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2022

HART TRIAL RESULTS

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NOTES

Front cover photo by Sandy Kimber.

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

Research supporters

We also receive project funding support provided by the Australian Government

Collaborators

Hart 2023 calendar

HART FIELD DAY

September 19

Our main Field Day attracts over 600 visitors from all over South Australia and interstate.

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

This is Hart's main event of the year.

Hart AGM

October 2023

Getting The Crop In

March 8

8am – 12:30pm

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

Winter Walk

July 18

9am – 12pm

An informal guided walk around the trial site; the 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 17

5pm followed by BBQ

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

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

Acknowledgements

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

Supporters

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

Peter Baker
Andy Barr
Andrew Cootes
Rob & Dennis Dall
Matt Dare
Trevor Day
Colin Edmondson
Marg Evans
Simon Honner
Damien Hooper
Michael Jaeschke
Simon Jaeschke
Paul Jarret
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Stuart Sherriff
Kelvin Tiller
James Venning
Rob & Glenn Wandel
Scott Weckert
Rob Wheeler
Glen Wilkinson
Matt Williams
Justin, Bradley & Dennis Wundke

We would also like to thank various organisations for the provision of seed and/or products that were trialed in the 2022 research program.

ADAMA
Advanta Seeds
Agriculture Victoria – field pea breeding program
Agriculture Victoria – lentil breeding program
Agspec
Australian Grain Technologies
Barenbrug
BASF
Bayer Crop Science
Corteva Agriscience
CSIRO
FMC
Global Grain Genetics
Imtrade
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SARDI Clare
SARDI Vetch Breeding Program
SARDI Agronomy & Crop Sciences
Seednet
Seed Force
Sumitomo
Syngenta
University of Adelaide
University of Adelaide – bean breeding program
UPL

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

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Sarah Noack
Rob Price
Stuart Sherriff
Scott Weckert
Glen Wilkinson

And finally, thank you to those who have volunteered their time to support Hart's 'BEEN FARMING LONG?' workshop series for early career farmers.

Jim & Katherine Maitland
Andrew Mitchell
Rob Pratt
Deb Purvis
Scott & Jeff Weckert
Ben Wundersitz
Ben Marshman
Alec Bowyer
Damien Sommerville
Nufarm
Viterra

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

OUR VAULES

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 Field-Site Group board

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Rebekah Allen	Research & extension manager
Declan Anderson	Regional intern
Gabrielle Hall	Media

Site Management

SARDI, Agronomy Clare:
Patrick Thomas, John Nairn, Sarah Day, Dili Mao, Navneet Aggarwal, Penny Roberts, Dylan Bruce, Greg Walkley, Amber Spronk and Jacob Nickolai

Hart Field-Site Group:
Rebekah Allen and Declan Anderson

Contact us in person…

Chairman	Research & Extension Manager	Executive Officer
Andre Sabeeney	Rebekah Allen	Sandy Kimber
04718 835 599	0428 782 470	0427 423 154
		admin@hartfieldsite.org.au

Or find out more about us…

HART
SA's premier cropping field site

Hart Field Day

September 19, 2023

www.hartfieldsite.org.au

The Hart site

The Hart field site (40 ha owned by the group) is managed as four quarters that are rotated each year. In 2022, Quarter 4 hosted our trials.

Quarter 1 was sown with Mulgara oats and was cut for hay to tidy the site in preparation for 2023 trials.

Quarters 2 and 3 were sown with wheat as our commercial crop.

