouring plots during crop harvest or by wind. All pre-emergent herbicides were sprayed just prior to crop sowing and incorporated by the no-till seeding tines (IBS). Broadleaf weeds, insect pests and diseases were managed effectively in all crops. Information on herbicide products, active ingredients and label rates can be found in Table 2. All data was analysed by using the statistical software GenStat 23rd Edition.

Table 1. Trial management details for 2025.

Project duration	2024–2026 (3-years)
Trial location	Snowtown, SA
Plot size	12 m x 1.5 m
Replications	4
Soil type	Sandy loam
Sowing date	May 5, 2025
Target crop density (m^2)	Wheat 180, lentils 120 and canola 50
Fertiliser	80 kg/ha MAP with Zn at sowing; canola and wheat also had 80 kg/ha urea at sowing
Herbicides	See Table 2
Crop-topping	Paraquat 800 ml/ha or glyphosate 4L/ha DST 470 (System 6) on October 27
Harvest date	Lentils - November 5; wheat and canola - November 19

Table 2. Information about the herbicides used for brome grass control in the trial at Snowtown in 2025.

Product name	Active ingredient	Label rate
Sakura®	Pyroxasulfone 850 g/kg	118 g/ha
Overwatch®	Bixlozone 400 g/L	1.25 L/ha
Avadex®	Triallate 500 g/L	3.2 L/ha when used as incorporated by sowing in no-till
Crusader GoDri	Pyroxsulam 215 g/kg	70 g/ha
Intercept®	Imazamox 33 g/L + Imazapyr 15 g/L	375-750 mL/ha for brome grass
Propyzamide	Propyzamide 500 g/L	1 L/ha
Ultro	Carbetamide 900 g/kg	1.1-1.7 kg/ha
Clethodim 360	Clethodim 360 g/L	116-333 mL/ha
Verdict®	Haloxyfop 520 g/L	75 mL/ha
Metribuzin 750 WG	Metribuzin 750 g/kg	370 mL/ha
Crucial®	Glyphosate 600 g/L	1-1.5 L/ha (in Truflex canola) x 2

Paraquat 250	Paraquat 250 g/L	400-800 mL/ha

The summer of 2025 was extremely dry with only 16.4 mm rainfall from January to the end of May. Therefore, the seedbed was extremely dry when the trial was sown on May 5. Rainfall in June was close to the long-term average for the site, but July was extremely wet with more than double the long-term average rainfall (Table 3). However, August and September were slightly below the average. Over the whole growing season (April to October), rainfall received at the site was close to the long-term average.

Table 3. Rainfall during 2025 and long-term rainfall for the trial site. Rainfall data for 2025 and long-term was obtained from climate data online from Bureau of Meteorology for Snowtown (Rayville Park).

Month	Rainfall in 2025 (mm)	Long-term rainfall (mm)
Jan	1.0	17.4
Feb	0.0	17.0
Mar	4.8	15.5
Apr	3.0	23.0
May	7.6	33.8
Jun	39.8	49.9
Jul	107.6	40.4
Aug	38.4	42.9
Sep	23.8	36.5
Oct	26.0	26.7
Nov	30.0	28.7
Dec	4.6	28.7
Annual total	286.6	360.5
Growing season	246.2	253.2

In this trial report, the 'break' refers to the year where crop × herbicide combinations are expected to effectively prevent brome grass seed production.

No-break system (S1): Pre-emergent Overwatch + Avadex was followed by Crusader (pyroxsulam) post-emergent (Table 4) to prevent excessive build-up in brome grass infestation. This system is expected to allow some brome grass seed production each year.

1-year break systems (S2 and S3): Canola (S2) or lentils (S3) in 2024 were followed by wheat sprayed with pre-emergent herbicides in 2025. These management systems are expected to lead to a rebound in brome grass populations due to weed establishment from the residual seedbank.

2-year break systems (S4 and S5): Brome grass was controlled in 2024 in CL barley (Maximus CL), which was followed in 2025 by Thunder lentils with either carbetamide (S4) or propyzamide (S5) as the pre-sowing treatment followed by group 1 post-emergent herbicides and crop-topping to prevent any seed set.

3-year break systems (S6 and S7): Thunder lentils in 2024 were followed by canola in 2025 (S6) to provide an effective second break from brome grass. This canola variety allowed use of Group 1 herbicides early post-emergent followed by glyphosate late to eliminate brome grass (Table 4). In the other 3-year break system (S7), AX barley grown in 2024 was followed by metribuzin tolerant Metro lentils. The Hart Research Committee group was interested in exploring the suitability of Metro lentil variety in this trial. Metro lentils are tolerant to metribuzin, which can control brome grass and several broadleaf weed species when used post-emergent in lentils. However, this variety also suffers from a significant fitness penalty associated with the metribuzin tolerance gene. This trial will provide local data to objectively assess the pros and cons of using Metro lentils in this medium rainfall environment.

Table 4. Crops, varieties and herbicide input programs at Snowtown in 2024 and 2025.

System (S)	Weed management 2024	Weed management 2025
S1 (no break)	**Scepter wheat** PRE: Sakura @ 118 g + Avadex @ 2 L	**Tomahawk CL wheat** PRE: Overwatch @ 1.25 L/ha + Avadex @ 2.4 L/ha POST: Crusader GoDri @ 70 g/ha
S2 (1-year break)	**HyTTec Trophy TT Canola** PRE: Propyzamide @ 1 L/ha + Simazine @ 1 kg/ha POST: Clethodim 240 @ 500 ml/ha + Atrazine @ 1 kg/ha	**Tomahawk CL wheat** PRE: Sakura @ 118 g/ha + Avadex @ 2.4 L/ha
S3 (1-year break)	**GIA Thunder XT** PRE: Propyzamide @ 2 L/ha POST: Factor @ 180 g/ha + Clethodim 240 @ 500 mL/ha + Intercept @ 375 mL/ha Fb Crop topping	**Tomahawk CL wheat** PRE: Overwatch @ 1.25 L/ha
S4 (2-year break)	**Maximus barley CL** PRE: BoxerGold @ 2.5 L/ha + Trifluralin @ 2 L/ha POST: Intercept @ 750 mL/ha	**GIA Thunder XT** PRE: Ultro @ 1.4 kg/ha POST: Clethodim 360 @ 330 mL/ha + Verdict @ 75mL Crop-topping: Paraquat @ 800 mL/ha
S5 (2-year break)	**Maximus barley CL** PRE: BoxerGold @ 2.5 L/ha + Trifluralin @ 2 L/ha + Sentry @ 40 g/ha	**GIA Thunder XT** PRE: Propyzamide 900 @ 560 mL/ha POST: Clethodim 360 @ 330 mL/ha + Verdict @ 75 mL Crop-topping: Paraquat @ 800 mL/ha
S6 (3-year break)	**GIA Thunder XT** PRE: Propyzamide @ 2 L/ha POST: Factor @ 180 g/ha + Clethodim 240 @ 500 mL/ha + Intercept @ 375 mL/ha Fb Crop Topping	**Hyola Regiment XC** PRE: Overwatch @ 1.25 L/ha POST: Crucial @ 1.5 L/ha + Clethodim 360 @ 330 mL POST 2: Crucial @ 1.5 L/ha Crop-topping: Glyphosate DST 470 @ 4 L/ha
S7 (3-year break)	**Titan AX barley** PRE: Trifluralin @ 2 L/ha + Avadex @ 2 L/ha + Metribuzin @ 280 g/ha POST: Aggressor @ 200 mL/ha	**Metro lentils** PRE: Ultro @ 1.4 kg/ha POST: Metribuzin 750 @ 370 mL Clethodim 360 @ 330 mL/ha + Verdict @ 75 mL Crop-topping: Paraquat @ 800 mL/ha

Results and discussion

Crop establishment

Wheat plant establishment in this trial was close to the target of 180 plants/m^2 (Table 5). This is an impressive result considering the dry seedbed at sowing and that significant rainfall post-seeding did not arrive until June. Plant establishment in both lentil cultivars was slightly greater than the target of 120 plants/m^2. A similar trend was also seen in canola, where plant establishment was also greater than the target of 50 plants/m^2. Importantly, good establishment of all crop species would have allowed them to effectively compete with brome grass plants that survived the herbicide treatments.

Table 5. Density of crop plants established in the Snowtown trial in 2025. Crop names in bold indicate the phase in 2025.

System (S)	Rotation sequence	Crop density (plants/m^2) ± SEM
S1 (no break)	Wheat – **Wheat** – Barley (PRE herbicides – weak system)	134 ± 1.4
S2 (1-year break)	TT Canola – **Wheat** - Barley	162 ± 8.0
S3 (1-year break)	Lentil XT – **Wheat** - Barley	185 ± 11.0
S4 (2-year break)	Barley CL – **Lentil XT** - Wheat	132 ± 11.3
S5 (2-year break)	Barley CL – **Lentil XT** - Wheat	139 ± 3.5
S6 (3-year break)	Lentil XT – **Canola XC** – Wheat CL	63 ± 4.4
S7 (3-year break)	Barley AX – **Metro lentil** – Canola TF	145 ± 12.4

Brome grass plant and panicle density

Brome grass plant density in System 1 (no break) appears to have stabilised around 300 plants/m^2 (Table 4). However, such high brome grass densities are likely to cause a significant loss in crop yield. The use of post-emergent Crusader (pyroxsulam) in S1 reduced brome grass panicle density by about 50% when compared to 2024. Crusader was applied prior to tiller production, which allowed for some weed kill and suppress growth and panicle production of the survivors. Consistent with the results from other brome management trials in this project, 1-year break from brome seed set is inadequate and leads to a rapid rise in panicle density and seed set in year two (Table 6). In this trial, brome grass panicle density in S2 and S3 increased by 40 to 50-fold from 2024 to 2025. The lower brome grass panicle density in S2 compared to S3 appears to be related to superior brome grass control by pre-emergent Sakura + Avadex than Overwatch (Figure 1). It should be noted that these two systems had very similar brome grass plant and panicle density in 2024. In contrast, the 2-year and 3-year break systems were highly effective in maintaining brome grass panicle density at a very low level in 2025 (0 to 3.4 panicles/m^2). Such low plant and panicle density levels are expected to lead to very low brome grass infestations in 2026.

Table 6. Densities of brome grass plants and panicles across crop rotation sequences and herbicide input programs at Snowtown in 2024 and 2025. Crop names in bold indicate the phase in 2025. Shaded values in each column indicate best performing treatments. Means followed by a different letter indicate statistical significance (P=0.05).

System (S)	Rotation sequence	Brome density[1] 2024 (plants/m^2)	Brome density[1] 2025 (plants/m^2)	Brome panicles 2024 (panicles/m^2)	Brome panicles 2025 (panicles/m^2)
S1 (no break)	Wheat – **Wheat** – Barley (PRE herbicides – weak system)	316^{cd}	327^{d}	526^{d}	272.8^{d}
S2 (1-year break)	TT Canola – **Wheat** - barley	0^{a}	50^{b}	1^{a}	59.1^{b}
S3 (1-year break)	Lentil XT – **Wheat** - Barley	4^{a}	189^{c}	4^{a}	181.1^{c}
S4 (2-year break)	Barley CL – **Lentil XT** - Wheat	89^{b}	2^{a}	35^{ab}	0^{a}
S5 (2-year break)	Barley CL – **Lentil XT** - Wheat	410^{d}	5^{a}	115^{c}	1.1^{a}
S6 (3-year break)	Lentil XT – **Canola XC** – Wheat CL	8^{a}	29^{b}	1^{a}	3.4^{a}
S7 (3-year break)	Barley AX – **Metro lentil** – Canola TF	298^{c}	23^{ab}	70^{bc}	2.2^{a}
P-value		**<0.001**	**<0.001**	**<0.001**	**<0.001**

[1]Plant density of brome in Oct (late spring); all data for weed density and panicle density were square root transformed before performing ANOVA.

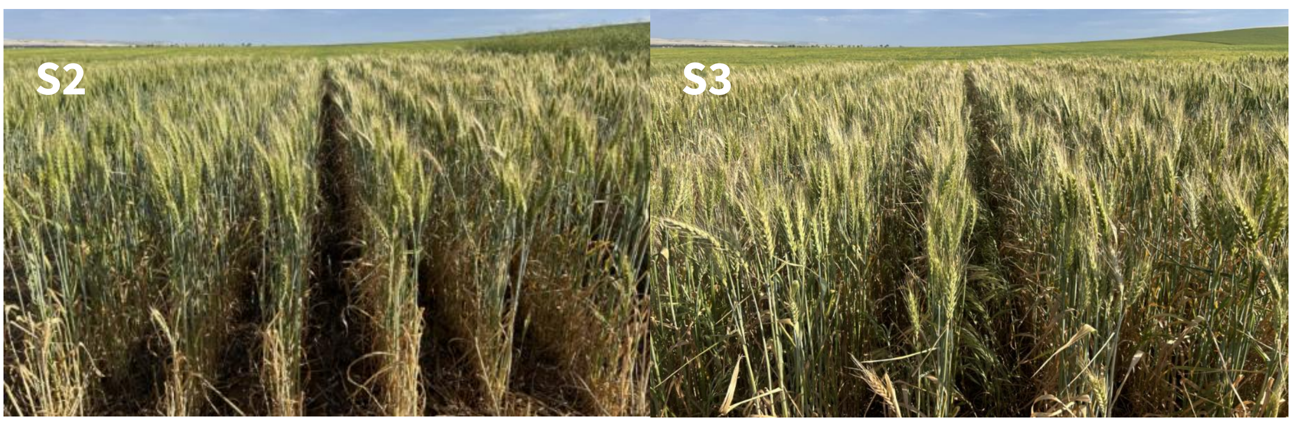

Figure 1. Late season brome grass pressure in Tomahawk CL wheat for System 2 (S2) and System 3 (S3). Improved brome grass control was noticed in S2 where Sakura + Avadex were applied when compared to Overwatch application in S3.

Crop grain yield

A comparison between S1 and S3, which were all in wheat in 2025, provides useful insights into the competitive ability of brome grass. Presence of more than 300 plants/m^2 of brome grass in wheat in S1 reduced wheat grain yield by more than 1000 kg/ha when compared to the single year break (S2 and S3; Table 7). S2, which had excellent weed control in canola in 2024 and was treated with Sakura + Avadex in 2025, had a much lower brome grass density (50 plants/m^2) and produced wheat yield of 3,076 kg/ha as compared to 1,741 kg/ha in S1. Brome grass is known to be a highly competitive weed with wheat where even 10 plants/m^2 can reduce yield by 5% (Gill and Davidson 2000). Therefore, it was not surprising to see around 50% yield loss in wheat in S1, which was infested by more than 300 plants/m^2 of brome grass.

The comparison of grain yield in the lentil-based systems provides an important insight into the fitness penalty associated with the metribuzin tolerance gene in Metro lentils. Even though brome grass panicle density in the three systems with lentils in 2025 was very similar (0 to 2.2 panicles/m^2), Metro lentil yield was 500 kg/ha lower than GIA Thunder (Table 7). A similar level of fitness penalty in metribuzin tolerant lentils has been reported previously. Even though Metro offers the opportunity to use metribuzin for post-emergent weed control, it would be associated with a considerable financial cost to the grower.

Table 7. Response of crop grain yield to brome grass management systems at Snowtown in 2025. Crop names in bold indicate the phase in 2025. Shaded values in each column indicate best performing treatments. Means followed by a different letter indicate statistical significance (P=0.05).

System (S)	Rotation sequence	Grain yield (kg/ha)
S1 (no break)	Wheat – **Wheat** – Barley (PRE herbicides – weak system)	1741^{ab}
S2 (1-year break)	TT Canola – **Wheat** – Barley	3076^{c}
S3 (1-year break)	Lentil XT – **Wheat** – Barley	2687^{c}
S4 (2-year break)	Barley CL – **Lentil XT** – Wheat	2058^{b}
S5 (2-year break)	Barley CL – **Lentil XT** – Wheat	2031^{ab}
S6 (3-year break)	Lentil XT – **Canola XC** – Wheat CL	1525^{ab}
S7 (3-year break)	Barley AX – **Metro lentil** – Canola TF	1514^{a}
P-value		**<0.001**

Canola XC (Hyola Regiment XC) is tolerant to glyphosate and Clearfield (imidazolinone) herbicides, which are both highly effective on brome grass (Table 5). In this system brome grass only produced 3 panicles/m^2 and canola grain yield of 1500 kg/ha. At canola grain price of >$600/t in 2025 and grain yield of >1.5 t/ha, inclusion of canola in the rotation for brome grass management would be a highly profitable option.

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Investigating the effects of time of sowing, sowing speed and sowing depth on pre-emergent herbicide crop safety and weed control

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Key findings

- The 2025 season was not conducive to excessive pre-emergent herbicide crop effect. There were few, if any, large or intense rainfall events at, or around the time of sowing, for both time of sowing (TOS) treatments. This led to the observation of minimal phytotoxicity of the emerging wheat plants.
- Sowing dry in April reduced plant establishment when compared to sowing into moisture in June. However, no difference in yield was observed.
- Minor phytotoxicity was observed (up to 8%), however this was temporary and did not affect final yield or quality in the TOS trial.
- Pre-emergent herbicides with high solubilities did not cause significant crop effect in 2025. Conversely, those herbicides with low solubilities may not have had acceptable weed control, as they did not receive enough rain to "activate" the active ingredient.

Aim

1. Demonstrate crop safety and weed control for a range of pre-emergent herbicides in wheat across two starting soil moisture conditions.
2. Demonstrate the implications of increasing sowing speed and sowing depth on wheat crop safety.

Introduction

With increased variation in autumn rainfall in recent years, many growers in the Mid North have been faced with the decision to dry sow or wait until moisture is available, influencing their pre-emergent herbicide selection. Many factors influence the efficacy and safety of herbicides in these conditions.

Herbicide damage is often observed as a result of decisions made at seeding. Common causes include shallow sowing, herbicide placement, post-sowing environmental conditions, soil characteristics and herbicide choice (Congreve & Cameron, 2023). Increasing sowing speed can increase the throw of treated soil, causing it to land in the adjoining crop rows. Sowing depth is a compromise between accessing soil moisture and separating the seed from the pre-emergent herbicide, while not affecting crop emergence. However, sowing too shallow can potentially place the seed into the herbicide band (Preston, 2022).

Two plot trials were conducted at Hart, SA in 2025 to evaluate the crop safety of various pre-emergent herbicides on wheat (*Triticum aestivum,* cv. Calibre and Scepter) in different sowing conditions.

Calibre and Septer were selected for their differing coleoptile lengths. Calibre has a very long coleoptile, so will tolerate sowing at greater depths, while Scepter has a short coleoptile, which can result in compromises with sowing depth and separation from the pre-emergent herbicide.

Table 1. Trial details for 2025 de-risking the seeding program trial at Hart, SA.

Plot size	1.75 x 10 m	**Previous crop**	Bale (awnless) wheat
Location	Hart, SA	**Soil N**	120.4 kg N/ha
Seeding date 1	April 24, 2025	**Fertiliser**	Seeding: TOS DAP (18:20) Zn 1% + Flutriafol at 100 kg/ha
Seeding date 2	June 13, 2025		
Harvest date	December 3, 2025		Speed x depth DAP (18:20) Zn 1% + Flutriafol at 80 kg/ha
GSR*	Decile 3 (223 mm)		

**GSR = Growing season rainfall*

Methodology

Trial design and treatments

Two trials were established at the Hart field site on a clay loam soil type using a small-plot knife-point press wheel seeder on 23 cm row spacings.

Trial 1: Pre-emergent herbicide time of sowing trial

This trial aimed to assess the impact of soil moisture conditions on pre-emergent herbicides applied IBS (incorporated by sowing), either standalone or in combination with Avadex (triallate) or trifluralin. Three treatments had a follow up application of either Mateno Complete or Boxer Gold early post-emergent at growth stage 23 (Table 2). This trial was replicated across two times of sowing; time of sowing one (TOS 1) which was dry sown in April and time of sowing two (TOS 2), sown in June following approximately 15 mm of rain, with 9.6 mm received one week later. Annual ryegrass seed was applied to each plot at a rate of 250 seeds/m^2 and lightly incorporated prior to the application of IBS herbicides.

Table 2. Treatment list for 2025 pre-emergent herbicide time of sowing trial at Hart, SA.

Treatment	Pre-emergent treatments (IBS)	Early post-emergent (GS 23)
1	Untreated control	
2	Sakura 118 g/ha	
3	Trifluralin 2 L/ha	
4	Boxer Gold 2.5 L/ha	
5	Overwatch 1.25 L/ha	
6	Luximax 0.5 L/ha	
7	Mateno Complete 1 L/ha	
8	Sakura 118 g/ha + Avadex 2 L/ha	
9	Trifluralin 2 L/ha + Avadex 2 L/ha	
10	Overwatch 1.25 L/ha + Avadex 2 L/ha	
11	Luximax 0.5 L/ha + Avadex 2 L/ha	
12	Overwatch 1.25 L + Trifluralin 2 L/ha	
13	Overwatch 1.25 L/ha	Mateno Complete 1 L/ha
14	Trifluralin 2 L/ha + Avadex 2 L/ha	Mateno Complete 1 L/ha
15	Sakura 118 g/ha	Boxer Gold 2.5 L/ha

Trial 2: Sowing speed x depth trial

This field trial tested various IBS herbicides and their effects at two sowing depths (10 or 40 mm) and two sowing speeds (4 and 8 km/hr) on crop safety across two wheat varieties; Calibre and Scepter (Table 3). Pre-emergent herbicide treatments were applied directly prior to sowing on June 13, 2025.

Table 3. Treatment list for 2025 pre-emergent herbicide sowing speed x depth trial at Hart, SA.

Variety	**Treatment**	**IBS treatments**
Calibre	1	Untreated control
	2	Trifluralin 2 L/ha
	3	Luximax 500 ml/Ha
	4	Boxer Gold 2.5 L/ha
	5	Sakura 118 g/ha
	6	Overwatch 1.25 L/ha
Scepter	7	Untreated control
	8	Luximax 500 ml/Ha
	9	Overwatch 1.25 L/ha

Each treatment is replicated for four different combinations of sowing depth and speed

Site management and environmental conditions

The trial was managed through the application of pesticides to ensure an insect, broadleaf weed and disease-free canopy. The 2025 growing season was characterised by below average rainfall (Decile 3; 223 mm) and this should be considered when interpreting crop safety and weed control data. The trial was not subject to stress from any other external or environmental factors.

Assessments

Trial data was analysed utilising REML spatial model (Regular Grid) in GenStat 24th Edition. Bonferroni critical difference values (Bonferroni CD) were calculated using average standard error of difference (SED) from the GenStat output and the relevant t critical value calculated in Excel. This number can be used to determine the difference required for a significant effect between treatments.

Trial 1: Pre-emergent herbicide time of sowing trial

Visual crop phytotoxicity (%) was assessed 11.5 weeks after TOS 1 and 4.5 weeks after TOS 2. Crop plant counts were conducted 12.5 weeks after TOS 1 and 6.5 weeks after sowing TOS 2 to determine plants/m^2 and any crop herbicide impacts on plant establishment. Annual ryegrass assessments include weed counts prior to early-post emergent application and head counts (m^2) to assess herbicide efficacy. Grain yield (t/ha), protein (%), test weight (kg/hL) and screenings (%) were assessed post-harvest.

Trial 2: Sowing speed x depth trial

Visual crop phytotoxicity (%) and normalised difference vegetation index (NDVI) was assessed using a handheld Greenseeker as a measure of crop biomass 4.5 weeks after sowing. Crop plant counts were conducted 5 weeks after sowing to determine plants/m^2 and any impact to crop safety. Grain yield (t/ha), protein (%), test weight (kg/hL) and screenings (%) were assessed post-harvest.

Results and discussion

Trial 1: Pre-emergent herbicide time of sowing trial

Wheat sown in April, into dry soil significantly reduced plant establishment when compared to sowing into moisture in June which was consistent with observations made in a time of sowing trial completed at Hart, SA in 2023. Crop phytotoxicity was more evident following TOS 2 (Table 4). Earlier sowing also significantly reduced wheat screenings when compared to TOS 2, with later sowing shortening the growing window, limiting time for grain fill and exposing critical developmental stages to warmer and drier conditions (Green et al, 2025).

Table 4. Time of sowing effect on crop emergence, phytotoxicity, yield and grain quality values for wheat from pre-emergent herbicide time of sowing trial at Hart, SA. Shaded values in each column indicate best performing treatments. Any difference between two means greater than the Bonferroni critical difference value is significant at α = 0.05 after Bonferroni correction.

TOS	Crop emergence (plants/m^2)	Phytotoxicity (%)	Yield (t/ha)	Protein (%)	Test weight (kg/hL)	Screenings (%)
1	183	0.2	1.86	11.6	79	6.3
2	223	1	1.83	11.7	79.1	7.4
P-value	**<0.001**	**<0.001**	**0.576**	**0.8**	**0.359**	**<0.001**
Bonferroni CD	**9.19**	**0.45**	**NS**	**NS**	**NS**	**0.57**

No difference was observed in annual ryegrass plant or head counts between any time of sowing or herbicide treatment. Annual ryegrass pressure was low across the trial site due to dry conditions.

Expression of crop phytotoxicity was very low (<5%) across the Hart site in 2025, with Overwatch and Luximax showing some temporary symptoms 12.5 weeks after TOS 1 and 6.5 weeks after sowing TOS 2 (Table 5 and Figure 1).

Figure 1. Image showing the effect on wheat resulting from the movement of cinmethylin (Luximax) herbicide into the furrow near the seed – July 15, 2025.

Figure 2. Photograph showing crop bleaching in wheat resulting from Bixlozone herbicide (Overwatch) - July 15, 2025.

Table 5. Herbicide effect on crop emergence, phytotoxicity, yield and grain quality values for wheat and plant and head counts for annual ryegrass (ARG) in the pre-emergent herbicide time of sowing trial at Hart. Shaded values in each column indicate best performing treatments. Any difference between two means greater than the Bonferroni critical difference value is significant at α = 0.05 after Bonferroni correction.

Pre-emergent Treatment	Early post-emergent treatment	Crop emergence (plants/m²)	Phytotoxicity (%)	ARG plant count (plants/m²)	ARG head count (heads/m²)	Yield (t/ha)	Protein (%)	Test weight (kg/hL)	Screenings (%)
Control		216	0.0^{a}	5	2	1.91^{ab}	11.7	79.2	6.1^{a}
Boxer Gold		194	0.0^{a}	2	2	1.86^{ab}	11.5	79.4	6.7^{abc}
Luximax		201	0.8^{ab}	0	0	1.81^{ab}	11.6	79.1	7.2^{abc}
Luximax + Avadex		187	0.0^{a}	2	0	1.74^{a}	11.7	79.0	7.0^{abc}
Mateno complete		212	0.0^{a}	1	2	1.83^{ab}	11.6	79.3	6.8^{abc}
Overwatch + Trifluralin		206	0.5^{a}	0	0	1.93^{ab}	11.7	79.4	6.6^{abc}
Overwatch		216	1.5^{abc}	0	0	1.88^{ab}	11.7	79.1	6.4^{ab}
Overwatch + Avadex		196	3.0^{bc}	0	0	1.92^{ab}	11.6	79.4	6.1^{a}
Overwatch	Mateno Complete	197	3.2^{c}	0	0	1.76^{a}	11.7	78.6	7.7^{bc}
Sakura		199	0.0^{a}	1	0	1.73^{a}	11.7	78.7	7.7^{abc}
Sakura + Avadex		211	0.0^{a}	0	0	1.88^{ab}	11.6	79.1	7.0^{abc}
Sakura	Boxer Gold	198	0.0^{a}	1	0	1.73^{a}	11.6	78.8	7.2^{abc}
Trifluralin		202	0.0^{a}	2	0	1.99^{b}	11.7	79.3	6.3^{a}
Trifluralin + Avadex		193	0.0^{a}	0	0	1.89^{ab}	11.7	79.2	6.5^{ab}
Trifluralin + Avadex	Mateno Complete	217	0.0^{a}	0	1	1.77^{ab}	11.6	78.5	8.2^{c}
P-value		**0.192**	**<0.001**	**0.209**	**0.339**	**<0.001**	**0.988**	**0.03***	**<0.001**
Bonferroni CD		**NS**	**2.29**	**NS**	**NS**	**0.23**	**NS**	**1.14**	**0.82**

**Results were variable, a significant result was identified, however differences between treatments were unable to be extracted by statistical model.*

Sakura, both standalone and followed by Boxer Gold, Luximax with Avadex, and Overwatch followed by Mateno Complete achieved the lowest yields (range 1.73-1.76 t/ha) which was significantly less than trifluralin standalone, however was statistically equivalent to all other treatments (Table 5). Trifluralin with Avadex followed by Mateno Complete had the highest level of screenings, however all treatments exceeded 5% and did not meet H1 or H2 receival standards.

Trial 2: Sowing speed x depth trial

Speed

No difference was observed across NDVI, crop phytotoxicity (%), crop emergence (plants/m^2), yield (t/ha) or protein (%) between 4 and 8 km/hr sowing speeds (data not shown). Differences were observed across screenings (%) and test weight (kg/hL), however results were variable and differences between treatments were unable to be extracted by statistical model.

Depth

Sowing shallow increased crop phytotoxicity slightly, however did not impact crop establishment or protein. Sowing at a standard depth of 40 mm significantly decreased yield, test weight, and increased screenings, as a result of small and inconsistent rainfall events during germination and emergence favouring shallow sowing (data not shown).

Herbicide

Crop phytotoxicity across both Calibre and Scepter was negligible, however the use of Overwatch did increase these effects (Table 6 and Figure 2). In comparison to the untreated control (UTC), wheat yield was reduced when Sakura was applied to Calibre, this was also observed in the TOS trial. All other treatments achieved equivalent yield to the UTC. Increased screenings and reduced test weight was also observed when Sakura was applied to Calibre. Scepter treatments achieved statistically equivalent yield, screenings, protein and test weight to the Scepter UTC.

Speed and depth

Sowing at 4 km/hr at 10 mm depth significantly increased yield and reduced protein when compared to sowing at the same speed at 40 mm depth, however, was statistically equivalent to both depths at 8 km/hr (Table 7). All speed and depth combinations achieved statistically equivalent screenings except for sowing at 4 km/hr at 10 mm which achieved significantly less.

Table 6. Herbicide effect on phytotoxicity, yield and grain quality values for wheat from pre-emergent herbicide speed x depth trial at Hart, SA. Shaded values in each column indicate best performing treatments. Any difference between two means greater than the Bonferroni critical difference value is significant at α = 0.05 after Bonferroni correction.

Variety	Treatment	Crop phytotoxicity (%)	Yield (t/ha)	Screenings (%)	Protein (%)	Test weight (kg/hL)
Calibre	1. Untreated control	0.0^{a}	1.78^{bc}	9.3^{abc}	13.2^{ab}	75.1^{b}
	2. Trifluralin 2 L/ha	0.0^{a}	1.71^{ab}	9.2^{abc}	13.3^{ab}	74.9^{ab}
	3. Luximax 500 ml/Ha	0.0^{a}	1.75^{abc}	10.3^{c}	13.4^{ab}	74.8^{ab}
	4. Boxer Gold 2.5 L/ha	0.0^{a}	1.75^{abc}	10.3^{bc}	13.4^{ab}	75.2^{b}
	5. Sakura 118 g/ha	0.3^{a}	1.66^{a}	11.7^{d}	13.6^{b}	74.2^{a}
	6. Overwatch 1.25 L/ha	1.9^{b}	1.80^{bc}	9.2^{abc}	13.3^{ab}	75.1^{b}
Scepter	7. Untreated control	0.0^{a}	1.82^{c}	8.6^{a}	13.0^{a}	77.6^{c}
	8. Luximax 500 ml/Ha	0.0^{a}	1.77^{bc}	9.6^{abc}	13.1^{ab}	77.2^{c}
	9. Overwatch 1.25 L/ha	5.3^{c}	1.81^{bc}	9.0^{ab}	13.2^{ab}	77.5^{c}
	P-value	**<0.001**	**<0.001**	**<0.001**	**0.007**	**<0.001**
	Bonferroni CD	**1.65**	**0.11**	**1.38**	**0.54**	**0.85**

Table 7. Speed and depth effect on phytotoxicity, yield and grain quality values for wheat from pre-emergent herbicide speed x depth trial at Hart, SA. Shaded values in each column indicate best performing treatments. Any difference between two means greater than the Bonferroni critical difference value is significant at α = 0.05 after Bonferroni correction.

	Crop phytotoxicity (%)	Yield (t/ha)	Screenings (%)	Protein (%)	Test weight (kg/hL)
4 km/hr 10mm	1.1	1.83^{b}	8.4^{a}	13.0^{a}	76.4
4 km/hr 40mm	0.3	1.71^{a}	10.6^{b}	13.5^{b}	75.4
8 km/hr 10mm	1.0	1.77^{ab}	9.7^{b}	13.4^{ab}	75.8
8 km/hr 40mm	0.9	1.75^{ab}	10.1^{b}	13.2^{ab}	75.3
P-value	**0.158**	**0.028**	**<0.001**	**0.008**	**0.271**
Bonferroni CD	**NS**	**0.08**	**1.14**	**0.47**	**NS**

Summary

The 2025 season was not conducive to excessive pre-emergent herbicide crop effect. There were few, if any, large or intense rainfall events at, or around the time of sowing, for both TOS treatments. This lead to the observation of minimal phytotoxicity of the emerging wheat plants in the trials. Dry conditions also reduced annual ryegrass emergence and limited the crop safety effects observed.

Pre-emergent herbicides with high solubilities did not cause significant crop effect in 2025. Conversely, those herbicides with low solubilities may not have had acceptable weed control, as they did not receive enough rain to “activate” the active ingredient.

It is a fine line between crop effect and weed control with the newer chemistries that growers have access to in current farming systems. Caution and consideration should be exercised on a seasonal basis, weighing up the risk of potential crop effect from the pre-emergent herbicides chosen for that crop, in that year, as every season is different. What worked, or didn't work, will vary from season to season, due to difference in herbicide characteristics, like the solubility of the active ingredient.

Acknowledgements

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Useful resources

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Tackling fusarium root rot of lentil with novel strategies – harvest report

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Key findings

- Root rots are common in lentil and often reduce yield.
- Fusarium avenaceum is a key fungal pathogen causing root rot, reducing germination and infecting plant roots.
- A field trial at Hart in 2025 demonstrated that F. avenaceum inoculum reduced lentil yield by up to 48%. Use of a seed treatment produced yields equivalent to the uninoculated control.

Introduction

Key cereal soilborne diseases such as crown rot, Rhizoctonia root rot and root lesion nematode are estimated to cost Australian grain growers more than $500 million per annum in direct yield losses. These diseases are quite well known by growers and agronomists, and often are identified where they have a clear impact on a crop. Pulses and canola are also impacted by soilborne diseases but unlike cereals, these diseases are less well known by industry, and impacts may go unnoticed or be misdiagnosed. Globally, several diseases are considered major constraints to pulse production, including root rots caused by various *Fusarium* species.

Previous surveys (2019-2020) of poor performing pulse crops across Australia have demonstrated that root diseases are common, and further work has led to the identification of key soilborne pathogens likely reducing pulse yields. *Fusarium avenaceum*, *Rhizoctonia solani* AG8, and *Didymella pinodella* are commonly found in soil/root DNA tests through the Mid North, as well as in other Australian growing regions. These pathogens have long been known to affect pasture legumes such as medic and clover, but their effect on lentil yield is not well established. Around 20% of poor performing pulse root samples were found to have *F. avenaceum* present. This means that some paddocks, but not all, will benefit from knowing the inoculum level present, and making a management plan. Seed treatments can be a cost-effective means of protecting crops against diseases that affect emerging and young plants. As the Mid North of SA is a key pulse production region, Hart is an ideal location to conduct pulse disease research relevant to a large number of growers. This experiment at Hart tested the effectiveness of three fungicide seed treatments in managing Fusarium root rot caused by *Fusarium avenaceum* at nil, low and medium inoculum levels in lentils.

Methodology

Plots of lentil cv. PBA Hallmark XT⚘ were sown at a target density of 120 plants/m^2 on June 27. The field experiment comprised three fungicide seed treatments as well as an untreated control, sown into three *F. avenaceum* inoculum densities. Inoculum was produced on sterile millet grain in the laboratory before being dried, then sown with the seed during normal sowing operations. Inoculum was applied either as nil (control), low (1 g inoculum/linear metre crop row) or medium (3 g/lm). Inoculum densities were based on previous research undertaken by the research team. The experiment was set out in a randomised complete block design with three replicates of each treatment. Not all possible combinations of seed treatment and inoculation were included due to space constraints.

Table 1. Treatments applied to lentil at Hart, 2025.

ID	Treatment	Inoc level	Seed treatment
1	Control untreated	nil	nil
2	Med untreated	med	nil
3	Control ST1	nil	ST1
4	Low ST1	low	ST1
5	Med ST1	med	ST1
6	Control ST2 (PPT)	nil	ST2
7	Low ST2 (PPT)	low	ST2
8	Med ST2 (PPT)	med	ST2
9	Control ST3	nil	ST3
10	Med ST3	med	ST3

Seed treatments were selected with input from crop protection companies, and chosen because their active ingredients are considered likely to have effect on the pathogen, and also because they are available in Australia, meaning they have potential to be registered if found to be sufficiently effective. One seed treatment (ST2, PPT/Evershield) is currently registered, and the two others are not registered for this use at this time.

Measurements taken throughout the year were emergence, plant and root weight at early flowering, root disease and nodulation assessment at early flowering, and yield. Statistical analysis was completed using a 1-way ANOVA in Genstat.

Results and discussion

Statistical analysis showed that there were significant effects of treatments on emergence, plant and root weight, root disease, nodulation and yield (Table 2).

The medium density of *F. avenaceum* inoculation reduced establishment by approximately 60% (Figure 1). However, all seed treatments were effective at both the low and medium inoculum densities, and had similar emergence to the non-inoculated control. This shows that the seed treatments were able to protect the lentils in the critical early stage of emergence.

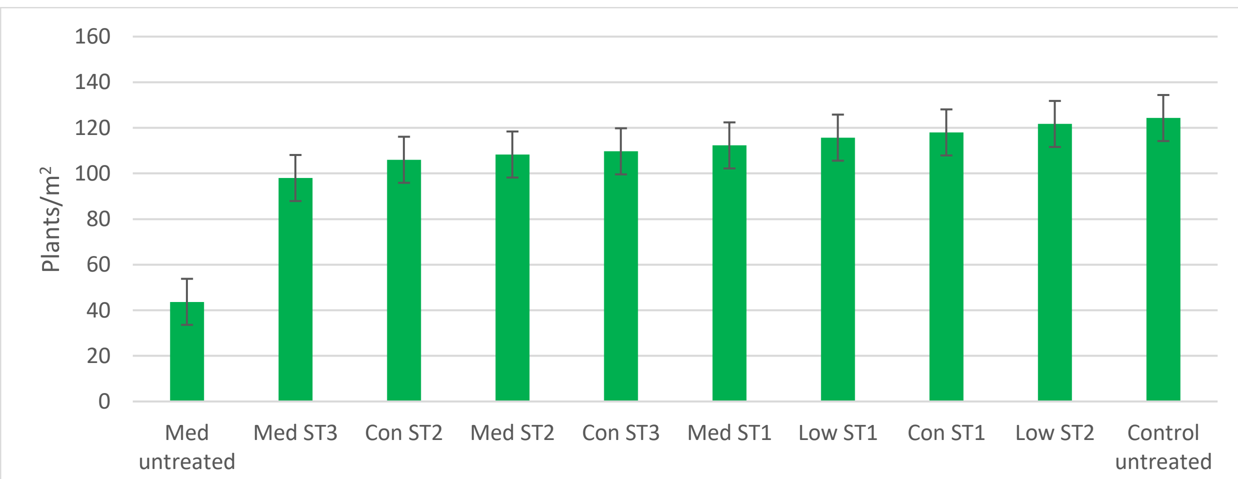

Figure 1: Emergence of lentils with different rates of fungal infection and/or fungicides.

Plant and root weight (results not shown) were similar in all treatments except the inoculated control. Due to the low plant numbers and less competition for resources in the inoculated control, the remaining plants and root systems were larger than the other treatments. This did not compensate for the lower plant numbers in harvested yield.

Root disease ratings were significantly higher in the inoculated plots with no seed treatment (Figure 2). Seed treatment resulted in root disease ratings being similar to the healthy control.

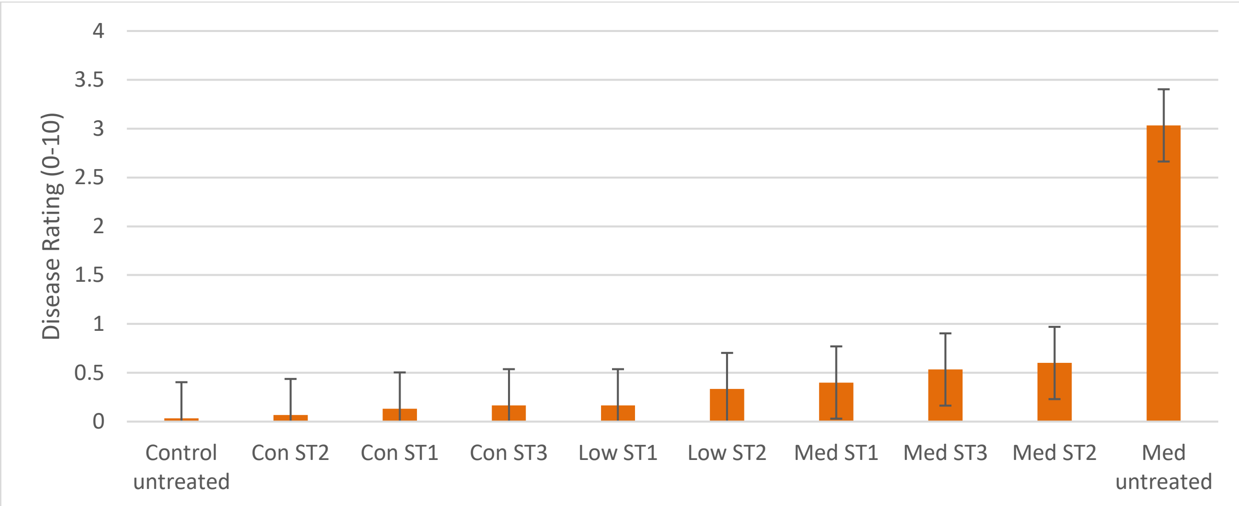

Figure 2: Disease rating (0-10) of lentil roots with different levels of F. avenaceum and seed treatment at Hart in 2025.