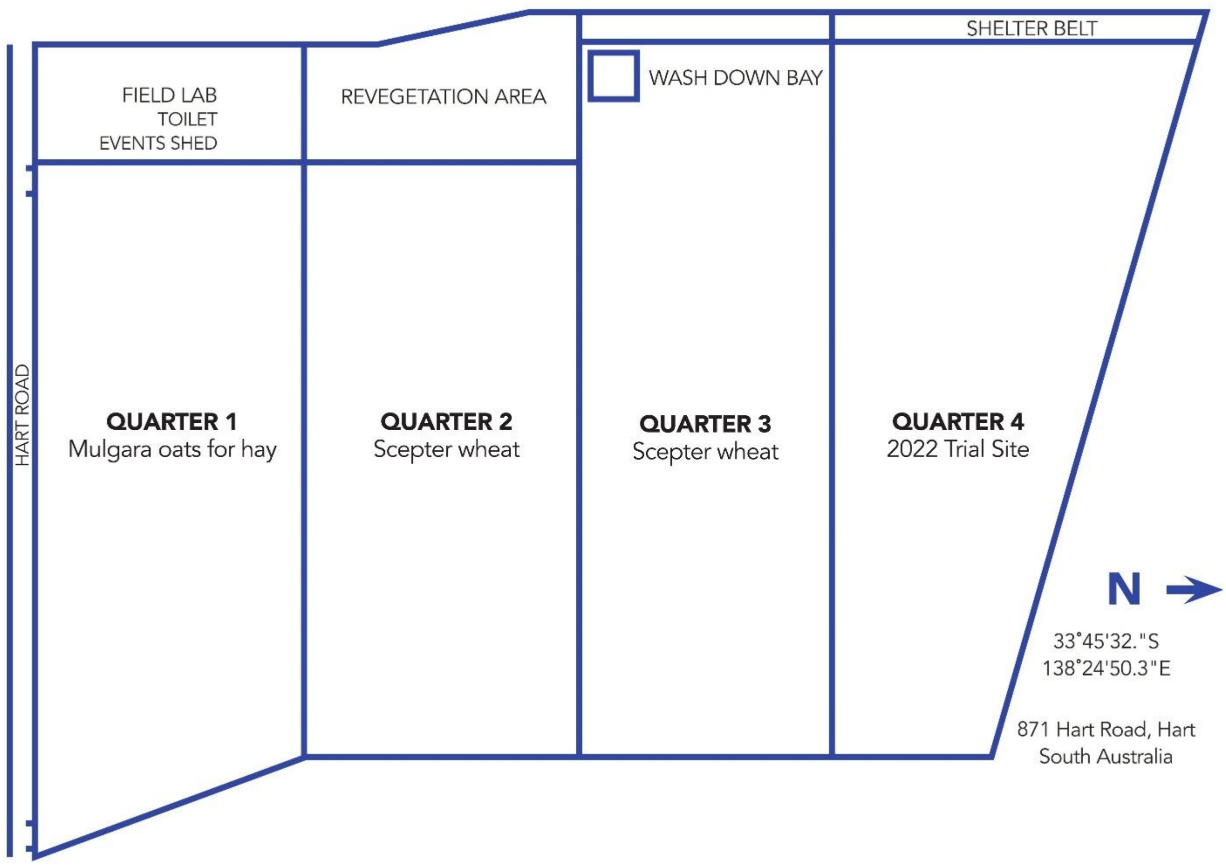


Photo. Hart site visit by Lucerne Australia's 2022 study tour.

Hart commercial crop report

Matt Dare; Hart Field-Site Group

The 2022 Hart commercial crop was sown in Quarters 2 & 3 (16.5 hectares) to Scepter wheat at 100 kg/ha on May 29.

There was marginal moisture at sowing from a 6 mm rain event a few days earlier.

Sakura was applied at recommended label rates (118 g/ha) prior to sowing Quarters 2 & 3 on May 28. A knockdown herbicide was not applied prior to sowing as there had not been enough rain to germinate any weeds.

Mulgara oats for hay was sown (~80-100 kg/ha) in Quarter 1 in preparation for 2023 trials. Fertiliser was applied; 75kg/ha DAP (18:20:0:0), with all seed.

Seeding was completed prior to the site receiving 38 mm rain on May 31. It was somewhat nostalgic sowing straight through the old cropping systems trial that had been in the same location on the site since 2000.

Thanks to Glen Wilkinson for providing Scepter seed and getting it to the site on Sunday so the commercial crop could be sown before the seasons break.

On July 10, 100 kg/ha of urea was spread on the commercial wheat crop. We received 2.6 mm of rainfall on July 12, but only 15 mm for the month in total.

Both the commercial wheat crop and oats were sprayed for broadleaf weeds on August 9; 25 g Paradigm, 400 ml MCPA LVE570, 70 ml Dicamba750, 100 ml Dimethoate and 0.5% Uptake oil per hectare was applied.

In addition, the wheat had 500 ml/ha of epoxiconazole applied.

A follow up application of 90 kg /ha of urea was applied by Peter McEwin on September 13 – thank you Peter.

A further fungicide application (500 ml/ha of epoxiconazole) was applied for stripe rust on September 23.

The commercial crop was harvested on the 5th January and yielded 4.54 t/ha (75 tonnes) of H2 quality wheat. Thanks to Matt Williams for harvesting and Peter Agnew for delivering the grain to Snowtown.

Thanks also to Rob Wandel who cut the oats in Quarter 1 in preparation for 2023 trial site.

The 2022 season at Hart; rainfall, temperature and soil analysis

Rebekah Allen and Declan Anderson

Hart Field-Site Group

The Mid-North region had a dry start leading into the 2022 growing season, with a lack of rainfall across summer months until the season break arrived late May. This meant there was very little stored soil moisture (Figure 1 & 2) at seeding. Some sowing windows across the region were either pushed back, or late crop emergence was noted. The season break occurred on May 30 at Hart, with 26 mm of rainfall received (Table 1).

Seeding at the Hart field site commenced on April 22, with early sown winter wheat and vetch trials. Most of Hart's pulse and cereal program was sown by late May, however no significant rain had occurred during this time. All remaining trials were sown by June 17 directly into soil moisture. By this time, Hart had noted 88 mm growing season rainfall (GSR) with majority of this rainfall received between May 30 and June 11.

Starting soil nitrogen (N) at Hart was 74.2 kg/ha at depth (0-105 cm), after an oaten hay crop in 2021 (Table 2).

Trials at Hart began emerging on June 8. The site experienced drier conditions through July (15 mm), with rainfall becoming more consistent mid-late August. Crop growth was very slow during winter months due to cold conditions (Figure 3), also resulting in minimal water use (Figure 2). Monthly rainfall was well above average from September to November (Figure 1).