Nodulation of the roots was assessed. The inoculated control had less rhizobium nodules than the healthy control and the treated inoculated plots.

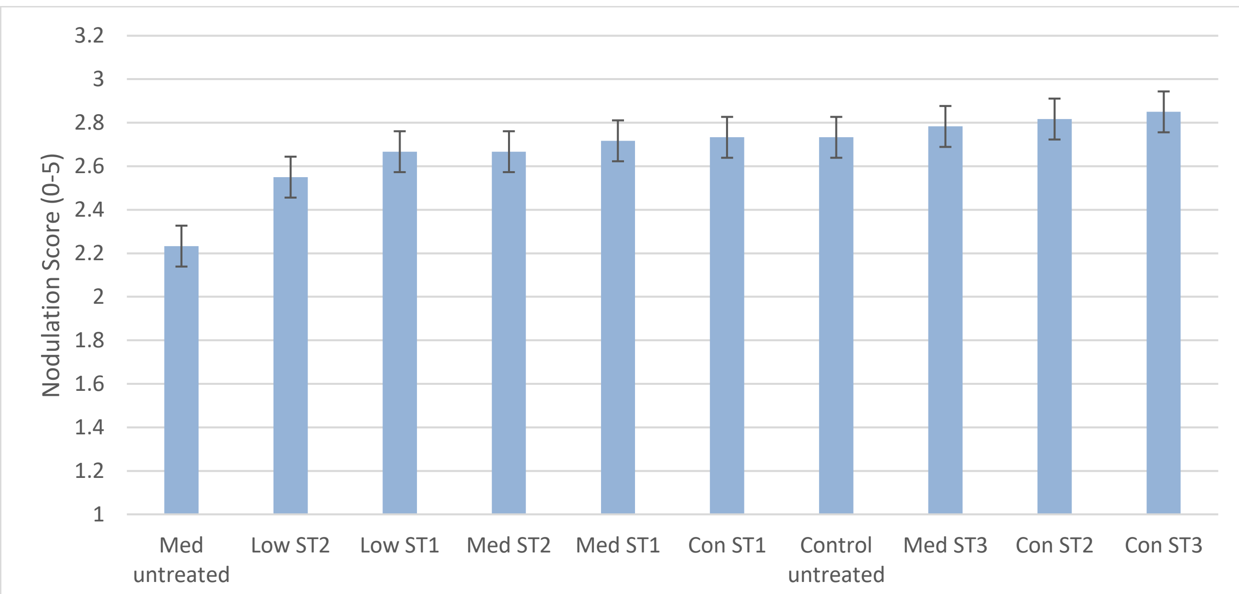

Figure 3: Lentil root nodulation scores (0-5) for lentil roots at Hart 2025.

Yield was significantly lower in the inoculated control plot, at 52% of the untreated control (Figure 4). This was due to the low number of plants in the inoculated control plot. Although these plants had grown larger, they were unable to compensate for the loss of numbers when it came to grain yield.

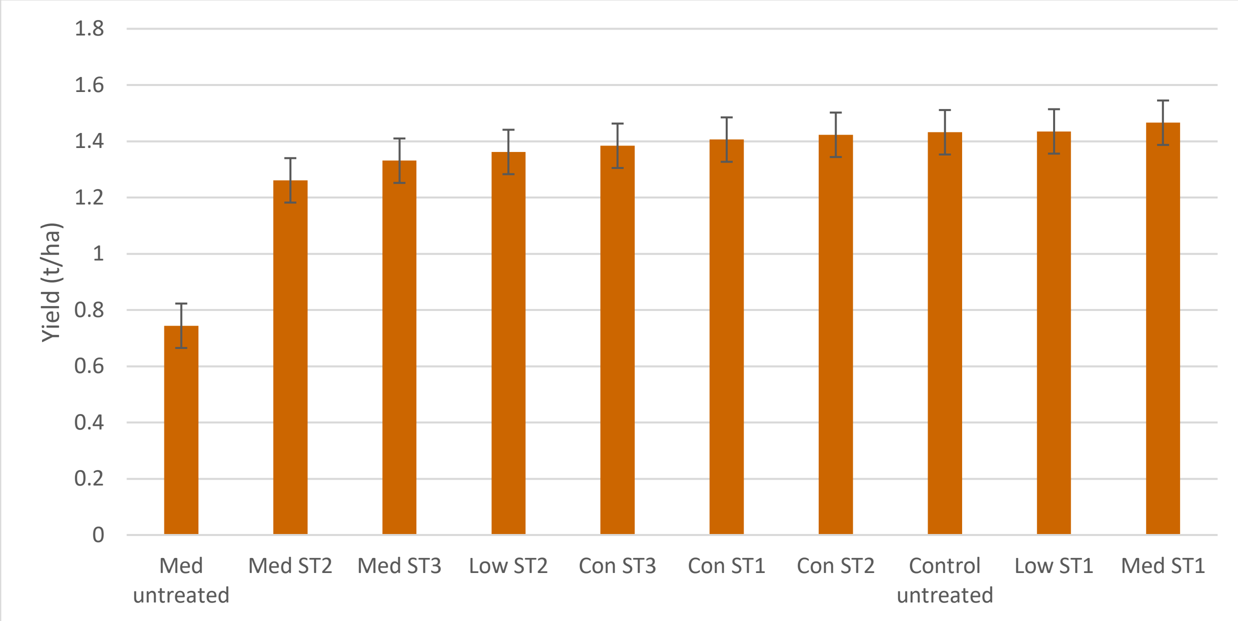

Figure 4: Lentil yield with F. avenaceum and seed treatment at Hart 2025.

Table 2: Results of measurements of lentil trial at Hart, 2025, comparing seed treatment effects on plots with and without F. avenaceum infection. Different letters indicate a significant effect at an alpha level of 0.05. Shaded values indicate significant best performing treatments.

Measurement / **Treatment**	**Emergence (p/m^2)**	**Root disease (0=none, 10 =max)**	**Nodulation (0=none, 5 = max)**	**Yield (t/ha)**
Control untreated	124^{c}	0.03^{a}	2.73^{bc}	1.43^{c}
Med untreated	44^{a}	3.03^{b}	2.23^{a}	0.74^{a}
Control ST1	118^{bc}	0.13^{a}	2.73^{bc}	1.41^{bc}
Low ST1	116^{bc}	0.17^{a}	2.67^{bc}	1.44^{c}
Med ST1	112^{bc}	0.4^{a}	2.71^{bc}	1.47^{c}
Control ST2	106^{bc}	0.07^{a}	2.81^{c}	1.42^{bc}
Low ST2	122^{c}	0.33^{a}	2.55^{b}	1.36^{bc}
Med ST2	108^{bc}	0.6^{a}	2.67^{bc}	1.26^{b}
Control ST3	110^{bc}	0.17^{a}	2.85^{c}	1.38^{bc}
Med ST3	98^{b}	0.53^{a}	2.78^{c}	1.33^{bc}
LSD	**21.7**	**0.79**	**0.2**	**0.165**
Significance	**<0.001**	**<0.001**	**<0.001**	**<0.001**

Conclusions

Seed treatment with a fungicide in inoculated plots resulted in improved emergence, root disease scores, rhizobium nodulation and yields when compared to inoculated plots with no seed treatment. Inoculated plots with seed treatment were mostly very similar to plots with no inoculation, showing that seed treatment can be an effective means of protecting against *F. avenaceum* during crop establishment.

Management of net form net blotch (NFNB) of barley in the low and medium rainfall zones of South Australia

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Key findings

- In 2025, low NFNB pressure meant disease did not cause economically significant yield losses in either the medium or low rainfall zones.
- Fungicide applications, particularly at GS 31 and GS 39, reduced NFNB severity in susceptible varieties, however this did not consistently translate into yield benefits under low disease pressure.

Introduction

Net form of net blotch (NFNB) is now a widespread foliar disease commonly observed across southern Australian barley regions. Surveillance shows it occurs in most crops, is often severe in high rainfall zones (HRZ), and can also cause losses in medium (MRZ) and low rainfall zones (LRZ) when conditions favour infection. The disease is most problematic in susceptible varieties grown widely and in areas where fungicide resistance has developed.

Despite its prevalence, little is known about yield losses in the MRZ and LRZ, the conditions required to cause losses across regions, or the level of varietal resistance needed to minimise risk.

Fungicides remain an important management tool, but their reliability has declined due to increasing resistance. Widespread resistance to Group 7 and Group 3 fungicides is commonly observed, however recently, a triple resistance involving Group 11 has been identified. As a result, growers will need to adopt more strategic, integrated management approaches.

To address this, trials in South Australia evaluated the roles of varietal resistance and fungicide timing at Hart (MRZ, Mid North) and Calca (LRZ, Eyre Peninsula).

Methodology

At both the low rainfall zone (LRZ; Calca) and medium rainfall zone (MRZ; Hart) sites, replicated field trials were established using a randomised complete block design with six replicates. At each site, three commonly grown barley varieties with differing levels of resistance to NFNB were selected and infected with NFNB spore inoculum using a knapsack sprayer at tillering stage (GS 25). Fungicide treatments were applied at two growth stages: stem elongation (GS 31) and flag leaf emergence (GS 39).

NFNB severity was visually assessed at key growth stages by estimating the percentage of leaf area affected on ten representative plants per plot. An average disease severity score was calculated for each plot by averaging scores across the ten plants. Grain yield and quality were measured at harvest on November 12, 2025 at Hart and on December 8, 2025 at Calca.

Statistical analyses were conducted using Genstat (VSNi 23), with fungicide treatments and varietal responses compared using standard analysis of variance (ANOVA) procedures.

Barley varieties used in the trials

- **Hart (MRZ):**
  #Maximus CL (MRMS), Commodus CL (MSS), RGT Planet (SVS)
- **Calca (LRZ):**
  #Maximus CL (MRMS), Beast (S), Spartacus CL (VS)

 # MRMS – Moderately resistant to moderately susceptible; MSS – Moderately susceptible to susceptible; S – Susceptible; SVS – Susceptible to very susceptible.

Fungicide treatments

Four treatments were applied at each site:

1. **Foliar application at GS 31:**
   Prosaro 420 SC® (Prothioconazole 210 g/L + Tebuconazole 210 g/L) at 150 mL/ha
2. **Foliar applications at GS 31 and GS 39:**
   Prosaro 420 SC® at 150 mL/ha at GS 31 followed by Amistar Xtra® at 200 mL/ha at GS 39 (Azoxystrobin 200 g/L + Cyproconazole 80 g/ha)
3. **Foliar application at GS 39:**
   Amistar Xtra® at 200 mL/ha
4. **Untreated control:**
   No fungicide applied.

Table 1. Trial details for 2025 net form net blotch trials at Hart and Minnipa (Calca), SA.

Location	Hart field site	Calca
Average annual rainfall	419.7 mm	376.7 mm
Average growing season rainfall (GSR)	308.9 mm	301.7 mm
2025 Total	234.0 mm	346.4 mm
2025 GSR	206.6 mm	292.2 mm
Soil type	Clay loam	
Paddock history		
2024	Bale awnless wheat	
2023	Kingbale oaten hay	
2022	Scepter wheat	
Plot size	12 m x 1.7 m x 6 replicates	20 m x 20 m x 6 replicates

Results and discussion

Seasonal conditions in 2025 were generally unfavourable for the development of NFNB, and disease development was slow at both trial sites.

At Hart (MRZ), fungicide treatments significantly reduced NFNB severity in the susceptible variety RGT Planet at flag leaf emergence (Table 2). The application of Prosaro 420 SC® at GS 31 followed by Amistar Xtra® at GS 39 had the greatest reduction in disease severity, reducing pressure from 10% in the untreated control (UTC) to 1% at grain filling stage (GS 73) in RGT Planet. However, disease pressure was transient, and flag-leaf emergence disease levels had no significant effect on final yield.

Disease levels were negligible in the moderately resistant varieties Commodus CL and Maximus CL, regardless of fungicide treatment. At Calca (LRZ), NFNB severity remained low across all varieties and fungicide treatments throughout the season. As a result, no significant differences in grain yield were observed between treatments (Table 3).

No significant differences were observed for grain quality between treatments (data not shown).

Table 2: Net form net blotch (NFNB) severity (%) and grain yield (t/ha) of three barley varieties in response to different fungicide treatments at Hart, Mid North, South Australia, 2025. Shaded values indicate best performing treatments.

Variety / Treatment	RGT Planet (SVS)		Commodus CL (MSS)		Maximus CL (MS)	
	NFNB severity % GS 73, Oct 10	Yield (t/ha)	NFNB severity % GS 73, Oct 10	Yield (t/ha)	NFNB severity % GS 73, Oct 10	Yield (t/ha)
Untreated control	10[c]	2.0	2	2.7	0	2.7
Foliar spray at GS 31	7[b]	2.1	2	2.7	0	2.8
Foliar spray at GS 39	7[b]	1.7	5	2.4	0	2.4
Foliar spray at GS 31 + 39	1[a]	1.8	1	2.6	0	2.6
P-value	**<0.001**	**0.46**	**0.22**	**0.58**	**0.44**	**0.35**
LSD (0.05)	**2.7**	**ns**	**ns**	**ns**	**ns**	**ns**

Table 3: Net form net blotch (NFNB) severity (%) and grain yield (t/ha) of three barley varieties in response to different fungicide treatments at Calca, Eyre Peninsula, South Australia, 2025.

Variety / Treatment	Spartacus CL (VS)		Beast (S)		Maximus CL (MS)	
	NFNB severity % GS 71, Oct 8	Yield (t/ha)	NFNB severity % GS 71, Oct 8	Yield (t/ha)	NFNB severity % GS 71, Oct 8	Yield (t/ha)
Untreated control	5	3.16	3	3.69	2	3.34
Foliar spray at GS 31	4	3.21	2	3.80	2	3.10
Foliar spray at GS 39	5	3.11	2	3.67	2	3.16
Foliar spray at GS 31 + 39	4	3.03	2	3.96	2	3.33
P-value	**0.57**	**0.91**	**0.24**	**0.60**	**0.78**	**0.83**
LSD (0.05)	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**

Summary

In 2025, seasonal conditions were not favourable for the development of net form of net blotch (NFNB), resulting in low disease pressure at both the medium (Hart) and low rainfall (Calca) sites. The application of Prosaro 420 SC® at GS 31 followed by Amistar Xtra® at GS 39 had the greatest reduction in disease severity, however all fungicides reduced NFNB severity in RGT Planet (SVS). This did not result in higher yields, as disease pressure declined later in the season.

At Calca, NFNB levels were low across all varieties and fungicide treatments, and no yield benefits from fungicide application were detected.

Overall, results indicate that under low to moderate NFNB pressure, fungicide applications are unlikely to deliver consistent economic returns, even in susceptible varieties. Growing moderately resistant varieties, such as Maximus CL, reduced disease risk and further limited the need for fungicides.

These findings highlight the importance of aligning fungicide use with seasonal disease risk and varietal resistance. In low rainfall zones and low disease pressure seasons with modest yield potential (~3 t/ha), regular crop monitoring is likely sufficient, and avoiding unnecessary fungicide applications can help reduce costs and slow the development of fungicide resistance.

Acknowledgements

The research undertaken as part of this project is made possible by the significant contributions of growers through both trial cooperation and the support of the GRDC, the authors would like to thank them for their continued support. Funding for this work was provided by the South Australian Government (SARDI) and the GRDC (DAQ2304-008RTX). Thanks to the Hart Field-Site Group and Minnipa Agricultural Centre for field trials and to our research collaborators across the country.

Photo. Looking over the net form net blotch trial at Hart, 2025.

Hart lentil disease management 2025

Amber Spronk[1], Sarah Day[2], Mohsen Khani[3] and Jamal Khan[1]

[1] SARDI Clare Agronomy, [2] Mallee Sustainable Farming, [3]SARDI Waite Pulse Pathology

Key findings

- Early season crop establishment was uneven, likely influenced by soil variability and dry conditions rather than disease.
- Lentil disease pressure was low in 2025, with only Ascochyta blight detected mid-season. No Botrytis grey mould (BGM) was observed.
- Due to the low disease pressure experienced during 2025, grain yield in plots receiving pre-canopy closure fungicide applications was not statistically greater than that of untreated plots.
- Results highlight that fungicide decisions should be guided by seasonal forecasts and disease risk during the season, as prophylactic sprays are unlikely to be cost-effective in low-pressure years.

Aim

Use different fungicide strategies to quantify yield loss resulting from disease infection in lentil crops.

Methodology

As part of the GRDC-funded South Australian Grain Legume Project (UOA2105-013RTX), a disease management field trial was conducted at the Hart field site in 2025 to assess grain yield loss from foliar diseases in lentil crops. The trial compared three fungicide management strategies (Table 1 and 2) across three lentil varieties – GIA Thunder, PBA Bolt and PBA Highland XT. Fungicide programs targeted ascochyta blight (AB) and botrytis grey mould (BGM). The trial was set up as a randomised block design with three replicates and was sown with a small plot seeder on May 16 at planting density of 120 plants/m^2 with 80 kg/ha of MAP + Zn. Weeds were controlled with herbicides or hand weeded as needed. Plots were harvested at crop maturity and grain yield was converted from kg/plot to t/ha. Data was analysed using a standard analysis of variance (ANOVA) and fisher's least significant difference tests was used to compare the treatment means in base R.

Table 1. Fungicide treatments applied to lentil for control of ascochyta blight and botrytis grey mould, compared to an untreated control, at Hart, SA 2025.

Proposed fungicide (timing of application)	Actual fungicide treatments applied
Untreated control	Untreated control (No fungicide)
Veritas Opti® (pre-canopy closure & podding stage)	Veritas Opti® (pre-canopy closure)
Miravis® Star (pre-canopy closure & podding stage)	Miravis® Star (pre-canopy closure)
Procymidone (canopy closure), Chlorothalonil (podding stage)	Procymidone (pre-canopy closure)

Table 2. *Fungicide product details including product, rate, active ingredient, and concentration applied at Hart lentil disease management field trial in 2025.*

Product	**Active ingredient (concentration)**	**Rate (mL or g/ha)**
Miravis® Star	Fludioxonil (150 g/L) + Pydiflumetofen (100 g/L)	540
Veritas Opti®	Tebuconazole (370 g/L) + Azoxystrobin (222 g/L)	1000
Fortress®500	Procymidone (500 g/L)	500

Results and discussion

The crop was sown on May 16 into very dry soil and received only minimal rainfall until mid-June, resulting in a slow and challenging start to the season. This led to uneven establishment, with patchiness and growth variability observed across the trial area (Figure 1a.) These differences were likely influenced by soil type variation and/or residual soil chemical effects. Overall, seasonal conditions were not conducive to disease development, mostly due to the dry early spring. The only visible disease noted was ascochyta blight, detected at minimal levels in late August (less than 10%; Figure 1b). Due to drier than average early spring, ascochyta blight did not progress further. Conditions conducive for the development of botrytis grey mould include a dense canopy combined with prolonged high humidity and temperatures above 15°C. These conditions were not experienced during early spring 2025; therefore, BGM was not observed at the field trial site.

Pre-canopy closure fungicide treatments were applied on September 8, however, due to low level of disease during the later stage of crop development, the planned fungicide sprays for podding stage were not applied. While podding sprays can be important for managing ascochyta blight pod infection, they were not considered economically viable under the conditions experienced in this trial. As a low level of disease was observed in the field trial, disease ratings were not undertaken. Grain yield did not vary significantly between fungicide treatments on average across all varieties in the absence of significant disease infection ($P = 0.799$ at $\alpha = 0.05$; Figure 2) and the interactive effect of fungicide and varieties did not change grain yield ($P = 0.915$ at $\alpha = 0.05$; Figure 3). These findings indicate that fungicide use should be driven by in-season disease risk and seasonal outlooks, as routine preventative applications are unlikely to be cost-effective in years with low disease pressure, like 2025.

Figure 1. a) Variation in crop performance/growth due to a dry spring and soil variability, b) Ascochyta blight symptoms on lentil plants. Photo credit: Sarah Day.

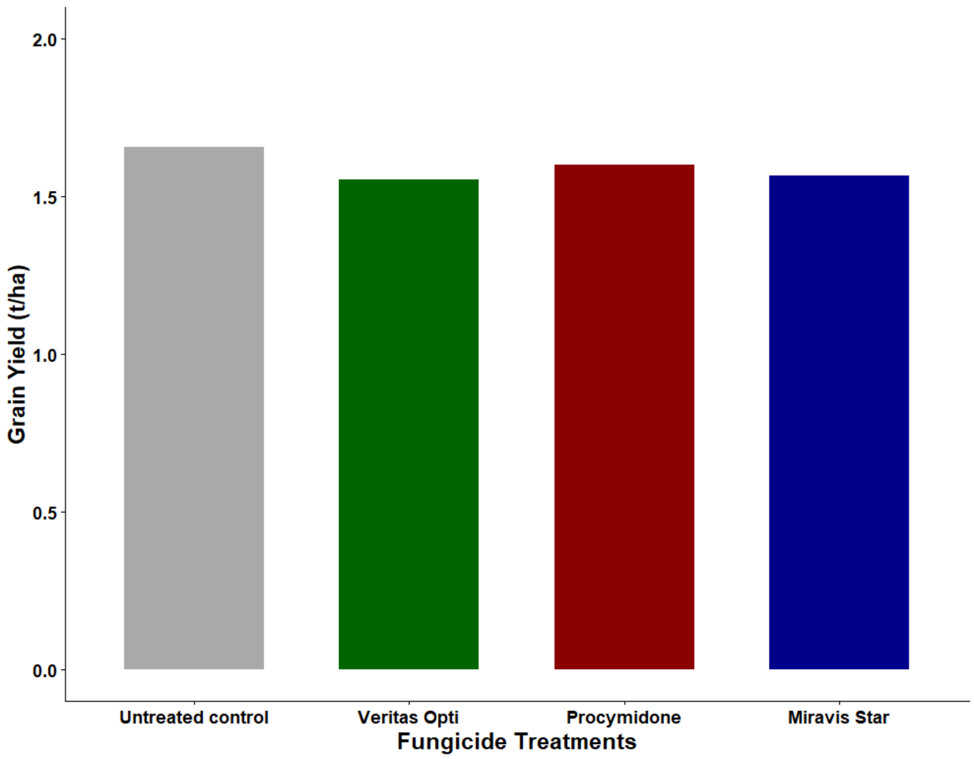

Figure 2. Impact of fungicide treatments on grain yield (t/ha) of lentil, averaged across all varieties, at Hart 2025 lentil disease management field trial in the absence of significant disease infection in 2025 (P = 0.788 at α = 0.05).

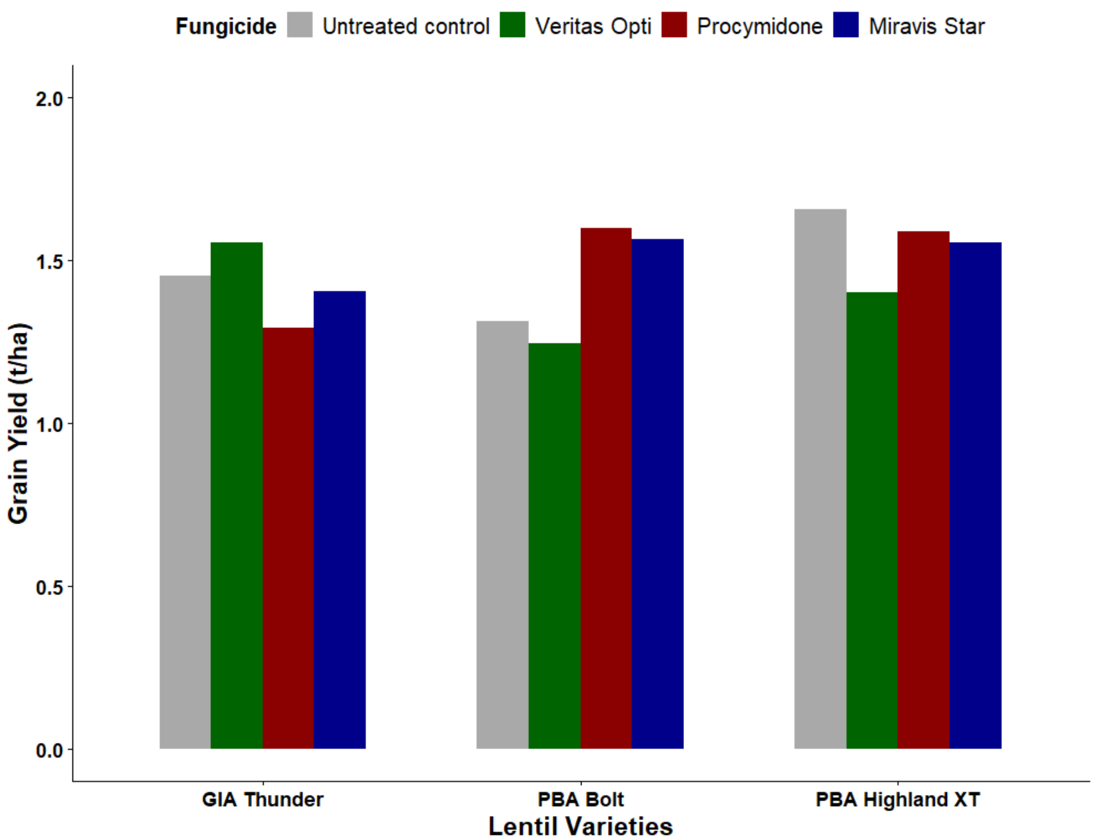

Figure 3: Interactive effect of fungicide treatments and lentil varieties on grain yield in the absence of significant disease infection in 2025 (P=0.915 at α = 0.05).

Resources:

SA Grain Legume project: https://msfp.org.au/projects/grain-legume-production-in-south-australia/

South Australian Crop Sowing Guide https://grdc.com.au/resources-and-publications/all-publications/nvt-crop-sowing-guides/sa-crop-sowing-guide

Pulse diseases - latest developments and trends https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2026/02/pulse-diseases-latest-developments-and-trends

Acknowledgments

The research undertaken as part of SA Grain Legume Project and is made possible by the significant contributions of growers through both trial cooperation and the support of the GRDC and Hart Field-Site Group, the authors thank them for their continued support.

Photo. SARDI senior researcher, Blake Gontar, presenting at the 2025 Hart Field Day.

Strategies to improve control of herbicide-resistant broadleaf weeds in lentils

Christopher Preston[1] and Kaidy Morgan[2]

[1]Adelaide University, [2]Hart Field-Site Group

Introduction

The cultivation of imidazolinone (Imi)-tolerant lentils has allowed for the control of a number of difficult broadleaf weeds in lentil production. However, the over-reliance on Intervix and other Imi herbicides for weed control has resulted in the evolution of weed resistance. In lentil growing regions Imi resistance is now common in common sowthistle, prickly lettuce and Indian hedge mustard. Resistance has also recently been reported in wild vetch and snail medic. Several of these weed species can germinate in early spring and cause problems at harvest. There are limited effective alternative herbicides for broadleaf weed control in lentils. Most of these herbicides are residual and can cause damage to lentils.

This trial was established to compare strategies that might be used to provide the extended control of broadleaf weeds required. One strategy is to sow lentils on time and increase the number of residual herbicides used. This strategy has the risk of increased crop damage. A second strategy is to sow lentils late, where fewer herbicides are needed to control spring germinating broadleaf weeds. This strategy will compromise lentil yield. The third strategy is to sow GIA Metro lentils, where metribuzin can be used safely. However, GIA Metro lentils have a yield penalty compared to cultivars like GIA Thunder.

Methodology

The trial was sown at Hart with GIA Thunder and GIA Metro sown on June 20, 2025. Seed of common sowthistle and Indian hedge mustard was spread on the plots prior to sowing. The late GIA Thunder sowing was on July 3, 2025. The six weed control strategies used are in Table 1. WeedErase is a mechanical weed control tool that uses blue light and heat to control weeds. The trial was harvested on November 18, 2025. Crop establishment was assessed on July 30, 2025, and weed counts conducted on October 23, 2025 to capture spring germinating weeds. The WeedErase treatment was applied to surviving broadleaf weeds on September 3, 2025.

Table 1. Weed control strategies used in the lentil trial at Hart in 2025.

Weed control strategy	Herbicides and other tactics applied
1	Nil
2	Reflex at 0.75 L/ha IBS
3	Terbyne Xtreme at 0.86 kg/ha IBS
4	Reflex at 0.75 L/ha IBS, Metribuzin at 280 g/ha PSPE
5	Terbyne Xtreme at 0.86 kg/ha IBS, Metribuzin at 280 g/ha PSPE
6	Terbyne Xtreme at 0.86 kg/ha IBS, Metribuzin at 280 g/ha PSPE, WeedErase post emergent

Results and discussion

While Indian hedge mustard and sowthistle seed were spread across the site prior to sowing, weed numbers in the trial were low (Table 2). For sowthistle, all the herbicide strategies worked well. For Indian hedge mustard, herbicide strategies containing metribuzin were the most effective.

Table 2. Crop establishment, crop yield and weed numbers in lentils at Hart in 2025.

Crop	Strategy	Crop establishment (plants/m²)	Crop yield (t/ha)	Indian hedge mustard (plants/m²)	Sowthistle (plants/m²)
GIA Thunder	1	134^{ab}	1.21^{ab}	5^{ab}	7^{a}
	2	132^{ab}	1.35^{a}	2^{b}	2^{bc}
	3	136^{ab}	1.40^{a}	10^{a}	0^{c}
	4	117^{b}	1.08^{ab}	0^{b}	1^{bc}
	5	113^{b}	0.96^{ab}	0^{b}	0^{c}
	6	114^{b}	0.85^{ab}	0^{b}	0^{c}
GIA Metro	1	147^{ab}	0.91^{ab}	13^{a}	3^{abc}
	2	142^{ab}	0.77^{b}	1^{b}	1^{bc}
	3	135^{ab}	0.86^{ab}	1^{b}	0^{c}
	4	153^{a}	0.98^{ab}	0^{b}	0^{c}
	5	161^{a}	1.10^{ab}	0^{b}	0^{c}
	6	159^{a}	0.87^{ab}	0^{b}	0^{c}
GIA Thunder sown late	1	122^{ab}	1.24^{ab}	6^{ab}	5^{ab}
	2	135^{ab}	1.22^{ab}	10^{a}	0^{c}
	3	133^{ab}	1.47^{a}	6^{ab}	0^{c}
	4	120^{ab}	1.20^{ab}	0^{b}	0^{c}
	5	130^{ab}	0.82^{ab}	0^{b}	0^{c}
	6	126^{ab}	0.65^{b}	0^{b}	0^{c}
P-value		**<0.0001**	**0.03**	**0.003**	**<0.0001**

Crop establishment was affected by herbicide strategy with metribuzin treatments reducing stand number for GIA Thunder. This did not occur when GIA Thunder was sown late, indicating the role that rainfall after herbicide application has on the safety of metribuzin. GIA Metro was not affected by metribuzin treatments.

The late start to the season and low spring rainfall resulted in low lentil yields. This meant there were only a few differences in yield. GIA Thunder with single residual herbicide applications had the highest yields.

Where multiple residual herbicides are to be used, it would be preferable to have the crop safety to metribuzin that is available in GIA Metro rather than risk increased crop damage. Where this is not the case, the yield penalty of GIA Metro makes it a less preferred cultivar.

This trial demonstrates that trying to control Imi-resistant broadleaf weeds in lentils will require choices to be made. Using multiple residual herbicides will increase the risk of herbicide damage to lentils. As crop damage is driven by rainfall patterns, which are unpredictable, this should not be the preferred strategy. One alternative to grow GIA Metro if broadleaf weed numbers are expected to be high, as metribuzin can be used safely in this cultivar. The other alternative is to have more cereal crops in the rotation where broadleaf weeds can be more easily controlled across the rotation.

Acknowledgements

This research was funded by the Grains Research and Development Corporation through the Weed Management Initiative, project UOA2501-004RTX.

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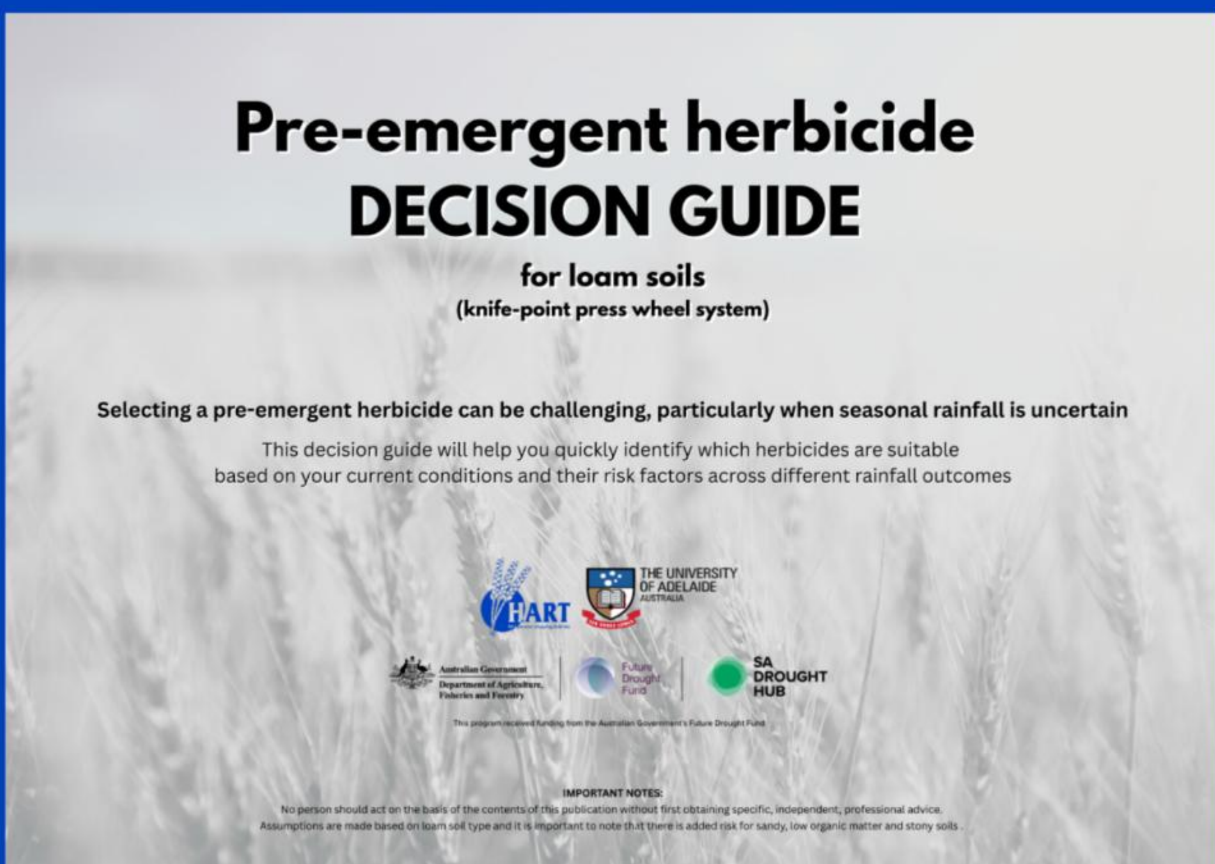

https://www.hartfieldsite.org.au/pages/resources/grower-guides.php

Evaluating impacts of applied nitrogen on grain yield and quality in wheat and barley

Mikaela Tiller and Kaidy Morgan
Hart Field-Site Group

Key findings

- At 12 weeks after application, wheat where nitrogen rates exceeded 120 kg N/ha exhibited significantly greater NDVI rating than the untreated control (UTC) and 30 kg N/ha. Higher rates of N, increased wheat biomass and vigour assisted by July rainfall favouring early crop development.
- Across the four NDVI assessment timings, Mowhawk exhibited greater NDVI ratings, indicating its early vigour and dense tillering when compared to Calibre.
- Wheat applied with 180 kg N/ha yielded more than the untreated control, however, was equivalent to all other rates of N applied.
- There were no differences observed in barley grain yield or quality across any nitrogen rate or between Commodus CL and Maximus CL.
- At higher rates of nitrogen, wheat protein and the percentage of screenings increased while test weight decreased for both varieties, indicating a potential "haying off" effect.
- Rates above 90 kg N/ha in wheat exceeded the minimum AH protein value of 13%, while all other rates including the UTC treatment exceeded the minimum APW protein value of 10.5%.

Introduction

In agricultural production systems, one of the most important yield influencing factors is nitrogen which is a major constraint to cereal production in Australia (Küstermann et al, 2010). In addition to nitrogen limitations, water availability and water use efficiency (WUE) frequently limit dryland broadacre productivity (Harries et al, 2022).

Nitrogen (N) is required abundantly during stem-elongation but has a greater requirement during reproductive phases when high protein is targeted (Angus, 2001). Additional N is required, when not water limited, to meet yield potential through correct application timing and rates, however matching crop N supply and demand when relying on variable rainfall is difficult (Angus, 2001). Applying additional N when a crop is water-limited, has been seen to cause a "haying off" effect as a result of vegetative crop growth utilising moisture and nutrient resources prior to grain fill, resulting in smaller, pinched grain with higher protein concentrations (Kirkegaard et al, 2001).

A small plot trial was conducted at Hart, SA in 2025 to evaluate the impact of increasing rates of nitrogen on haying off and grain quality parameters in wheat (*Triticum aestivum,* cv. Mowhawk and Calibre) and barley (*Hordeum vulgare*, cv. Commodus CL and Maximus CL).

Methodology

Trial design and treatments

Two varieties of both wheat and barley were selected based on suitability to the Mid North region and standardised grower benchmarks. In 2024, standard grower benchmark varieties selected were Scepter wheat and Compass barley, which were compared to Calibre and Maximus CL. In 2025, Scepter was replaced with Mowhawk, and Compass by Commodus CL after grower and advisor consultation to continue to align with grower practice across the Mid North. Comparison varieties Calibre and Maximus CL were utilised again in 2025.

Mowhawk, released by LongReach Plant Breeders, is an APW quality quick winter wheat variety, with dense tillering and an erect plant type (LRPB, 2024). Commodus CL, is a malt quality, quick-mid maturing barley variety, with good early vigour and a similar lodging tolerance to Compass (InterGrain, 2021).

At one application timing, seven nitrogen treatments were applied, starting with an untreated control (UTC), increasing in increments up to 240 kg N/ha (Table 1). Treatments were top dressed at early tillering, but before stem elongation.

Table 1. Treatment rates for 2025 wheat and barley variety X nitrogen rate comparison at Hart, SA.

Treatment Number	Rate (kg N/ha)
1 (UTC)	0
2	30
3	60
4	90
5	120
6	180
7	240

Site management and environmental conditions

Throughout the growing season the trial was managed through the application of pesticides to ensure an insect, weed and disease-free canopy.

Pre-sowing soil testing at the trial site indicated high background N (85.2 kg N/ha at 0-70 cm), likely as a result of dry conditions and following a failed wheaten hay crop in 2024. Despite being typically highly responsive to N at all decile ranges, high background N in 2025 indicated that there would only be small benefits of additional N, unless growing season rainfall exceeded Decile 3 (Hart Field-Site Group, 2025).

The 2025 growing season was characterised by below average rainfall (Decile 3, 223 mm) and this should be considered when interpreting grain quality data. The trial was not subject to stress from any other external or environmental factors.

Assessments

To measure baseline soil N, soil cores were taken across the trial prior to seeding, sampled to a depth of 70 cm and sectioned by depths of 0-10 cm, 10-40 cm and 40-70 cm for analysis. The same method was utilised for specific treatments post-harvest.

The trial was sown on May 16 with MAP (10:22) Zn 1% @ 80 kg/ha using a small-plot knife-point press wheel seeder on 23 cm row spacings. Normalised difference vegetation index (NDVI) was assessed prior to N application (July 8) and at two, eight and twelve weeks after nitrogen application utilising a handheld Greenseeker. Barley was harvested on November 7, and wheat on November 28 using a small-plot harvester. Grain yield (t/ha), protein (%), test weight (kg/hL), screenings (%) and retention (%) (barley only) were assessed post-harvest.

Trial data was analysed utilising REML spatial model (Regular Grid) in GenStat 24th Edition. Bonferroni critical difference values (Bonferroni CD) were calculated using average standard error of difference (SED) from the GenStat output and the relevant t critical value calculated in Excel. This number can be used to determine the difference required for a significant effect between treatments.

Lodging scores were to be completed two weeks prior to harvest and at harvest. However, as a result of short plant height due to growing season conditions, no lodging was observed.

Results and Discussion

Crop Biomass (NDVI)

Two weeks after application, all rates of N on wheat exhibited equivalent NDVI, however eight weeks after nitrogen application, rates above 90 kg N/ha recorded significantly greater NDVI rating than the UTC and 30 kg N/ha. Similarly, this was observed at 12 weeks after application, with rates above 120 kg N/ha achieving greater NDVI rating than the UTC and 30 kg N/ha, indicating increased biomass at higher N rates (Table 2). Above average rainfall for July favoured early crop development, however below average spring rainfall and overall lower than average growing season rainfall contributed to reduced yield potential.

Barley NDVI readings were not affected by variety selection or N rate at any of the four NDVI assessment timings (data not presented). Results were variable, particularly for NDVI 3 where a significant result was identified, however differences between treatments were unable to be extracted by statistical model (Table 2).

Table 2. NDVI values for wheat variety by N rate from 2025 nitrogen trials at Hart, SA. Shaded values in each column indicate higher biomass. Any difference between two means greater than the Bonferroni critical difference value is significant at α = 0.05 after Bonferroni correction.