Hart received 519 mm of annual rainfall in 2022, placing it at a decile 10 rainfall year (average annual rainfall 400 mm). Growing season rainfall (April – October) of 355 mm was 55 mm above Hart's 100-year average growing season rainfall (300 mm), equivalent to a decile 8 season.

Daily minimum and maximum temperature data at Hart in 2022 is provided in Figure 3.

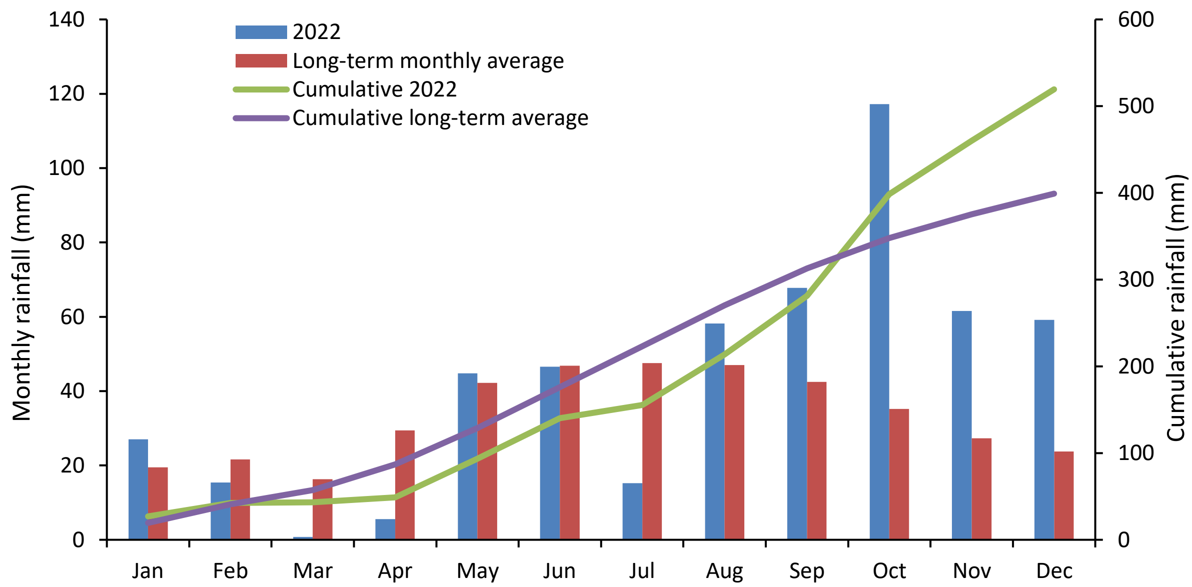


Figure 1. Hart rainfall graph for the 2022 season and long-term average. Lines are displayed to present cumulative rainfall for long-term average (purple) and 2022 (green).

Table 1. Hart rainfall chart for 2022 (Source: Mesonet)

	January	February	March	April	May	June	July	August	September	October	November	December
1	0	0.2	0	0	0	1	0.2	6.2	0.2	0.2	28.4	0
2	0	0	0	0	0	0	0	0	0	0	1.8	0
3	0	0	0	0	0	0	0	4.6	0	0	1.6	0
4	0	0	0	0	0.4	3.4	0	0	0.2	5.8	0	0
5	0	0	0	0	0	0.4	0	0.8	0	11.8	0	0
6	5.2	0	0	0.8	0.8	11.8	0.2	0.4	0	0	0	0
7	3.6	0	0	0	0.8	11.4	0.4	3	0.2	4	0	0
8	0.6	0	0	0	0	0.2	2.6	0.4	25.4	0.2	0	0
9	0	1.6	0	0	0	0	1	0	12.2	0	0	0.2
10	0	0	0	0	0	0.4	0.2	0.2	6.2	0	1.4	0.2
11	0	0	0	0	0	4.6	0	5	0	0	0	0
12	0	0	0	0	0	0	1.8	6	0.4	0.2	9.8	0
13	0	0	0	0	0	0	0.8	5.4	0	16.6	3.6	0
14	0	0	0	0	0	0	0.2	3.4	3.6	3.8	3.6	0
15	0	0	0	0.8	0	0	0	3	1.8	0.2	0.2	0
16	0	0	0	0.2	0	4.6	0	1.4	4.4	0	0	0
17	0	7.2	0	0	0	0	2	0	3	0	0	0
18	0	0	0	0.8	0	0	1.6	0.8	0.6	3.4	0	0
19	0	0	0	0.4	0	0	0.2	6.6	0.2	0	4.6	0
20	0	0	0	0	0	2.2	0	0.4	0	0	2.4	0
21	0	1	0	1.4	0	1.4	0	2	3.6	0	1.8	4.2
22	1.2	0	0	0	0	0.6	0	0	0.2	0	0.4	28.8
23	12.2	0	0.8	0	0	0	0	6	0.2	23.4	0	0
24	4.2	0	0	0	0	0	0	0.2	1.6	11.4	0	0
25	0	0	0	0	1.2	1.8	3.6	0.6	0	4	0	0
26	0	0	0	0	4.4	0.2	0.2	0.2	1.8	0	0	0
27	0	0	0	0	0	1.4	0	0	0.6	0	2	18.8
28	0	5.4	0	0	0	0	0	0	1	0	0	7
29	0		0	0	0	0	0	0	0.2	0.6	0	0
30	0		0	1.2	26.2	1.2	0	1.4	0.2	0	0	0
31	0		0		11		0.2	0.2		31.6		0
Montly total	**27.0**	**15.4**	**0.8**	**5.6**	**44.8**	**46.6**	**15.2**	**58.2**	**67.8**	**117.2**	**61.6**	**59.2**
GSR rainfall				5.6	50.4	97.0	112.2	170.4	238.2	355.4		
Total rainfall	27.0	42.4	43.2	48.8	93.6	140.2	155.4	213.6	281.4	398.6	460.2	519.4