N rate (kg N/ha)		NDVI 1	NDVI 2	NDVI 3	NDVI 4	N rate (kg N/ha)		NDVI 3
	0	0.17^{ab}	0.21	0.59^{a}	0.42^{a}		0	0.77
	30	0.17^{ab}	0.23	0.63^{ab}	0.45^{ab}		30	0.82
	60	0.19^{b}	0.23	0.68^{bc}	0.48^{abc}		60	0.79
Wheat	90	0.17^{ab}	0.23	0.69^{c}	0.49^{bc}	Barley	90	0.76
	120	0.17^{ab}	0.20	0.68^{c}	0.50^{c}		120	0.81
	180	0.17^{ab}	0.23	0.70^{c}	0.51^{c}		180	0.85
	240	0.16^{a}	0.20	0.70^{c}	0.52^{c}		240	0.82
P-value (<0.05)		**0.029**	**0.012***	**<0.001**	**<0.001**			**0.025***
Bonferroni CD		**0.02**	**0.04**	**0.05**	**0.06**			**0.11**

**Results were variable, a significant result was identified, however differences between treatments were unable to be extracted by statistical model.*

Across the four NDVI assessment timings Mowhawk exhibited greater NDVI ratings, indicating its early vigour and dense tillering when compared to Calibre (Table 3).

Table 3. NDVI values for wheat nitrogen by variety trial from Hart, SA, 2025. Shaded values in each column indicate higher biomass. Any difference between two means greater than the Bonferroni critical difference value is significant at α = 0.05 after Bonferroni correction.

Variety	**NDVI 1**	**NDVI 2**	**NDVI 3**	**NDVI 4**
Calibre	0.16	0.19	0.63	0.47
Mowhawk	0.18	0.25	0.71	0.49
P-value (<0.05)	**<0.001**	**<0.001**	**<0.001**	**0.01**
Bonferroni CD	**0.01**	**0.01**	**0.02**	**0.02**

Grain yield

Wheat applied with 180 kg N/ha yielded more than the untreated control, however, was statistically equivalent to all other treatments (Table 5). Mowhawk yielded higher than Calibre (1.89 t/ha and 1.83 t/ha respectively) across treatments, which was consistent with observations made in the wheat variety trial completed at Hart, SA in 2025.

Table 4. Yield and grain quality values for wheat from 2025 nitrogen trials at Hart, SA. Shaded values in each column indicate best performing treatments. Any difference between two means greater than the Bonferroni critical difference value is significant at α = 0.05 after Bonferroni correction.

N rate (kg N/ha)	**Yield (t/ha)**	**Test weight (kg/hL)**	**Protein (%)**	**Screenings (%)**
0	1.78[a]	81.8[b]	11.5[a]	3.8
30	1.86[ab]	81.6[b]	12.1[ab]	3.6
60	1.91[ab]	81.5[ab]	12.7[bc]	3.2
90	1.85[ab]	81.1[ab]	13.3[cd]	4.4
120	1.83[ab]	80.3[a]	14.1[de]	5.4
180	1.93[b]	80.7[ab]	14.0[de]	4.5
240	1.87[ab]	80.4[a]	14.4[e]	5.1
P-value (<0.05)	**0.037**	**<0.001**	**<0.001**	**0.046***
Bonferroni CD	**0.14**	**1.23**	**0.92**	**2.25**

**Results were variable, a significant result was identified, however differences between treatments were unable to be extracted*

There were no differences observed in barley grain yield across any nitrogen rate or between Commodus CL and Maximus CL (Table 5). This was consistent with results observed in the barley variety trial completed at Hart, SA in 2024 and 2025 where Commodus CL and Maximus CL yielded similarly.

Table 5. Yield and grain quality values for barley from 2025 nitrogen trials at Hart, SA.

N rate (kg N/ha)	Yield (t/ha)	Protein (%)	Retention (%)	Screenings (%)
0	2.99	14.7	51.6	10.6
30	3.04	15.5	54.1	9.0
60	2.94	15.4	48.6	11.9
90	3.16	14.3	56.1	9.5
120	3.16	13.8	59.4	7.6
180	3.09	15.7	52.2	10.3
240	3.01	15.5	50.5	10.3
P-value (<0.05)	**NS**	**NS**	**NS**	**NS**

The minimal response to differing N rates was likely due to high background nitrogen at the Hart site (Table 6). Assuming that 40 kg N/ha is required per tonne of grain for wheat and 35 kg N/ha of barley, initial soil nitrogen at Hart was sufficient to support approximately 3.5 t/ha of wheat and 4 t/ha of barley (BCG, 2014). The low yields observed indicate that crop productivity was most likely constrained by water availability in 2025; consequently, differences in applied nitrogen rates had a negligible effect on yield responses.

Table 6. Beginning of season total soil N stores accounting for mineral N, mineralisable N and sowing fertiliser for 2025 nitrogen trials at Hart, SA.

Starting soil mineral N (0-70 cm)	85.2	kg N/ha
** Mineralisable N	46.8	kg N/ha
Starting fertiliser	8	kg N/ha
Total	**140**	**kg N/ha**

*** Mineralisable N = 0.15 x OC% x GSR (for Hart 2025 = 0.15 x 1.4% x 223 mm)*

Grain quality

As the rate of nitrogen increased, protein increased for both wheat varieties, however, only rates above 90 kg N/ha exceeded the minimum AH protein value of 13%. All rates including the UTC exceeded the minimum APW protein value of 10.5% (Table 4). As nitrogen rate increased, the percentage of screenings also increased, and test weight decreased. This may indicate a potential "haying off" effect, with low yield, high protein, low test weight and high screenings being associated with this effect (Kirkegaard et al, 2001). There were no differences observed in barley grain quality across any nitrogen rate or between Commodus CL and Maximus CL (Table 5). This was consistent with results observed in the barley variety trial completed at Hart SA in 2024 and 2025.

Post-harvest N

Post-harvest soil samples sampled to a depth of 70 cm and sectioned by depths of 0-10 cm, 10-40 cm and 40-70 cm were conducted post-harvest to indicate carry-over nitrogen. Calibre and Maximus CL at four nitrogen rates (0 kg N/ha, 60 kg N/ha, 120 kg N/ha and 240 kg N/ha) were sampled.

Prior to sowing, starting N to a depth of 70 cm across the site was 85.2 N kg/ha. Soil nitrogen decreased from starting N in Maximus CL plots for rates from 0-120 kg N/ha but increased where 240 kg N/ha was applied (Figure 1). Alternatively, soil nitrogen increased for Calibre plots with rates above 120 kg N/ha and decreased from 0 and 60 kg N/ha. Remaining soil N was greater across all rates for wheat when compared to the same rate in barley. Yield benefits for the subsequent crop following a poor finish and a “hayed off” crop may be observed; however, growers should be cautious the following year to avoid over or under fertilising (Browne and Ie, 2017).

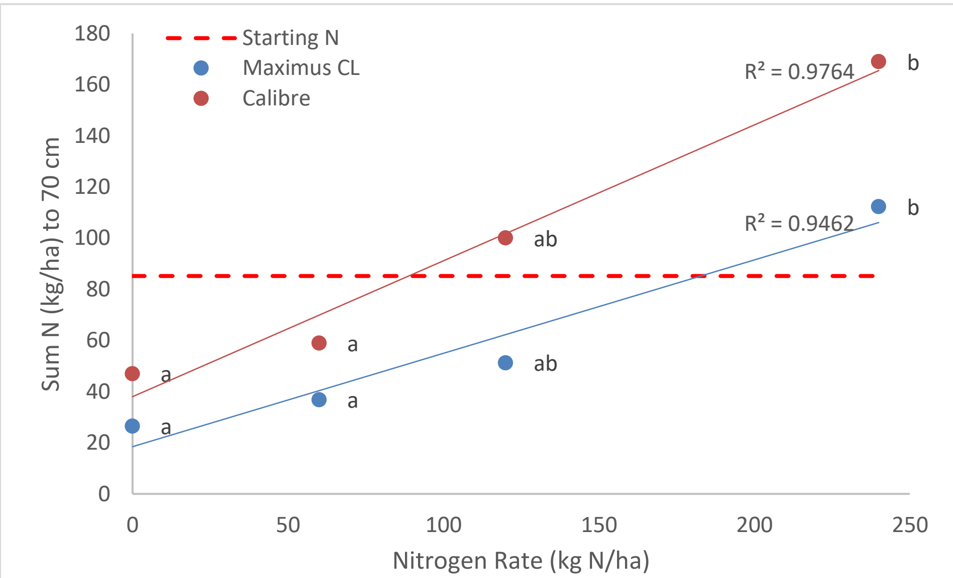

Figure 1. Soil nitrogen post-harvest of Maximus CL (P-value = 0.016, Bonferroni CD = 74.6 N kg/ha) and Calibre (P-value= 0.003, Bonferroni CD = 80.9 N kg/ha) sum of N (0-70 cm) across four nitrogen regimes: 0 kg N/ha, 60 kg N/ha, 120 kg N/ha and 240 kg N/ha. Any difference between two means greater than the Bonferroni critical difference value is significant at α = 0.05 after Bonferroni correction.

Summary

Decile 3 (223 mm) GSR at Hart in 2025 affected yield potential and quality across the trial site. Wheat applied with 180 kg N/ha achieved a yield of 1.93 t/ha which was significantly greater than the 1.78 t/ha achieved by the untreated control, however, was equivalent to all other N treatments. As the rate of nitrogen increased in wheat, protein percentage and the percentage of screenings increased while test weight decreased, indicating a potential “haying off” effect. There were no differences observed in barley grain yield or quality across any nitrogen rate or between Commodus CL and Maximus CL.

Acknowledgments

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 the various organisations who provided product and seed to conduct this trial.

This trial is funded by HART SA's premier cropping field site

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Enhancing efficiency fertilisers - preliminary results from two trials

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Key findings

- High starting soil N and below average growing season rainfall (Decile 3) limited treatment effects in the first season of this trial.
- There were no differences observed between inhibitor products or nitrogen rates for any of the in-season observations carried out.
- The dual inhibitor product applied at 75% and 100% of standard fertiliser rate outperformed the untreated control for grain protein (%), however did not differ from plots that were treated with standard urea (no inhibitor).

Introduction

Additional nitrogen (N) is required in many Australian cereal systems to meet water limited yield potential, however significant losses through gas, leaching and immobilisation are often experienced. The percentage of applied N taken up by the plant in dryland cropping systems in Australia is roughly 35-40%, therefore there is a need to minimise losses to increase nitrogen use efficiency (Suter and Pandey, 2025). Research into the use of enhancing efficiency fertilisers (EEF) has been increasing, targeting inhibiting enzymes related to the N transformation biochemical process. Each EEF impacts the N cycle by slowing one of the N transformation process (Figure 1). Coated urea controls and slows down the release of N in response to soil conditions. Urease and nitrification inhibitors slow the rate at which urea hydrolysis and nitrification occur. A dual inhibitor is a combination of a urease and nitrification inhibitor, consequently slowing down both processes.

Two plot trials were conducted at Hart, SA in 2025 to evaluate the efficacy of urea with or without inhibitors at various rates on wheat (*Triticum aestivum,* cv. Calibre). The first, a GRDC funded EEF trial, investigates N fertiliser efficiencies with and without inhibitor coatings at various rates. The second, a small Hart-funded extension to this work, tests the efficacy of efficiency fertilisers when applied at two timings.

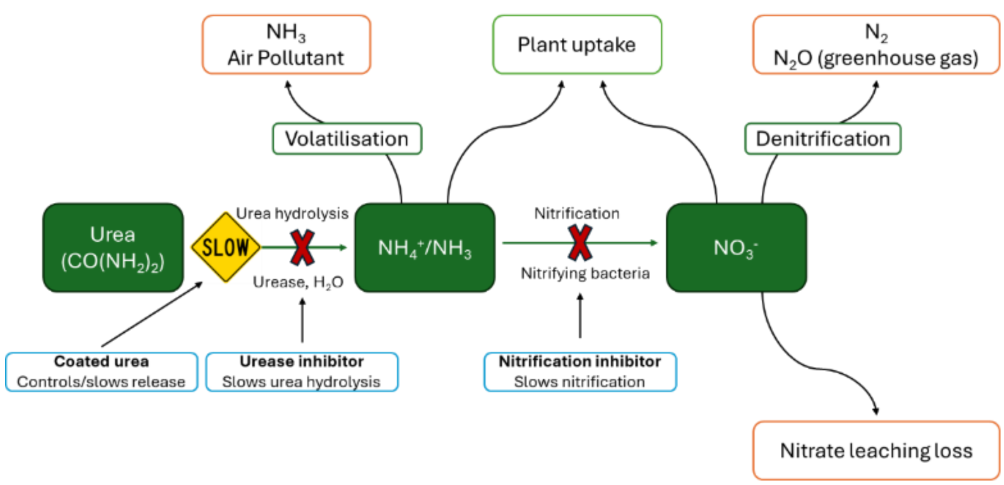

Figure 1. N pathways after application of urea and location of impact of the different EEFs and the impacted loss pathways. Adapted from Suter and Pandey, 2025.

Methodology

Trial design and treatments

Two trials were established at the Hart field site on a clay loam soil type using a small-plot knife-point press wheel seeder, with three replicates of each treatment (Table 1).

Table 1. Trial details for 2025 enhancing efficiencies fertiliser at Hart, SA.

Plot size	1.75 x 10 m	**Previous crop**	Bale awnless wheat
Location	Hart, SA	**Soil N**	120.4 kg N/ha
Seeding date	May 23, 2025	**Fertiliser**	Seeding: MAP (10:22)
Time of harvest	December 5, 2025		Zn 1% @ 80 kg/ha
GSR*	Decile 3 (223 mm)		Trial 1: August 22, 2025
			Trial 2 Timing 1: July 30, 2025
			Trial 2 Timing 2: August 22, 2025

**GSR = Growing season rainfall*

Trial 1: Enhancing efficiencies fertiliser agronomy

At one application timing, five nitrogen treatments were applied: urea, urea with urease inhibitor, urea with nitrification inhibitor, urea with dual inhibitor, and a controlled release fertiliser. Starting with an untreated control (UTC), treatment rates increased in 25% increments up to 100% of optimal target nitrogen. Urea without an inhibitor was also applied at 150% of the standard rate (Table 2). Nitrogen rates were determined by starting soil N and seasonal conditions. Treatments were top dressed at mid-tillering and received 20.8 mm of rainfall in the week post-application.

Table 2. Treatment list and rates for 2025 enhancing efficiencies fertiliser agronomy 15N at Hart, SA.

Nitrogen applied (% of standard rate)	Rate (kg N/ha)
UTC	0
25	5.3
50	18.5
75	31.8
100	45.0
150	71.5

Within the 75% treatment plots across all nitrogen types, a 1.38 x 1.38 m microplot was established. The microplots were treated with the same fertiliser and rate as the main plot, however, were applied with isotopically labelled ^{15}N to allow tracing of fertiliser-derived N in plant and soil DNA.

Trial 2: Enhancing efficiencies fertiliser timing

At two application timings, three nitrogen treatments were applied: standard granular urea, urea with a urease inhibitor, and urea with a dual inhibitor at 75% of the standard nitrogen target (31.8 kg N/ha).

Timing 1 was applied at a rain event and Timing 2 aimed for an application timing up to 10 days prior to a rain event. Timing 1 was applied after a cumulative 26.8 mm of rainfall had been received over the previous five days. Post-application conditions included an additional 20.8 mm of rainfall recorded during the week after application. Timing 2 was applied four days prior to receiving a cumulative 24.6 mm of rainfall across five days.

Site management and environmental conditions

Throughout the growing season the trial was managed through the application of pesticides to ensure an insect, weed and disease-free canopy.

Pre-sowing soil testing at the trial site indicated high background N (85.2 kg N/ha at 0-70 cm), likely as a result of dry conditions and following a failed wheaten hay crop in 2024. Despite being typically highly N responsive, high background N in 2025 implied that there would only be small benefits of additional N, unless growing season rainfall exceeded Decile 3 (Hart Field-Site Group, 2025).

The 2025 growing season was characterised by below average rainfall (Decile 3, 223 mm) which should be considered when interpreting grain yield and quality data. The trial was not subject to stress from any other external or environmental factors.

Assessments

Trial 1: Enhancing efficiencies fertiliser agronomy 15N

To measure baseline soil N, soil cores were taken across the site prior to seeding, sampled to a depth of 100 cm and sectioned by depths of 0-10 cm, 10-40 cm, 40-70 cm and 70-100 cm for analysis. Post harvest cores were taken per plot and sectioned by depths of 0-15 cm, 15-35 cm, 35-55 cm and 55-75 cm (data yet to be received).

Plant establishment counts (plants/m^2) were conducted at the first application timing approximately six weeks after emergence. Normalised difference vegetation index (NDVI) was assessed prior to N application (August 22) and again at two, four and six weeks after nitrogen application utilising a handheld Greenseeker. At flag leaf and anthesis, ground calibration cuts for dry matter were taken and NDVI readings were done separately in this area (UTC, 75% and 100% treatments only). Harvest index cuts were also taken prior to harvest. Wheat was harvested using a small-plot harvester and grain yield (t/ha), protein (%) and screenings (%) were assessed post-harvest. Within the ^{15}N microplots plant counts, anthesis ground cuts, harvest index and post-harvest soil N were conducted (data not yet available).

Trial 2: Enhancing efficiencies fertiliser timing

Baseline soil N was measured following the same method as Trial 1. In-season soil samples were conducted the day of application and approximately seven weeks after Timing 1 (T1) and four weeks after Timing 2 (T2) on September 19. Wheat was harvested using a small-plot harvester and grain yield (t/ha), screenings (%), protein (%), and test weight (kg/hL) were assessed post-harvest.

Photo. View of the Enhancing Efficiency Fertlisers trial at Hart in 2025.

Results and discussion

Trial 1: Enhancing efficiencies fertiliser agronomy

High starting soil N and below average growing season rainfall (Decile 3) limited treatment effects in the first season of this trial. There were no differences noticed between inhibitor products or nitrogen rates for any of the in-season observations, with all treatments performing similarly to the untreated control (Table 3).

Table 3. In-season observations for the Enhancing Efficiency Fertiliser trial at Hart, 2025.

	Biomass g/m^2	NDVI 1	NDVI 2	NDVI 3	NDVI 4
Untreated control	373.8	0.31	0.41	0.52	0.51
Urea @ 25%	317.5	0.34	0.42	0.52	0.52
Urea @ 50%	345.3	0.32	0.44	0.49	0.54
Urea @ 75%	357.1	0.33	0.44	0.57	0.53
Urea @ 100%	378.6	0.30	0.41	0.47	0.54
Urea @ 150%	348.1	0.32	0.43	0.54	0.55
CRF @ 25%	357.7	0.33	0.42	0.50	0.53
CRF @ 50%	348.7	0.31	0.40	0.54	0.54
CRF @ 75%	344.9	0.30	0.43	0.48	0.56
CRF @ 100%	367.5	0.35	0.41	0.52	0.56
Urea + Dual @ 25%	356.1	0.34	0.41	0.49	0.54
Urea + Dual @ 50%	400.0	0.32	0.41	0.51	0.54
Urea + Dual @ 75%	344.6	0.31	0.41	0.51	0.55
Urea + Dual @ 100%	320.7	0.28	0.39	0.52	0.51
Urea + Nitrification @ 25%	315.0	0.32	0.42	0.49	0.54
Urea + Nitrification @ 50%	352.3	0.33	0.41	0.48	0.54
Urea + Nitrification @ 75%	341.2	0.31	0.41	0.51	0.54
Urea + Nitrification @ 100%	348.4	0.33	0.43	0.54	0.52
Urea + Urease @ 25%	360.1	0.31	0.39	0.49	0.49
Urea + Urease @ 50%	344.5	0.32	0.40	0.52	0.53
Urea + Urease @ 75%	350.9	0.34	0.43	0.55	0.54
Urea + Urease @ 100%	380.4	0.32	0.47	0.55	0.58
P-value	**NS**	**NS**	**NS**	**NS**	**NS**

The dual inhibitor product applied at 75% and 100% of standard fertiliser rate outperformed the untreated control for grain protein (%), however remained similar to plots that were treated with standard urea (no inhibitor) (Table 4). There were no differences in any other quality parameters tested.

Table 4. Yield and grain quality data for enhancing efficiency fertiliser agronomy trial at Hart, 2025. Shaded values indicate best performing treatments. Any difference between two means greater than the Bonferroni critical difference value is significant at α = 0.05 after Bonferroni correction.