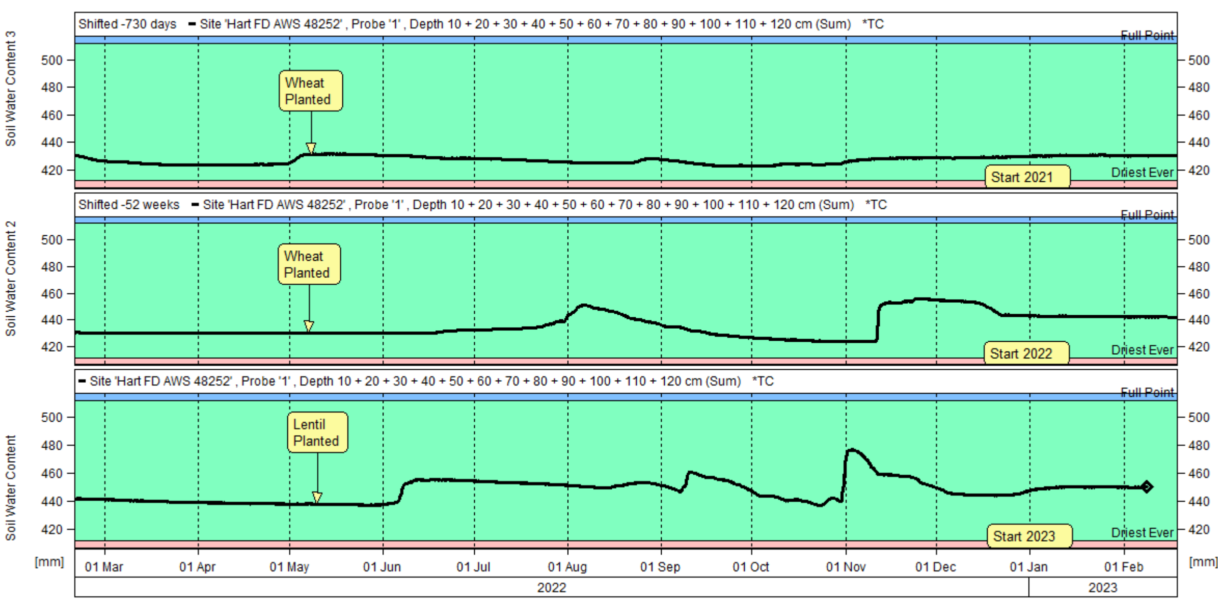


Figure 2. Soil moisture probe summed comparison (80cm) for 2020 (top), 2021 (middle) and 2022 (bottom) at the Hart field site.

Hart soil moisture data is free to view thanks to Agbyte and can be viewed here: https://www.hartfieldsite.org.au/pages/live-weather/soil-moisture-probe.php

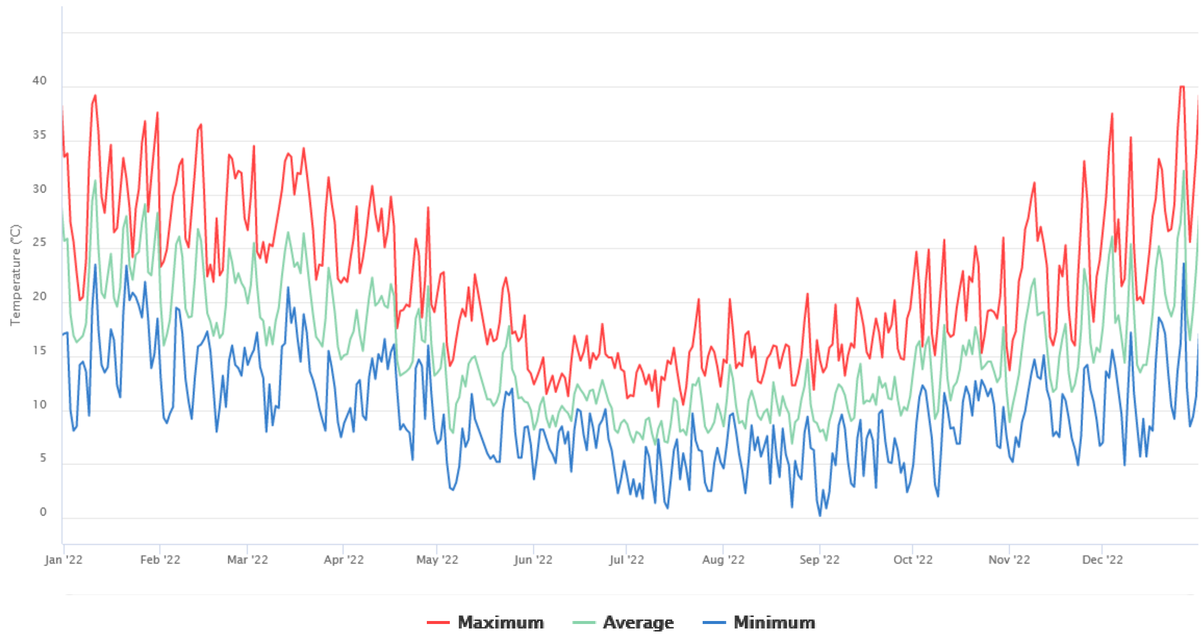


Figure 3. Daily minimum, average and maximum temperature (°C) from January 1 to December 31 at Hart in 2022. Temperature data sourced from Mid North Mesonet.

Table 2. Actual soil physical and chemical properties for the Hart field site, sampled March 31, 2022.

		Sampling Depth (cm)					
Soil property	**Units**	**0-15** (cm)	**15-35** (cm)	**35-55** (cm)	**55-75** (cm)	**75-105** (cm)	**Total profile** (0-90cm)
Texture		Loam	Loam	Loam	Loam	Loam	
Phosphorus Cowell	mg/kg	22	8	10	9	<5	
Potassium Colwell	mg/kg	273	146	145	129	133	
Available soil N	kg/ha	19.6	14.5	14.4	13.7	12	74.2
Sulphur	mg/kg	5.1	5.2	7.3	11	23	
Organic Carbon	%	1.00	0.60	0.59	0.48	0.25	
Conductivity	dS/m	0.15	0.13	0.15	0.27	0.47	
pH ($CaCl_2$)		7.8	7.8	7.9	8.1	8.6	

Yield Prophet® performance in 2022

Rebekah Allen
Hart Field-Site Group

Key findings

- A correlation is observed between Yield Prophet® predictions and actual yields at Hart from 2012 – 2022. Across ten years, 77% of wheat grain yields were close to those predicted by Yield Prophet®.
- Actual yield received for a comparison Scepter wheat crop with similar nitrogen (N) inputs yielded 86% of the predicted Yield Prophet® simulation. N deficiency contributed to low predicted grain yield for wheat at Hart, following excellent rainfall August – November, placing Hart at a decile 8 for GSR.

Introduction

Wheat growth models such as APSIM are highly valuable in their ability to predict wheat yield. This model simulates the effects of the environment and crop management on yield.

Yield Prophet® is an internet-based service using the APSIM wheat prediction model. The model relies on accurate soil information such as plant available water (PAW) and soil nitrogen (N) levels, as well as historical climate data (100 years of data) and current local weather information to predict plant growth rates and final hay or grain yield predictions.

This early prediction of grain yield potential means it can be used to directly influence crop input decisions. No other tool to provide information of this accuracy at such a useful time of the season is currently available to growers.

Yield Prophet® simulation

Location	Hart, SA	**Fertiliser**	May 1: 20 kg N/ha @ seeding
Seeding date	May 1, 2022		July 21: 40 kg N/ha
Variety	Scepter wheat @ 180 plants/m^2		

Yield Prophet® simulations were issued monthly during the growing season (June – October) to track the progress of wheat growth stages and changes in predicted grain yield. This data was published for 8 Mid-North sites and can be viewed on Hart's website: *https://www.hartfieldsite.org.au/pages/resources/hart-beat-newsletters.php*

Hart Beat newsletters report the average grain yield prediction for Scepter wheat sown on May 1 and May 20, representing an early and late sowing time. These reported yields are based on a 50% probability (or decile 5 season) for the remainder of the season.

Growing season rainfall (GSR) deciles provide an update on how Hart's rainfall is tracking based on the previous 100 years of rainfall data. For example, if the GSR is decile 3, Hart is in the 30th percentile (or the lowest 30% of rainfall records). A decile 9 would mean that 90% of years had less than the current season.

Soil at the Hart field site ranges from a loam to clay-loam texture (0-30 cm) and provides moderate infiltration and PAW. The estimated starting available soil N entered in Yield Prophet® at Hart in 2022 was 63 kg/ha. Yield Prophet® uses APSOIL, a national soil data base to collect pre-characterised soil information from various locations. Soil data for sites includes; layer depth, EC (dS/m), pH (Cacl2), Cl (mg/kg), ESP%, Boron and Aluminium. Pre-seeding nitrogen and water content (%) values were entered into the prediction model to determine accurate starting levels. It's important to note that only soil water content (%) is physically measured in the field for Hart Beat newsletters. This is to provide an estimate of soil water in each location pre-seeding. Soil water content generally varies as a result of soil type and summer rainfall.