Treatment	Yield (t/ha)	Protein (%)	Screenings (%)	Test weight (kg/hL)
Untreated control	1.52	11.3^{a-d}	7.3	77.1
Urea @ 25%	1.59	11.1^{ab}	7.3	77.4
Urea @ 50%	1.63	12.0^{a-f}	7.4	77.0
Urea @ 75%	1.48	12.7^{f}	8.8	76.1
Urea @ 100%	1.55	12.4^{def}	8.5	76.7
Urea @ 150%	1.68	12.5^{def}	8.1	76.5
CRF @ 25%	1.56	11.0^{a}	7.2	77.1
CRF @ 50%	1.63	11.6^{a-f}	7.8	76.6
CRF @ 75%	1.58	11.7^{a-f}	8.0	76.7
CRF @ 100%	1.63	11.3^{a-d}	7.7	77.3
Urea + Dual @ 25%	1.61	11.1^{abc}	7.6	77.1
Urea + Dual @ 50%	1.63	11.4^{a-e}	7.4	77.3
Urea + Dual @ 75%	1.49	12.6^{ef}	8.8	76.4
Urea + Dual @ 100%	1.52	12.7^{a-d}	8.3	76.1
Urea + Nitrification @ 25%	1.51	11.5^{a-f}	8.0	76.3
Urea + Nitrification @ 50%	1.52	11.9^{a-f}	8.2	76.4
Urea + Nitrification @ 75%	1.46	12.2^{a-f}	8.7	75.9
Urea + Nitrification @ 100%	1.64	12.2^{a-f}	8.1	76.6
Urea + Urease @ 25%	1.50	11.3^{a-d}	7.8	77.0
Urea + Urease @ 50%	1.60	11.7^{a-f}	7.8	77.0
Urea + Urease @ 75%	1.53	12.3^{b-f}	8.3	76.7
Urea + Urease @ 100%	1.71	12.3^{c-f}	7.7	76.5
P-value	**NS**	**<0.001**	**NS**	**NS**
Bonferroni CD		**1.3**		

At the time of compiling this article, grain and biomass data from the ^{15}N-labelled microplots was not yet available. Differences between inhibitor products may be identified once this data is analysed, however conditions in 2025 were not favourable to test the effectiveness of enhancing efficiency fertilisers due to dry conditions and reduced N requirements.

This trial will continue in 2026, where it is anticipated that treatment effects may become clear if favourable growing season conditions are experienced.

Trial 2: Enhancing efficiencies fertiliser timing

Application timing or the use of inhibitors did not affect any parameters measured in 2025 (data not shown). Additionally, over one season, there was no effect of application treatment on soil nitrogen (0-30 cm) for any of the four tests carried out.

Table 5. Soil nitrogen (0-30 cm) results for the enhancing efficiency fertilisers trial at Hart, 2025.

Application timing (T) & fertiliser product applied	Pre- T1 (soil N kg/ha)	Pre-T2 (soil N kg/ha)	Post-T2 (soil N kg/ha)	Post-harvest (soil N kg/ha)
T1 dual	76.81	80.93	73.59	39.55
T1 urea	62.34	85.94	47.52	52.75
T1 urease	109.75	89.57	46.7	54.04
T2 dual	117.82	72.04	51.57	50.17
T2 urea	88.75	61.27	62.17	62.33
T2 urease	88.44	50.09	80.66	73.17

Summary

Limited differences were observed in 2025 for both the enhancing efficiencies fertiliser agronomy (Trial 1) and the enhancing efficiencies fertiliser timing (Trial 2) trials at Hart. Limited biomass production and adverse growing season conditions likely impacted potential results of nitrogen treatments. Both trials will be repeated in 2026.

Acknowledgments

The research undertaken as part of this project is made possible by the significant contributions of growers through both trial cooperation and the support of the GRDC. The authors would like to thank them and for their continued support (GRDC Project UOM2404-007RTX). Hart also acknowledge the collaboration of The University of Melbourne as the team who lead this national project.

The Hart Field-Site Group would also like to acknowledge the generous support of our sponsors who provide funding that allows us to conduct the enhancing efficiencies fertiliser timing trial in 2025. Proceeds from Hart's ongoing commercial crop also support Hart's research and extension program. We would like to thank the various organisations who provided product and seed to conduct this trial.

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Thank you for your support during the 2025/26 harvest

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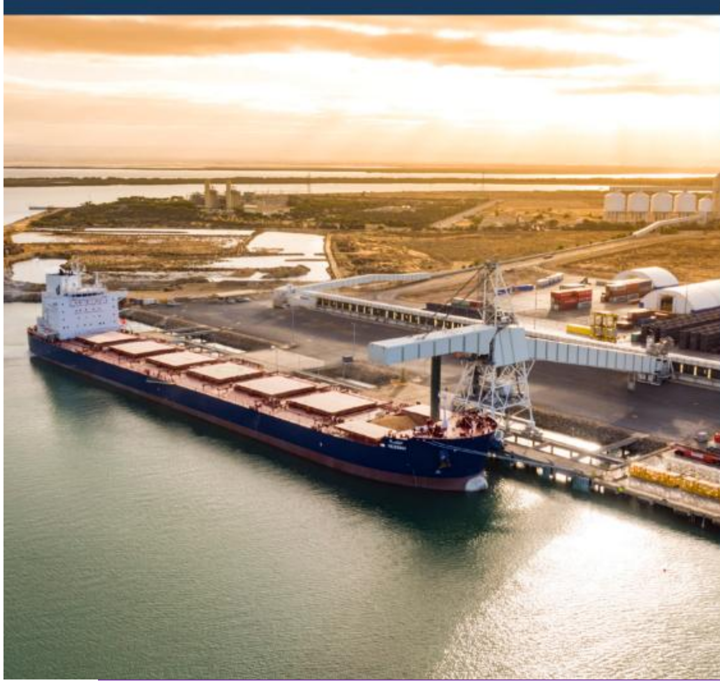
- **delivered 5.5+ million** tonnes of grain to our South Australian and western Victorian sites
- broke our **daily receival records** at **5 sites** (Lock, Rudall, Cummins, Port Lincoln, Wolseley)
- broke Wolseley's **all time receival record** following the **significant expansion** of the site as part of our **$50 million investment**
- produced high quality grain with **85% of wheat and barley** classified as **major grades**



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- **shipped 1.9+ million** tonnes across **45+ vessels** to **23 countries** so far
- worked with **33 buyers** including **7 exporters** to connect farmers' grain with end users
- a further **4.1+ million tonnes shipping booked** for the rest of the season
- **4.1+ million tonnes shipping forward booked** for 2026/27

all figures as at 31/01/26

Agronomic and management options to improve soil fertility and nutrient cycling

Kaidy Morgan and Mikaela Tiller
Hart Field-Site Group

Key findings

- Chicken litter treatments (5 t/ha surface applied) recorded improved growth and vigour at all NDVI timings, however nitrogen was not the limiting factor in 2025 and water stress resulted in no yield benefit.
- Biochar when applied without chicken litter, performed similarly to standard practice management across all parameters measured in 2025.
- Background soil N was more than what was needed to produce the ~1.5 t/ha yields observed, meaning that differences in nitrogen rates likely had little to no effect in 2025. Biochar applied with a full rate, half rate or no inorganic fertiliser (IF) all performed similarly, as did chicken litter treatments when applied with a full or half rate of IF fertiliser.
- Sowing vetch with wheat did not impact wheat yield, however reduced grain quality, likely due to competition and water depletion caused by vetch growth in a season where water was already a limiting factor.

Introduction

In low to medium rainfall areas, available water can become a limiting factor impacting not only crop growth and yield, but biological function, nutrient cycling and overall soil health. The sustainability and productivity of farming systems are dependent on the ability to sustain and enhance soil biological function to support the cycling of nutrients, disease suppression and the tolerance to abiotic stresses including temperature and drought conditions (Gupta et al, 2025).

A decline in soil fertility and natural capital is being observed on a global scale (Osman, 2014). To sustain or improve agricultural productivity to meet the growing food demand, it is essential that soil health and function be addressed (Strickland et al, 2019).

Despite the potential benefits of maintaining soil cover through increased stubble retention, the slow breakdown of residue often creates issues for farmers. The use of amendments to promote stubble breakdown is being investigated in a new long-term trial at Hart. Two products are included, which both assist with plant cell wall (cellulose) degradation by promoting microbial activity through two different approaches. Through this process, stubble load can be reduced and plant residues converted into useful forms of organic carbon including humus.

The use of organic amendments to improve soil cover, nutrient retention and cycling, water infiltration and water holding capacity are also being investigated. These amendments include biochar at various rates and chicken litter (year 1 only at 5 t/ha) with and without inorganic fertiliser. Soil and crop residual effects will be monitored for three years. In addition, this trial investigates the interaction between chicken litter application and the use of inorganic fertilisers.

We aim to quantify the economic and productivity potential of various treatments to improve system resilience. There is published evidence to show that biochar applied with either inorganic fertiliser or chicken manure can significantly improve yield while reducing fertiliser requirements (Bai & al, 2022), (Ye, Camps- Arbestain, Shen, & Lehmann, 2019) which will be tested in these trials.

The use of companion cropping to improve soil function through increased diversity, soil cover and nutrient cycling will be addressed through the inclusion of a treatment where vetch is under sown in cereal rotations and sprayed out at peak biomass. It is intended that vetch residue will remain as soil cover to provide additional benefits over summer months, in addition to its N fixation during the growing season.

A plot trial was established at Hart, SA in 2025 to evaluate agricultural practices to improve soil water and fertility in wheat (*Triticum aestivum*, cv. Calibre) over three growing seasons (Table 1).

Table 1. Trial details for 2025 soil water and fertility trial at Hart, SA.

Plot size	1.75 x 10 m	**Soil N**	120.4 kg N/ha
Location	Hart, SA	**Fertiliser**	Seeding: DAP (18:20) Zn 1% + Flutriafol @ 80 kg/ha
Seeding date	June 20, 2025		
Harvest date	December 3, 2025		
Previous crop	Bale awnless wheat		
Growing season rainfall	Decile 3 (223 mm)		

Methodology

Trial design and treatments

This project will be delivered across three growing seasons (2025, 2026 and 2027) and will follow a wheat, barley and lentil crop rotation, respectively. All treatments will be replicated three times across two stubble management strategies (standard and tall) to determine if soil fertility and water retention can be increased by management strategies which promote soil cover, microbial activity and nutrient cycling to improve the resilience of South Australian soils (Table 2).

This project was developed by Hart Field-Site Group and is one of several trials across the state forming part of the Future Drought Fund (FDF) funded SA Discovery Farms project, led by SARDI and Flinders University. Treatments for the field trial at Hart (Table 2) were developed in consultation with local growers and advisors considering soil improvement practices to advance soil health.

Table 2. Treatment list for 2025 soil water and fertility trial at Hart, SA.

Treatment Number	Treatment	Rate
1	Standard practice	Standard practice
2	High tolerance to summer weeds	No summer weed control
3	Increased diversity: mixed species temporary companion cropping	Under sown with vetch (30 kg/ha)
4	Stubble degradation enzyme (post-harvest)	Res + @ 1.2 L/ha
5	Fungi promoting stubble break-down amendment (post-harvest)	BioMAX Digest Inoculum @ 1 L/ha + BioMAX Digest Kicker @ 5 L/ha
6	Biochar (with inorganic fertiliser)	300 kg/ha (full synthetic rate)
7	Biochar (no inorganic fertiliser)	300 kg/ha
8	Biochar (with half inorganic fertiliser)	Half synthetic rate + 20% biochar (of fertiliser rate = 6.5 kg/ha biochar)
9	Organic amendment (with inorganic fertiliser)	Standard practice *
10	Organic amendment (with half inorganic fertiliser)	Half synthetic rate *
11	Organic amendment + biochar (with inorganic fertiliser)	300 kg/ha biochar (full synthetic rate) *
12	Organic amendment + biochar (with half inorganic fertiliser)	Half synthetic rate + 20% biochar (of fertiliser rate = 6.5 kg/ha biochar)*

**Organic amendment applied = chicken littler @ 5 t/ha in year 1 only*
Each treatment is replicated for two stubble management strategies (standard and tall)

Site management and environmental conditions

The trial was managed through the application of pesticides to ensure an insect, weed and disease-free canopy (excluding treatments with specific pest management plans). The 2025 growing season was characterised by below average rainfall (Decile 3, 223 mm) which should be considered when interpreting these results. The trial was not subject to stress from any other external or environmental factors.

Assessments

Prior to sowing in 2025, site characterisation including chemical analysis, bulk density, soil structure, water repellence, infiltration, soil strength (penetrometer), macrofauna, slaking & dispersion and carbon tests were undertaken. A PredictaB test and estimated soil water (GWC% and VWC%) for the site were also conducted. A visual percentage of ground cover and initial stubble dry matter (DM) was measured from five locations across the site. For subsequent years, stubble measured prior to sowing will be the total stubble, including the remaining residue from all years for each plot. For the duration of the project, soil temperature will be measured.

Plant counts were conducted in each plot to determine emergence (plants/m^2). Normalised difference vegetation index (NDVI) was conducted to measure biomass at four separate timings; growth stage (GS) 13-21, GS 31, GS 43 and GS 65-69 utilising a handheld Greenseeker. During the growing season anthesis microbiome & full physical-chemical soil sampling was conducted. At harvest maturity, whole plant samples were taken to estimate harvest index (HI). Plots were harvested by a plot harvester and yield was determined. Post-harvest analysis was conducted to determine protein (%), screenings (%), test weight (kg/hL) and 1000 grain weight. Post harvest weed counts per plot will be conducted after summer rain when weed emergence is evident. Similar in-crop field measurements will be conducted in 2026 and 2027.

Trial data was analysed utilising REML spatial model (Regular Grid) in GenStat 24th Edition. Bonferroni critical difference values (Bonferroni CD) were calculated using average standard error of difference (SED) from the GenStat output and the relevant t critical value calculated in Excel. This number can be used to determine the difference required for a significant effect between treatments.

Results and discussion

High starting soil N and below average growing season rainfall (Decile 3) limited treatment effects in the first season of this trial. Despite there being differences in biomass production (NDVI) and grain quality between treatments, yield effects were not observed.

This trial will continue for an additional two seasons, where it is anticipated that compounding treatment effects will become clear, particularly if favourable growing season conditions are experienced.

Prior to application, both the chicken litter and biochar were analysed for complete composition to determine the amount of additional nutrients being added into the system. By applying 5 t/ha of chicken litter, an additional 159 kg of N/ha was supplied (Table 3). Soil nitrogen stores were already high across the site (~120 kg N), meaning that despite chicken litter treatments (Treatments 9-12), recording improved growth and vigour at all NDVI timings (Table 4), water stress resulted in no yield benefit. The residual effect of a single chicken litter application will be measured in 2026 and 2027 growing seasons, where additional benefits may be observed as break down occurs and additional nitrogen becomes available.

Table 3. Amount of nutrient applied with 5 t/ha chicken litter application.

Nutrient analysed	Applied nutrient (kg nutrient/ha)
Total Nitrogen	159.2
Calcium	96.6
Iron	5.4
Magnesium	34.7
Phosphorus	45.4
Potassium	139.7
Sodium	30.6
Sulphur	32.4
Zinc	2.2

Biochar was applied at various rates and by multiple methods detailed in Table 4 (Treatments 6-8, 11 and 12), however when applied without chicken litter (Treatments 6-8), performed similarly to standard practice management across all parameters measured in 2025 (Table 4). Additionally, there was no short-term benefit of applying biochar with chicken litter (Treatment 11 and 12) when compared to treatments where chicken litter was applied standalone (Treatments 9 and 10). Unlike the chicken litter, which will be applied in the first year only, biochar treatments will be repeated for each season of the trial. Compounding effects of biochar application may be noticed in future years, as it is slow to break down within systems. Biochar is also known for its high surface area and water holding capacity, meaning that as levels within the system increase over the three seasons, soil and productivity differences may be observed.

Table 4. Results from first season of new long-term trial at Hart, SA. Shaded values in each column indicate best performing treatments. Any difference between two means greater than the Bonferroni critical difference value is significant at α = 0.05 after Bonferroni correction.

Treatment		NDVI 1	NDVI 2	NDVI 3	NDVI 4	Yield t/ha	Protein %	Screenings %	Test weight kg hL	1000 GW
1,2,4,5	Standard practice (SP)	0.18^{ab}	0.39^{abc}	0.56^{a}	0.30^{abc}	1.51	13.3^{c}	7.1^{a}	76.0^{bc}	26.7^{abc}
3	Increased diversity	0.19^{cd}	0.47^{de}	0.61^{b}	0.34^{d}	1.53	13.6^{cd}	8.3^{b}	75.2^{a}	25.8^{a}
6	Biochar 300 kg/ha *+ full SP fertiliser*	0.18^{abc}	0.38^{ab}	0.54^{a}	0.29^{ab}	1.55	13.2^{bc}	6.8^{a}	76.2^{bc}	26.5^{abc}
7	Biochar 300 kg ha *(no additional fertiliser)*	0.18^{a-d}	0.40^{a-d}	0.54^{a}	0.28^{a}	1.51	12.4^{a}	6.6^{a}	76.5^{bc}	27.0^{abc}
8	Biochar 6.5 kg ha (as urea coating) *+ half SP fertiliser*	0.16^{a}	0.36^{a}	0.53^{a}	0.28^{a}	1.50	12.9^{ab}	6.6^{a}	76.5^{c}	27.4^{bc}
9	Organic amendment *+ full SP fertiliser*	0.19^{bcd}	0.46^{bde}	0.66^{bc}	0.34^{d}	1.47	14.4^{f}	7.2^{ab}	75.8^{ab}	27.1^{bc}
10	Organic amendment *+ half SP fertiliser*	0.20^{d}	0.49^{e}	0.66^{bc}	0.34^{bcd}	1.47	14.1^{ed}	7.3^{ab}	75.9^{abc}	26.1^{ab}
11	Organic amendment + biochar 300 kg ha *+ full SP fertiliser*	0.20^{d}	0.51^{e}	0.66^{bc}	0.35^{d}	1.56	14.2^{ed}	6.6^{a}	76.1^{bc}	27.3^{bc}
12	Organic amendment + biochar 6.5 kg ha (as urea coating) + *half SP fertiliser*	0.20^{d}	0.53^{e}	0.68^{c}	0.34^{cd}	1.47	13.8^{de}	6.6^{a}	76.2^{bc}	27.4^{c}
	P-value	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**NS**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
	Bonferroni CD	**0.02**	**0.07**	**0.06**	**0.04**		**0.43**	**1.18**	**0.69**	**1.2**

Both the chicken litter and biochar treatments were applied with varying inorganic fertiliser (IF) strategies to test if amendments could potentially reduce IF requirements (detailed in Table 4). There were no effects of varying IF rates noticed in 2025, likely due to already high background N as previously stated. Biochar applied with full, half or no IF all performed similarly, as did chicken litter treatments when applied with a full or half rate of IF fertiliser. Background soil N was more than what was needed to produce the ~1.5 t/ha yields observed across all treatments, meaning that differences in nitrogen rates likely had little to no effect on plant and grain production in 2025. Future soil tests may however highlight differences in applied nitrogen, as a result of reduced uptake in 2025 and nitrogen carryover across seasons. It is important to consider the dry conditions when interpreting these results, as nitrogen availability is likely to have a more pronounced effect when growing season conditions are conducive to increased plant growth and yield potential.

Carbon and nitrogen composition of both the chicken litter and biochar were tested prior to sowing (Table 5). While chicken litter contained a significantly higher percent of nitrogen, carbon levels were close to half that of the biochar. Carbon to nitrogen ratios (C:N ratio) impact nutrient cycling and the rate at which nitrogen becomes available. Chicken manure is nitrogen-rich and therefore decomposes relatively quickly, with a low C:N ratio. Conversely, biochar has an extremely high C:N ratio due to being majority carbon with very little nitrogen. While both products fall outside of the ideal C:N ratio (20:1-30:1) to balance mineralisation and immobilisation for nutrient release (Brust, 2019), applying the two amendments together may assist with slowing chicken litter nutrient release by increasing the C: N ratio of chicken litter standalone. This relationship will be further investigated over future years of the trial.

Table 5. Carbon and nitrogen composition of chicken litter and biochar used in 2025.

	Chicken litter	Biochar
Total carbon %	35.5	73.7
Total nitrogen %	3.18	0.58
C:N ratio	11:1	127:1

Where species diversity was increased through the addition of a half rate (30 kg/ha) of vetch sown with wheat (Treatment 3), NDVI was higher than the standard practice treatment at all timings (Table 5). Despite there being no yield penalty of including vetch with a standard rate of wheat, reduced wheat grain quality was observed. Screenings, test weight and 1000 grain weight (GW) were all lower for the increased diversity treatment than standard practice, which can likely be attributed to increased competition and water depletion caused by vetch growth in a season where water was already a limiting factor.

In spring of 2025, all plots were characterised for their microbial population and diversity (results pending), to allow for soil biology treatment comparisons at the conclusion of the trial. This will provide valuable information about the potential effects of various management strategies imposed over multiple seasons to improve soil health, nutrient cycling and system resilience.

In 2025 Treatments 2, 4 and 5 were all managed as per standard practice (Treatment 1), as the stubble sprays and summer weed control treatments were not carried out until after harvest. For this reason, all Treatment 2, 4 and 5 plots were analysed as Treatment 1 this season so that results accurately reflected 2025 treatments. Additionally, stubble was not cut at different heights in 2024, meaning that stubble height treatments were not applicable for 2025 analysis. Plots were cut at two heights during the 2025 harvest, which will allow for all treatments and both stubble heights to be differentiated during statistical analysis in 2026.