Results and discussion

The first yield prediction was simulated on June 16, 2022 for Scepter wheat sown on May 1 and was estimated to yield 3.6 t/ha in 50% of years. In 20% of years, the same crop would achieve a grain yield of 4.4 t/ha and in 80% of years, 2.15 t/ha (Figure 1). The 20%, 50% and 80% level of probability refers to the percentage of years where the predicted yield estimate would have been met, according to the previous 100 years of rainfall data at Hart.

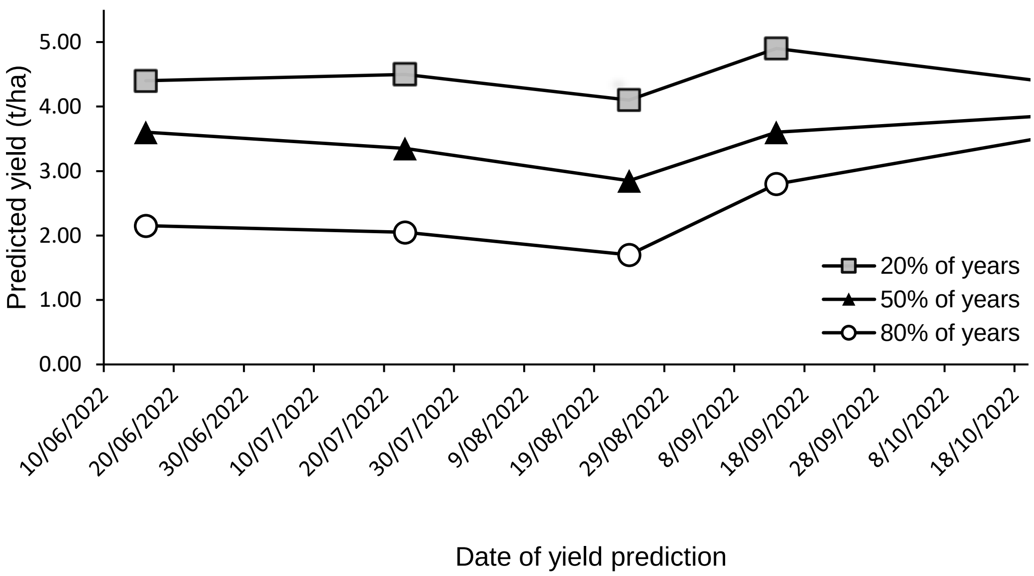


Figure 1. Yield Prophet® predicted yields at 20%, 50% and 80% probabilities at Hart, 2022.

Below average rainfall was received for July (15 mm), reducing predicted yields to 3.35 t/ha (a difference of -0.25 t/ha since June). At this time GSR was 102 mm and total soil PAW was 50 mm (Figure 2). The August Yield Prophet® prediction estimated an even lower yield of 2.85 t/ha, with a prediction of 98 mm rainfall left for the growing season, based on historic rainfall data. The reduction in yield potential was likely due to N-limiting factors with increased rainfall received.

September and October both received well above average rainfall, totalling 185 mm, with the October simulation predicting an increase in wheat grain yield to 3.9 t/ha, similar to yield estimated in June. A wheat crop sown at Hart on May 5 with similar N inputs, yielded 2.69 t/ha (86% of predicted yield). Many wheat crops at Hart, and more broadly within the Mid-North region, produced well above average yields, however N deficiency contributed to low predicted grain yields at Hart, with excellent decile 8 GSR rainfall (355 mm) and decile 10 for annual rainfall, receiving 519 mm (Table 1) in total.

A model of predicted and actual yield at Hart over ten years (2012-2022) demonstrates a moderate to strong correlation between Yield Prophet® predictions and observed yields. Over ten years, 77% of wheat grain yields were close to those predicted by Yield Prophet® (Figure 3).