Summary

High starting soil N and below average growing season rainfall (Decile 3) limited treatment effects in the first season of this trial. Despite there being differences in biomass production (NDVI) and grain quality between treatments, yield effects were not observed. Chicken litter treatments (5 t/ha surface applied) recorded improved growth and vigour at all NDVI timings, however nitrogen was not the limiting factor in 2025 and water stress resulted in no yield benefit. Background soil N was more than what was needed to produce the ~1.5 t/ha yields observed, meaning that differences in nitrogen rates likely had little to no effect in 2025. It is important to consider the dry conditions when interpreting these results, as nitrogen availability is likely to have a more pronounced effect when growing season conditions are conducive to increased plant growth and yield potential. This trial will continue for an additional two seasons, where it is anticipated that compounding treatment effects may become clear, particularly if favourable growing season conditions are experienced.

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Evaluating management strategies to reduce pod shatter in lentils

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Hart Field-Site Group

Key findings

- Pod loss (pods/m^2) and yield (t/ha) were affected by time of harvest (TOH), as environmental conditions between the two harvest timings were conducive to pod loss.
- The application of a desiccant reduced seed loss (seeds/m^2) when compared to non-dessicated treatments.
- The application of Enviroshield® or iron sulphate had no effect on pod shatter (seeds/m^2), pod loss (pods/m^2) or grain yield (t/ha).

Introduction

In agricultural systems, pod shatter and pod drop remain a significant cause of pre-harvest seed losses and consequently yield loss for lentil growers worldwide (Aslan & Kahraman, 2025). Advances in technology and plant breeding have allowed for trait selection to reduce pod losses, however unfavourable environmental conditions prior to and during harvest heavily influence these losses (Parker et al, 2021).

Alternative methods to reducing lentil losses are being explored, including the use of desiccants, pod protector products and trace elements for optimal harvest timing and improved pod strength and durability.

A small plot trial was conducted at Hart, SA in 2025 to evaluate the impact of harvest timing and the use of desiccants alone or in conjunction with pod protectants or trace elements as a management strategy to reduce lentil losses.

Methodology

Trial design and treatments

GIA Thunder is a mid-maturity, small, red lentil and was selected for its suitability to the Mid North. It has a lodging resistance of moderately resistant to moderately susceptible (MRMS), a pod drop rating of moderately resistant (MR) and a shattering rating of resistant to moderately resistant (RMR). It has a good disease package rating MRMS-MR for common legume diseases and yielded above the National Variety Trial average for the Mid North region from 2020-2024 (long-term yield data for 2025 not yet published) (GRDC, 2025).

The trial was established at the Hart Field-Site as a split-split block design with three replicates of each treatment (Table 1). Three variables were assessed: time of harvest (TOH), the presence or absence of a desiccant and the application of either Enviroshield® or iron sulphate (Table 2).

Aslan and Kahraman (2025) investigated and identified that lentils vegetative growth and yield was limited by Zinc (Zn) and Iron (Fe) uptake due to lentil producing soils being below critical levels of Fe and Zn. They suggested that pod shatter and consequently yield loss may be affected by limited solubility of Fe and Zn (Aslan and Kahraman, 2025). Iron deficiency issues may be observed, even when abundant due to poor availability, often in alkaline, high pH soils typically associated with water logging (GRDC, 2017; Incitec Pivot Fertilisers, 2022). At Hart, soil is slightly alkaline with a pH ($CaCl_2$) ranging from 7.75 (0-15cm) to 8.45 (75-135cm) with Fe levels ranging from 3.7-9.7 mg/kg (SAGIT, 2024). Iron sulphate was applied as a foliar application at 1 kg/ha on September 22 at pod set stage (Incitec Pivot Fertilisers, 2022).

EnviroShield®, developed by Agspec, applies a polymer film to the pod acting as a pod protectant to repel moisture and consequently reducing pod shatter (Agspec, 2022). EnviroShield® was applied as a foliar application at 1 L/ha on the October 14 at 'green pod' stage where pods were pliable without splitting and releasing the seed.

Table 1. Trial details for 2025 lentil pod and seed loss management at Hart, SA.

Harvested plot size	1.75 x 10 m	**Previous crop**	Bale awnless wheat
Location	Hart, SA	**Soil N**	120.4 kg N/ha
Seeding date	June 20, 2025	**Fertiliser**	Seeding: MAP (10:22) Zn 1% @ 80 kg/ha
Time of Harvest 1 date	November 5, 2025		
Time of Harvest 2 date	November 18, 2025		
GSR*	Decile 3 (223 mm)		

**GSR = Growing season rainfall*

Table 2. Treatment list for 2025 lentil pod and seed loss management trial at Hart, SA.

Treatment	Time of Harvest (TOH)	Desiccation	Pod Treatment
1	1	Nil desiccation	Nil
2			Enviroshield® @ 1 L/ha
3			Iron sulphate @ 1 kg/ha
4		+ Desiccation	Enviroshield® @ 1 L/ha
5			Iron sulphate @ 1 kg/ha
6			Nil
7	2	+ Desiccation	Nil
8			Iron sulphate @ 1 kg/ha
9			Enviroshield® @ 1 L/ha
10		Nil desiccation	Enviroshield® @ 1 L/ha
11			Iron sulphate @ 1 kg/ha
12			Nil

Site management and environmental conditions

The trial was managed through the application of pesticides to ensure an insect, weed and disease-free canopy. The 2025 growing season was characterised by below average rainfall (Decile 3; 223 mm). This should be considered when interpreting these results.

Assessments

Normalised difference vegetation index (NDVI) was assessed prior to treatment application utilising a handheld Greenseeker. Time of harvest one (TOH1) was completed at the optimal time when the lentils were ripe and ready to be harvested. Time of harvest two (TOH2) was late, approximately 14 days after the ideal time. Grain yield (t/ha) was obtained from both times of harvest. Post-harvest ground pod and grain counts were conducted via quadrats per plot, with data being converted to m^2 to assess pod shatter (seeds) and pod drop (whole pods).

Trial data was analysed utilising REML spatial model (Regular Grid) in GenStat 24th Edition. Bonferroni critical difference values (Bonferroni CD) were calculated using average standard error of difference (SED) from the GenStat output and the relevant t critical value calculated in Excel. This number can be used to determine the difference required for a significant effect between treatments.

Results and discussion

Time of Harvest

Time of harvest (TOH) influenced pod drop in 2025, with late harvest treatments showing significant pod losses (Table 3). Unfavourable conditions occurred between TOH1 and TOH2; wind gusts exceeding 50 km/hr occurred on eight days throughout this period and on two occasions wind gusts exceeded 60 km/hr, including two days prior to harvest. There was a yield penalty of 0.1 t/ha comparing treatments harvested on time, to treatments harvested late.

A similar trial conducted at Hart in 2022 observed significant pod shatter effects between TOH1 and TOH2 due to unfavourable weather conditions, however no yield penalty was observed. Alternatively, in 2023, because of mild conditions between TOH1 and TOH2, no difference was observed in pod shatter, however a yield penalty of 0.4 t/ha was still observed.

Table 3. Yield, pod shatter (grain/m2) and pod loss (pod/m^2) from time of harvest (TOH) in 2025. Shaded values indicate significant best performing treatments. Any difference between two means greater than the Bonferroni critical difference value is significant at α = 0.05 after Bonferroni correction.

TOH	Yield (t/ha)	Grain/m^2	Pods/m^2
1	1.19	27	297
2	1.09	41	517
P-value (<0.05)	**0.007**	**NS**	**<0.001**
Bonferroni CD	**0.06**	**-**	**94**

Desiccation

Desiccation influenced grain loss in 2025 with nil desiccant plots exhibiting significant seed loss when compared to non-desiccant treatments (Table 4). Although not significant, pod shatter increased and yield decreased when no desiccant was utilised. The warm, dry conditions leading into harvest may have influenced these results.

Table 4. Yield, pod shatter (grain/m²) and pod loss (pod/m²) from the use of desiccants in 2025. Shaded values indicate significant best performing treatments. Any difference between two means greater than the Bonferroni critical difference value is significant at α = 0.05 after Bonferroni correction.

	Yield (t/ha)	Grain/m²	Pods/m²
Desiccation	1.16	28	402
Nil desiccation	1.13	40	412
P-value (<0.05)	**NS**	**0.037**	**NS**
Bonferroni CD	**-**	**11**	**-**

Pod treatment

Enviroshield® applications at 1 L/ha had no effect on yield, pod drop or pod shatter when applied at 'green pod'. The same results were observed in the 2022 and 2023 pod loss trial at Hart, observing that Enviroshield did not minimise pre-harvest losses.

Iron sulphate applications at 1 kg/ha had no effect on yield or lentil losses when applied at pod set stage.

Further investigation into application timings and rates, over varying seasonal conditions would provide additional information to make informed management decisions.

Table 5. Yield, pod shatter (grain/m²) and pod loss (pod/m²) from pod treatment in 2025.

Treatment	**Yield (t/ha)**	**Grain/m²**	**Pods/m²**
Enviroshield® @ 1 L/ha	1.14	27	404
Iron sulphate @ 1 kg/ha	1.14	38	406
Nil	1.14	38	410
P-value (<0.05)	**NS**	**NS**	**NS**

Summary

Time of harvest (TOH) influenced pod shatter in 2025, with late harvest treatments showing significant pod losses as a result of unfavourable conditions between TOH1 and TOH2.

Desiccation influenced grain loss in 2025 with nil desiccant plots exhibiting significant seed loss when compared to non-desiccant treatments.

No effect on yield, pod shatter or grain loss was observed when Enviroshield® or iron sulphate were applied. Further investigation into application timings and rates, over varying seasonal conditions would provide additional information to make informed management decisions.

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Photo. View of the lentil pod loss trial at Hart in 2025.

Time of sowing, depth and rainfall interactions on wheat and barley establishment and yield

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Key findings

- Germination of wheat occurred with 10 mm of simulated rainfall; however significant emergence required at least 20 mm on a loam soil.
- Seed can remain viable and achieve a high rate of emergence after 3-4 weeks in dry soil.
- Early emergence was more important than achieving a high plant density: higher yields were achieved with dry sowing despite lower crop establishment compared to delaying sowing until after the break.
- Sowing at a depth of 40 mm reduced seedling emergence and grain yield.
- Increasing sowing rate to compensate for poorer establishment gives inconsistent results and generally provides little benefit.

Introduction

The run of dry autumns in recent years coupled with an increase in cropped area on farms has meant that dry sowing has become more common. This may be a long-term trend because in parts of southern Australia, the autumn opening rains are occurring later in the season. There are still some potential risks from dry sowing, including poor establishment and low plant densities due to germination in dry soil as well as the risk of seedling loss from false breaks. A question that is often asked is how much rainfall is required to allow germination and emergence of crops to occur. Soil type has a major effect on this, with much less rainfall required on sandy and light textured soil compared to loams and clay loams.

Dry seeding experiments over the last two years at three sites in the Mid North and upper Yorke Peninsula have found:

(i) There has been little to no benefit to yield of wheat and canola from delayed sowing until after opening rains. The grain yield of canola and wheat sown dry in late April-early May has generally produced higher yields than crops sown with rainfall events later in May and June. Yields of some dry sown crops of wheat that have emerged in late April–early May have been affected by frost damage, which highlights the need to match maturity to sowing time.

(ii) On loam and clay loam soils there has been no benefit from sowing deeper than the standard sowing depth in dry soil. Seedlings take longer to emerge and often the early vigour of these crops is reduced. Yields can be reduced because of the later emergence and the lower plant density. The adverse effect of deep sowing can be exacerbated in cereals with short coleoptiles. Sandy soils are more forgiving of deep sowing.

(iii) Increasing plant density to compensate for lower establishment has had variable effects. Increasing sowing rates by 25% or 50% above the normal rate, often has no significant effect on yield but there have been instances where there has been some benefit. Responses to increased plant density will generally be more likely with crops that are sown or emerge late rather than with early-emerging crops.

(iv) Seed can remain viable in dry soil without compromising emergence for considerable periods of time. Pot studies have indicated that seed can remain in dry soil for six weeks without affecting emergence and this was supported by experimental results at Hart in 2024.

Two experiments were established at Hart in 2025. In experiment 1, different amounts of water were applied to dry-sown wheat to simulate the effects of rainfall events on germination and emergence. The aim was to examine the sensitivity of emergence and seedling survival to different rainfall events

In the second experiment, wheat and barley were sown dry or after rainfall in June at two different depths and plant densities. The aim was to examine the effects of dry sowing on emergence, growth and yield and if changes in sowing depth and plant density could mitigate any adverse effects of dry sowing.

Methodology

Experiment 1: Effect of rainfall events after dry sowing on wheat germination and emergence

Calibre wheat was sown at a depth of ~40 mm on April 24 into dry soil using a 6-row knifepoint press wheel plot cone seeder on 23 cm row spacings. Seeding depth was variable due to dry conditions causing the soil to be hard and producing clods during sowing, however a standard depth was targeted. There were six replicate plots of 10 m x 1.75 m. Within each plot, five watering treatments equivalent to 5, 10, 15, 20 and 25 mm, plus a dry control (0 mm) were randomly allocated in microplots (4 rows x 1 m per plot). A buffer area of one metre was allowed between microplots to prevent any lateral movement of water between treatments. The experiment was designed as a randomised complete block.

The watering treatments were applied to dry soil on April 29. Water was added using a watering can in 5 mm increments. Measurements of soil water content in the surface 60 mm was measured one hour after completion of watering, 24 hours later and then 8, 15, 22 and 27 days after watering.

Seedling emergence was assessed in 50 cm x two central rows in each microplot. Seeds were recovered from each microplot 8 and 22 days after watering. The seed was categorised as (i) not germinated, (ii) emerged and (iii) germinated but not emerged.

Experiment 2: Effects of time of sowing, sowing depth and sowing rate on emergence and yield

This experiment was sown to examine the effect of time of sowing, sowing depth and sowing rate on emergence of wheat and barley. Two wheat varieties and one barley variety with different coleoptile lengths were sown at shallow and standard sowing depths. Two sowing rates were also tested: standard sowing rate and 25% higher than the standard sowing rate (Table 1).

Table 1. Treatments used in Experiment 2 at Hart, 2025.

Sowing dates	Varieties (coleoptile length)	Sowing depth	Sowing rates
Dry: April 24 (Emerged June 2)	RockStar wheat (short) Calibre wheat (long)	Shallow: 10 mm Standard: 40 mm	Wheat: 180 & 225 plants/m^2
After rain: June 27 (Emerged July 7)	Neo CL barley (moderate)		Barley: 150 & 188 plants/m^2

Results and discussion

Experiment 1: Effect of rainfall events after dry sowing on wheat germination and emergence

At sowing the moisture content in the surface 60 mm was about 3% without additional water and it remained dry in the three weeks after the watering treatments were applied due to the lack of rain in May (Figure 1). The largest decline in soil moisture after watering occurred within the first few days and there was little change after 10 days. At 21 days after watering, soil moisture ranged from approximately 3% (dry soil) to 10% (25 mm treatment) and by this time the amount of water lost (mainly by evaporation) was up to 100% of the water applied (Table 2).

Less than 5 mm of rainfall was received in the three weeks after watering and the first significant rainfall (~9 mm) occurred 29 days after the plots were watered after which time all treatments showed similar soil moisture contents (Figure 1).

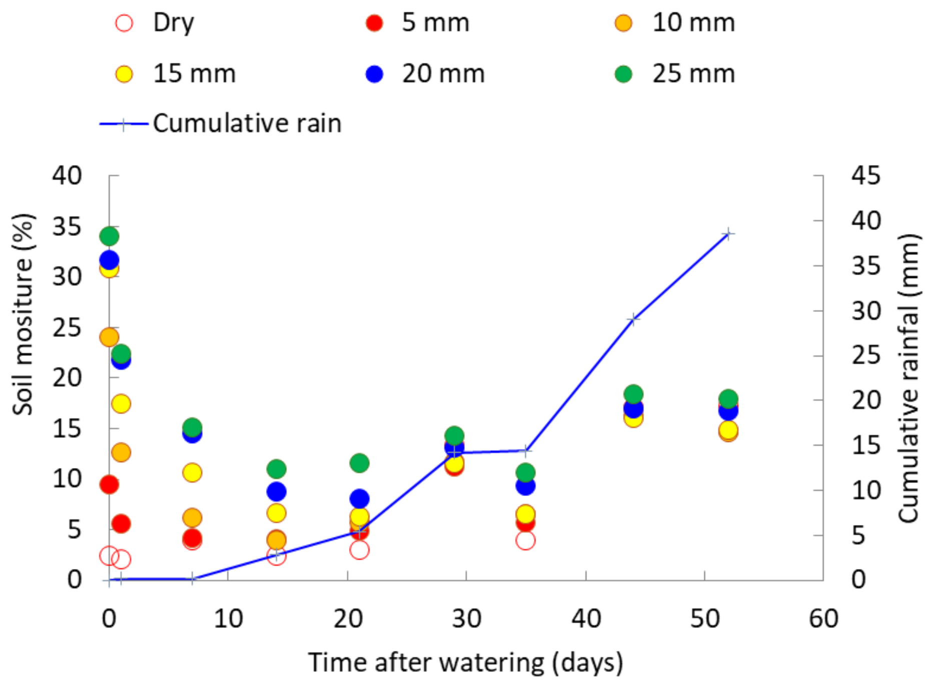

Figure 1. The changes in seed bed soil moisture content after receiving the rainfall equivalent of 5-25 mm of rainfall and the cumulative rainfall in the seven weeks after watering.

Table 2. Estimated loss of soil moisture from the surface 60 mm in the 20 days after watering.

	Rainfall equivalent (mm)					
	Dry	**5**	**10**	**15**	**20**	**25**
Loss (mm)	0	2.8	11	14.8	14.2	13.5
% of amount applied		56	100	99	71	54

Three weeks after watering with the equivalent of 10 mm of rainfall, 90% of the seeds had germinated, however none had emerged. It required the equivalent of 15 mm of rainfall to achieve at least 50% emergence, and maximum emergence was observed after the equivalent of 25 mm (Figure 2). There was a four-week period of dry weather after the watering treatments were applied, during which seedlings became severely stressed if less than 15-20 mm had been applied (Figure 3). Consequently, a number of seedlings died and as a result, final plant populations were low (Table 3). Plant establishment ranged from 6 plants/m^2 (3% establishment) to 103 plants/m^2 (57% establishment). Very dry soil (clay loam) and poor surface structure resulted in a very cloddy seedbed leading to poor seed-soil contact in many plots, which contributed to the poor seedling establishment.

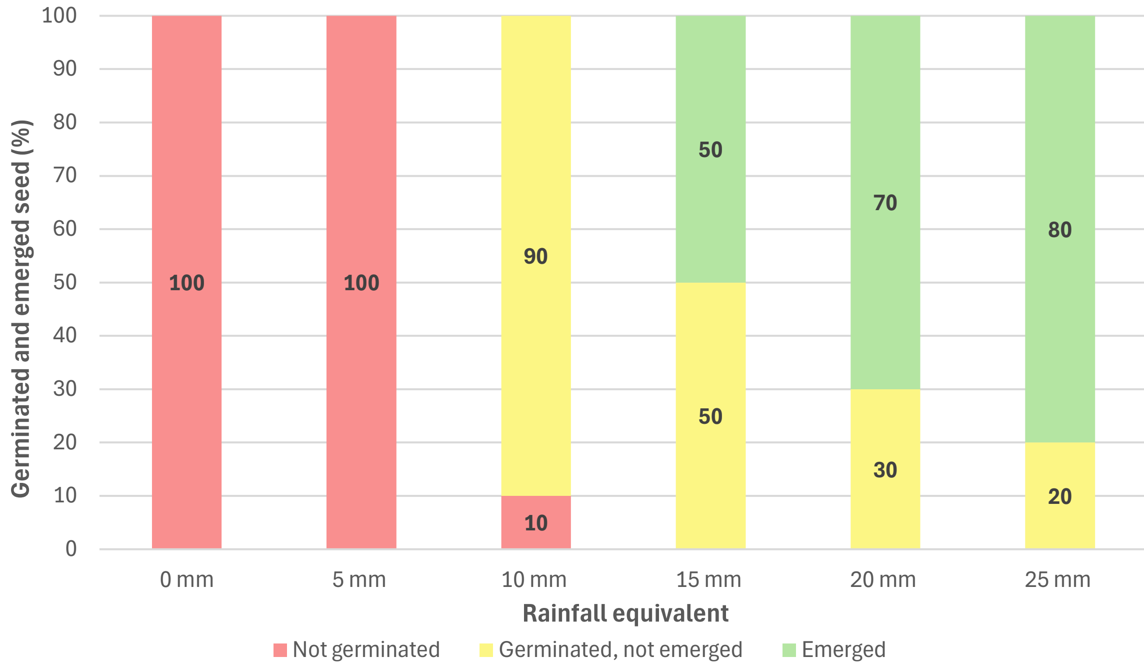

Figure 2. The effect of different amounts of water on the percentage of seed that had not germinated, germinated, but not emerged and emerged at 22 days after watering.