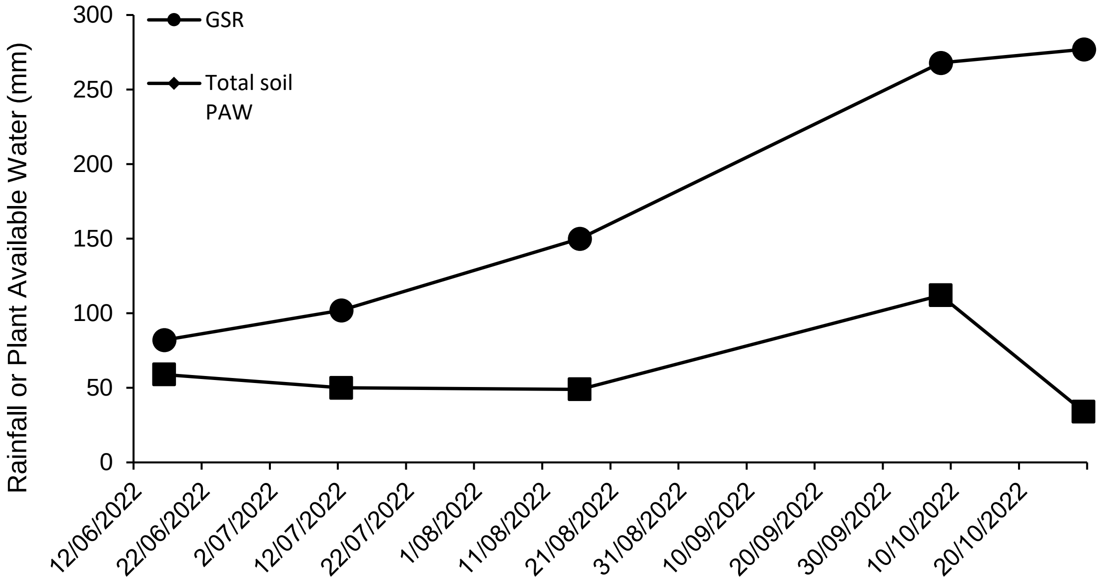


Figure 2. Growing season rainfall (GSR) and plant available water (PAW) on simulation dates at Hart in 2021.

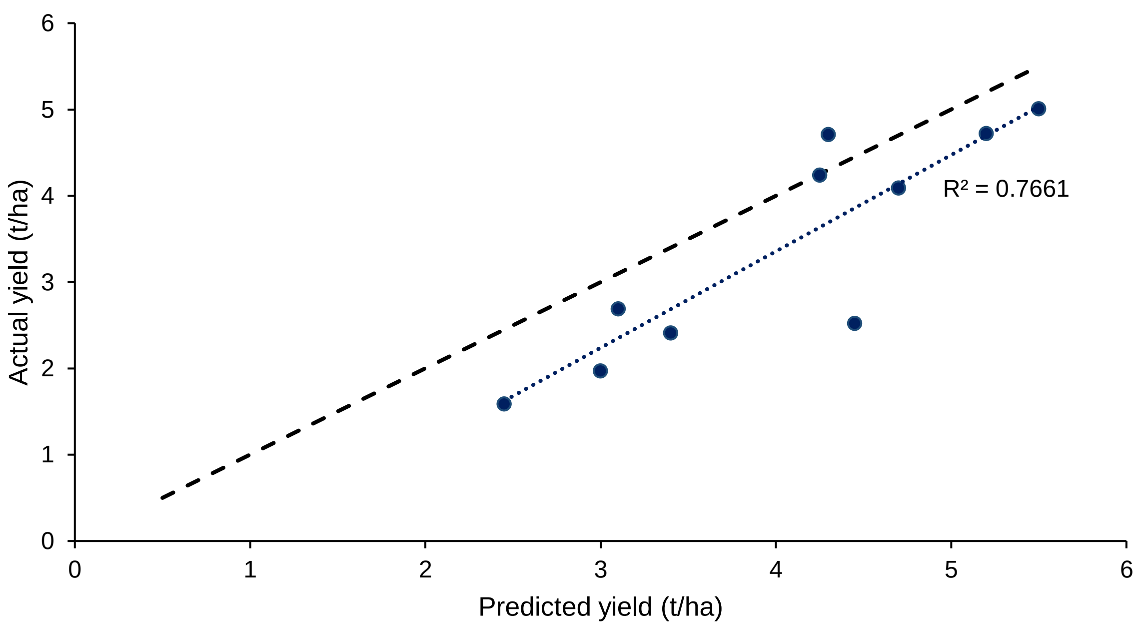


Figure 3. The relationship between Yield Prophet® grain yield predictions and actual yield at Hart across ten seasons (2012 – 2022). Predicted yields have been generated from August simulations. Yields from 2021 are not included in this data set, due to grain losses prior to harvest.

Table 1. Long-term average (100 years) and 2022 rainfall at Hart. Shaded values show months with above average rainfall (mm).

Month	Long-term monthly rainfall average (mm)	2022 Monthly rainfall (mm)	+/- Rainfall difference (mm)
January	20	27	+7
February	22	15	-7
March	16	0.8	-15
April	29	6	-23
May	43	45	+2
June	47	47	0
July	47	15	-32
August	47	58	+11
September	43	68	+25
October	35	117	+82
November	27	62	+35
December	24	59	+35
Rainfall total	**400**	**519**	

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 Andrew Cootes, Daniel Neil, Justin & Bradley Wundke, Rob Dall, Kelvin Tiller, Damien Sommerville, Trevor Day and Anthony Pfitzner for providing paddocks for sampling in 2022.