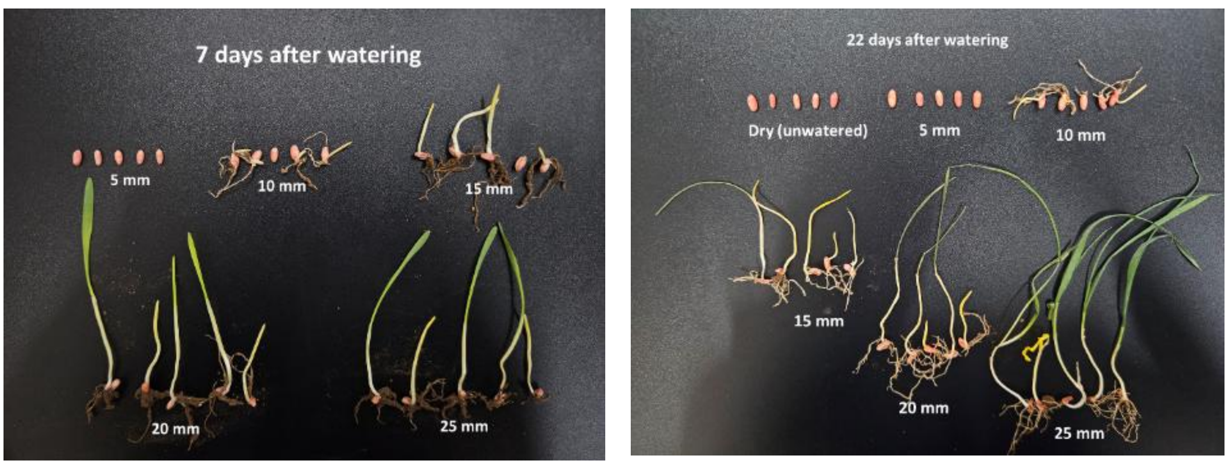

Figure 3. Images of wheat seed recovered from the plots 7 and 22 days after water was applied. By 22 days after water, seedlings were showing symptoms of water stress, and some seedling death had occurred in lower rainfall treatments.

Table 3. Final plant establishment in watered microplots. Values of plants/m² followed by the same letter are not significantly different. Shaded values indicate treatments with highest crop establishment. Counts were conducted on July 11 (73 days after watering).

	Rainfall equivalent (mm)				
	5	**10**	**15**	**20**	**25**
Plants/m²	13^{ab}	15^{ab}	6^{a}	49^{bc}	103^{c}
Establishment (%)	8	8	3	27	57

The low rainfall in May after the watering treatments were applied in late April essentially simulated a 'false break' resulting in seedling death and low establishment. High seed mortality was observed in treatments with lower amounts of simulated rainfall. In Experiment 2 (see below), much higher (>80%) establishment was observed after dry sowing at a depth of 10 mm at the end of April. Improved establishment in the dry, 10 mm sown treatments in Experiment 2 when compared to high simulated rainfall treatments in Experiment 1 were likely caused by consistently dry conditions prior to the season break and reduced clods (improved seed-soil contact) from shallow sowing which reduced emergence time once the season break had occurred. Similarly, in a trial conducted at Hart in 2023, canola and wheat dry sown in late April with no follow-up rain for 57 days achieved establishment rates of 85% in canola and 70% in wheat. While germination and emergence can occur after relatively small amounts of rainfall (10-15 mm), follow up rains are critical to achieve high rates of establishment.

Experiment 2: Effects of time of sowing, sowing depth and sowing rate on emergence and yield

Emergence from April sowing occurred on June 2 (49 days after sowing) and June sowing on July 7 (10 days after sowing). Plant establishment was lower with dry sowing and with sowing at a depth of 40 mm. Reduced plant population was observed with dry sowing (145 plants/m^2) when compared to sowing after the break (173 plants/m^2). However, the establishment rate (established plants/m^2 relative to the number of seeds/m^2 sown) was still high at 78%, which is consistent with results from 2023 when wheat sown into dry soil in late April achieved establishment rates of 70% after being in dry soil with no rain for 57 days. The critical factor in both years was likely that the soil remained dry after sowing rather than receiving a 'false break' that caused the seed to germinate (see Experiment 1).

Based on the results from Experiment 1, if it is assumed that between 10 and 20 mm of rainfall is sufficient to cause germination but not full emergence (i.e. a 'false break') the long-term rainfall data can be used to estimate the probability of a 'false break' with early sowing (Figure 4). During April to mid-May, 10-20 mm was received in the week after sowing between 10% and 20% of the years and this rose to 25% after mid-May. This suggests on average a 'false break' can occur once in every 5-10 years with April to mid-May sowing.

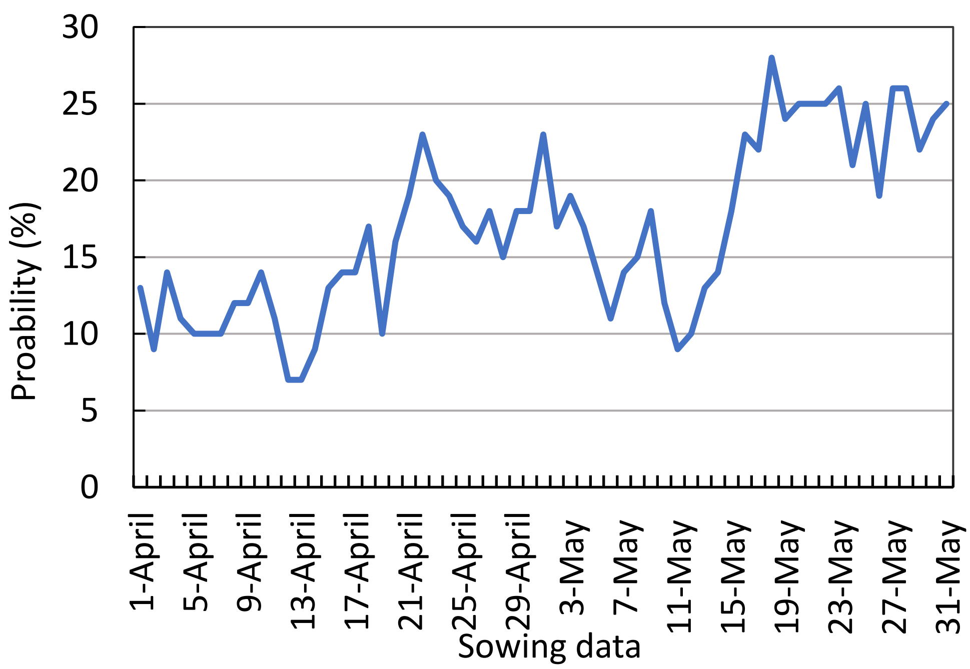

Figure 4 The probability of receiving between 10 mm and 20 mm of rainfall in a 7-day period after sowing between April 1 and May 31 at Blyth. Values are the percentage of years this amount of rainfall was received between 1970 and 2025. (Data were derived from CliMATE https://climateapp.net.au)

Sowing at a depth of 40 mm significantly reduced emergence in all varieties and at both sowing times, however the biggest reduction occurred from dry sowing. At both sowing times, at a depth of 10 mm, average established plant density was 187 plants/m^2 however, this was reduced to 103 plants/m^2 when dry-sown at 40 mm and to 159 plants/m^2 when sown after rain. Genetic differences in coleoptile length did not affect emergence from 40 mm sowing depth. Calibre (long coleoptile) and RockStar (short coleoptile) had similar average plant densities (159 plants/m^2 and 167 plants/m^2, respectively) and both were significantly higher than Neo CL (intermediate coleoptile length; 150 plants/m^2). All varieties showed a similar reduction in establishment from deep sowing; 30% for RockStar and Neo CL and 40% for Calibre.

The main factors influencing grain yield were the interactions between sowing date, sowing depth and variety. Grain yield was reduced by 40 mm sowing depth at both times of sowing with the larger reduction occurring with the early, dry sowing (Table 4). A greater yield loss (43% reduction) was observed from 40 mm, dry sowing on April 24 when compared to delaying and sowing into moisture.

Table 4. The effects of time of sowing and depth of sowing on the average yield (t/ha) of wheat and barley. Shaded values in each column indicate best performing treatments.

	Sowing date	
Sowing depth	April 24	June 27
10 mm	1.9	1.33
40 mm	1.05	1.08
P-value	**<0.001**	
LSD (5%)	**0.161**	

Among the three varieties, the highest average yield was achieved by Neo CL (1.42 t/ha) and Calibre (1.40 t/ha) both of which were higher yielding than RockStar (1.19 t/ha) (Table 5). Increasing the sowing rate by 25% had no effect on yield; the same yield (1.34 t/ha) was achieved at both sowing rates despite a significantly higher plant density at the higher sowing rate (136 plants/m^2 compared with 113 plants/m^2; $p<0.001$). This is not an uncommon occurrence because plasticity in growth in cereal can compensate for differences in plant density.

The average grain size was small, and screenings were high in all treatments, reflecting the dry spring. There was a significant interaction between sowing date, sowing depth and variety for 1000 grain weight and screenings (Table 5). The early, 40 mm, dry sowing, treatment resulted in smaller grain and higher screenings, however at the later sowing date there was no significant effect of sowing depth on either 1000 grain weight or screenings. Neo CL barley had the highest grain weight but also high screenings while RockStar recorded lower screenings than the other varieties.

Table 5. The effects of time of sowing and sowing depth on the 1000 grain weight and screenings % in three cereal varieties. Shaded values in each column indicate best performing treatments.

Variety	Sowing depth (mm)	Yield (t/ha)		1000 grain weight (g)		Screenings (%)	
		April 24	June 27	April 24	June 27	April 24	June 27
Calibre	10	1.95[de]	1.34[b]	23.5[bc]	21.7[ab]	11.3[ab]	21.5[cd]
	40	1.10[ab]	1.21[ab]	20.2[a]	21.2[ab]	27.9[e]	22.3[bcde]
Rockstar	10	1.69[cd]	1.17[ab]	25.1[cd]	24.4[cd]	10.3[a]	9.4[a]
	40	0.94[a]	0.98[a]	22.5[abc]	24.9[cd]	16.5[bc]	9.2[a]
Neo CL	10	2.06[e]	1.49[bc]	26.2[cde]	29.8[f]	39.1[f]	24.2[de]
	40	1.09[ab]	1.05[a]	31.4[f]	29.7[def]	23.3[de]	27.3[de]
P-value		**NS**		**<0.001**		**<0.001**	
LSD (5%)		**0.278**		**3.1**		**5.83**	

Conclusions

In 2025, 10 mm of rainfall was sufficient to germinate seeds, however 20-25 mm was required for seedling emergence. Receiving between 10 and 20 mm allowed the seed to germinate, but on the loamy soil at Hart, germination was patchy and the coleoptile did not fully elongate making the seedling susceptible to dry conditions. Long-term rainfall data for Blyth suggests the chance of a 'false break' with a mid-April to early May sowing is 10-20% (one in every 5-10 years).

The experiment with wheat and barley largely verified past results at Hart. Higher yields were achieved with early, dry sowing compared to waiting to sow until the break despite a lower plant population. While good establishment is a desirable aim, it is not a prerequisite for high yields and delaying sowing until the seed bed is wet does not necessarily 'de-risk' sowing.

Sowing deep into dry soil is not recommended on this soil type. The responses to deeper sowing was similar to past experiments conducted at Hart in canola and wheat. Deeper sowing reduced plant establishment and grain yield. In 2025, the effect of 40 mm sowing was more severe than a 2-month delay in sowing.

Acknowledgement

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Tracking profit and risk of cropping systems in the southern region – a preliminary scorecard

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Key findings

- Systems that achieved higher gross margins compared to baseline systems also tended to be less variable.
- System gross margin was primarily determined by the frequency of the most valuable crop in the sequence and its yield, especially in the wetter year (2023).
- Adaptive decision-making regarding variety, sowing time and crop end use resulted in improved gross margins.
- Despite two dry seasons, sequence legacy effects were apparent. Legumes typically left more residual soil water, while yield and gross margin responses varied with nitrogen management and seasonal conditions.

Introduction

The 'Farming Systems South' project

Despite advances in the productivity of individual crops, there remains a need to understand how crops interact within the cropping sequence to influence the profitability of the farming system. The GRDC 'Farming Systems South' (FSS) project was established in 2023 to deliver new insights into the drivers of profitability and sustainability of cropping systems in the southern region, by identifying strategies that improve a range of performance metrics such as system gross margin (GM) and economic water use efficiency ($WUE).

Nine field trials have been established across South Australia and Victoria following consultation with farming systems groups, agronomists and growers. The trials span a range of environments, from low to high rainfall zones (with varying seasonality) and different soil types. Each field trial is fully phased to avoid seasonal biases.

At each site, a Baseline system was identified, representing the most common practice in the region. The remaining systems differed in the presence, frequency and sequence of cereal, pulse, and canola crops. Some systems also include different N management (based on different rainfall deciles) and time of sowing strategies. Varieties, target plant densities and sowing times are all based on best practice with local adviser recommendations. Nitrogen rates are determined from pre-sowing soil water and N tests (to 60 cm) and estimates of yield potential. Weed, disease and pest management are as per best practice.

A responsive, adviser-led system is also assessed at selected sites, involving adaptive decision-making on crop or variety choice, crop end use, N rates and sowing times in each season. Decisions are made by a local adviser based on available information on current conditions, including starting soil moisture and N, seasonal forecasts and commodity prices.

Methodology

The trial at Hart, located within the medium rainfall zone (MRZ) of the Mid North SA, is one of four large-scale 'core' trials. Other 'core' trial sites are located at Kinnabulla (Southern Vic Mallee), Manangatang (Northern Vic Mallee) and Streatham (South-west Vic).

The range of systems that were identified following consultation with local growers and advisers in the Mid North SA are listed in Table 1. In some of these systems, there are additional tactical N treatments, which are not reported here for brevity.

Table 1. Cropping systems under investigation at the Hart FSS field site. Bold text identified differences compared to the Baseline.

#	System ID	Cropping system
1	Baseline*	Lentil – Wheat – Barley
2	Adviser-led, risk neutral^	Wheat (long-season) – Barley (hay) – Lentil – ?
3	More lentils	Lentil – Wheat – **Lentil** – Barley
4	Canola*	Lentil – Wheat – **Canola** – Barley
5	Adviser-led, risk tolerant^	Lentil – Chickpea – Oaten hay – ?
6	Double break	Lentil – **Canola** – Wheat – Barley
7	Pulse on pulse	Lentil - **Field pea** – Wheat – Barley
8	More cereals	Lentil – Wheat – Barley – **Wheat**
9	Winter cover crop	**Vetch (brown manure) – Canola** – Wheat – Barley
10	Intercropping*	**(Canola + Lentil)** – Wheat – Barley

This report presents results of selected systems at Hart from 2023 and 2024 (Table 2). System GMs were calculated using 5-year averages of commodity prices and input costs, averaged over all phases within each system. Economic water use efficiency ($WUE) of each system (for a given year) was calculated as:

$$\$\text{WUE } (\$/\text{ha.mm}) = \frac{\text{System GM } (\$/\text{ha})}{\text{Growing season rainfall (mm)}}.$$

The variability in GM of a system was estimated using a variability index (VI):

$$\text{VI } (-) = \frac{|\text{System GM}_{2024} - \text{System GM}_{2023}|}{\text{Average System GM}}.$$

Table 2. Key climate, soil and cropping system attributes of selected field sites.

Attribute	Hart
Average annual rainfall (mm)	387
Mean growing season rainfall (mm)	273
2023 (Decile)	236 (4)
2024 (Decile)	176 (2)
Soil classification	Calcarosol (clay loam)

Results to date

The 2023 and 2024 growing seasons were dry to very dry, with rainfall well below average (Table 2). Grain yields of all crops were much lower in 2024 due to drought. There was little to no response to N fertiliser rates and carryover of unused N between 2023 and 2024. The results presented below should be considered in the context of these two challenging years.

The Adviser-led system achieved the highest cumulative GM overall (Figure 1). This reflects the very high GM achieved in 2023 ($681/ha) due to the decision to sow a long-season spring wheat (cv. RockStar⦻) to exploit 125 mm of available soil water after a wetter than average summer, which resulted in a grain yield 27% higher than the Baseline (3.8 t/ha compared to 3.0 t/ha). In 2024, the decision to cut the barley for hay due to extreme drought conditions mitigated economic loss (barley hay GM $41/ha compared to barley grain crop GM -$280/ha). The Adviser-led system also displayed a lower GM variability than the Baseline (VI 1.8 compared to 2.5). The superior performance of the Adviser-led system highlights the value of adaptive decision-making to match crop choice, sowing time and crop end use based on available information.

Compared to the Baseline system, increasing the frequency of lentils (More pulses, Figure 1) led to a higher cumulative GM by $141/ha ($679/ha versus $538/ha). Its superior performance was due to two factors: the higher proportion of lentils, a high value grain crop in the system, and the legacy benefits of lentils, which increased yields of subsequent crops. For example, there was an extra 22 mm of soil water and 49 kg/ha of soil N after lentils compared to wheat. This contributed to an extra 1.4 t/ha of barley in 2024 (on average 2.2 t/ha after lentil compared to 0.8 t/ha after wheat). The additional revenue from the higher yield of barley ($388/ha) and the saving in N fertiliser ($40/ha) in the barley crop following lentil provide an indication of the rotational value of lentils.

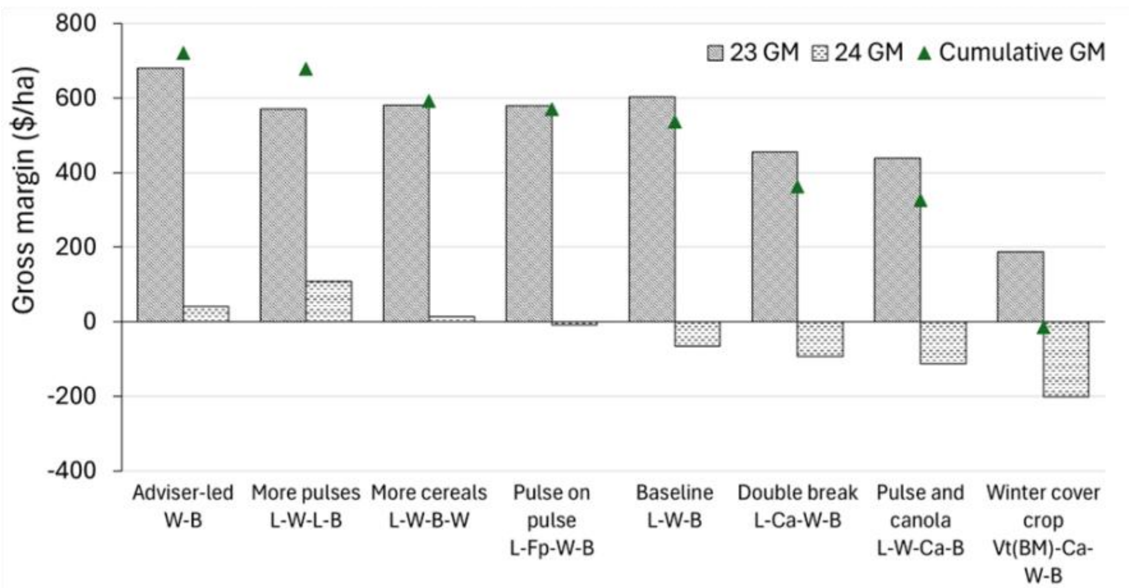

Figure 1. Cumulative (triangle) and individual-year (bar) system gross margins (GM $/ha) at Hart.

While seasonal variation was high, increasing the frequency of lentils also reduced the variation in GM, with VI decreasing from 2.5 for the Baseline to 1.4. Despite challenging conditions in 2024, the More pulses system returned the highest GM (Figure 1). These results highlight the suitability of lentils in the Mid North of SA, especially in dry years, and their value to subsequent crops.

Although increasing the frequency of lentil improved economic performance overall, the cumulative GMs for other legume-cereal systems were similar to the Baseline (Figure 1). Reducing lentil frequency to one-in-four years (More cereals) and growing consecutive pulses (Pulse on pulse) resulted in cumulative GMs that were within $56/ha of the Baseline. These results suggest there was reasonable flexibility in decision-making regarding the intensity of pulses within the system.

The potential gains in GM and $WUE as well as reduced variability that can be achieved are indicated by the comparison between the Baseline and the most profitable system (Table 3). Gross margin and $WUE of the most profitable system were ~30% higher than those of the Baseline system, combined with their considerably higher reliability in converting rainfall into GM (VI reduction 35%). While achieving both higher cumulative GM and reduced variability suggests that there may be lower risk means to increase system profit, the extent to which this holds needs to be evaluated based on more experimental years to ensure biological pressures are fully expressed, especially following dry seasons.

Table 3: Average gross margin (GM) and economic water use efficiency ($WUE) in each year, and variability index (VI) between years, for the Baseline and most profitable system. Here, VI is calculated based on $WUE.

Site and year(s)	GM ($/ha)		$WUE ($/ha/mm)		VI	
	Baseline	**Most profitable**	**Baseline**	**Most profitable**	**Baseline**	**Most profitable**
Hart 2023	603	681	2.6	2.9	2.7	1.7
Hart 2024	-65	41	-0.4	0.2		
Cumulative 2023-24	***538***	***722***	***1.3***	***1.8***		

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