Useful Resources

Yield Prophet Lite (Free online tool)
https://www.yieldprophet.com.au/yplite/

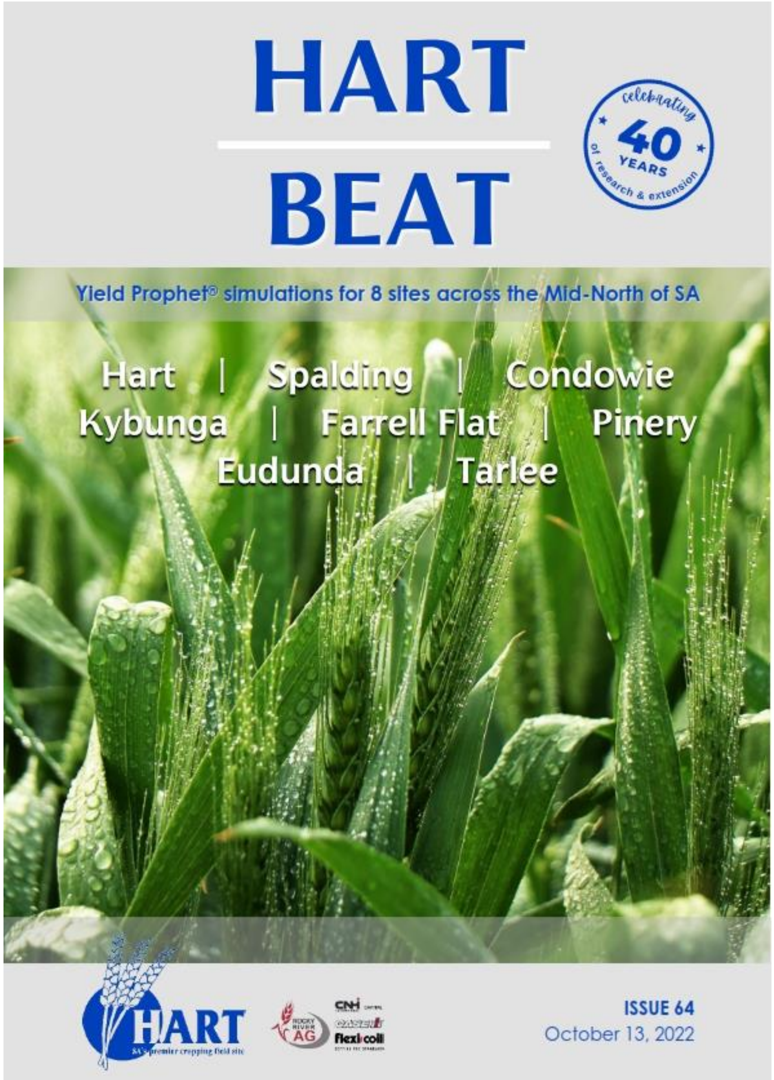
Hart Beat Newsletters (updated June – October each year)
https://www.hartfieldsite.org.au/pages/resources/hart-beat-newsletters.php

Yield Prophet 2017, 'How it works'
https://www.yieldprophet.com.au/yp/HowItWorks.aspx

The Very Fast Break
https://www.youtube.com/channel/UClDCIIl7gRZhUs03opGqH1g/videos

Climate outlooks – weeks, months and seasons
http://www.bom.gov.au/climate/outlooks/#/overview/summary

HART BEAT - yield predictions through the growing season for 8 Mid-North sites



VIEW & SUBSCRIBE ON THE HART WEBSITE

The *HART BEAT* newsletter, first introduced in 2009, is an initiative of the Hart Field-Site Group.

It is aimed at providing farmers and agronomists with regular updates of current and predicted crop and soil conditions as a season progresses.

We believe it will assist in making informed choices on the need for additional nitrogen and fungicide applications.

The Yield Prophet® simulations featured are not a crystal ball but provide a realistic prediction of the available soil water and nitrogen status of your crop.

Current (and historical) editions are all available online now, for free:

www.hartfieldsite.org.au

Rainfall variability trial at Hart in 2022

Declan Anderson and Rebekah Allen

Hart Field-Site Group

Key findings

- Growing season rainfall varied by 14.5 mm (5%) across the Hart field site in 2022. Annual rainfall also varied by 5% (21 mm) with high levels of variation across the site.
- Individual rainfall patterns remained variable, with no location in the paddock recording consistently high rainfall.
- Autumn rainfall was recorded to be the most variable, with a CV% of 13.9%. Winter, spring and summer received the most consistent rainfall, with less variation between locations in the paddock.
- Rainfall variability and inconsistency in spatial distribution of rainfall remain similar across 2021 and 2022, meaning predictable trends are not likely to develop during growing seasons.

Introduction

Rainfall is known to be widely variable across broad agricultural areas. Factors that contribute to variability include rainfall duration, intensity, location and topography. This knowledge can help growers understand where it is more likely for higher rainfall to occur.

The use of remote weather stations, including the Mid-North Mesonet, have become useful tools for growers to track rainfall events and compare measured rainfall against various locations. Variation on a paddock level, however, is not well understood.

This two-year trial aims to identify seasonal trends and capture variability of rainfall differences for individual rainfall events within a single paddock.

Methodology

In 2021, 11 manual rain gauges were positioned across 40 hectares (ha) at the Hart field site. In 2022, there were changes to positioning of some gauges to reflect the change in the location of 2022 trials (Figure 1). Rainfall measurements from all gauges were measured and recorded after each rainfall event.

Rainfall events ranged from 1-5 days, dependent on the persistence of rainfall during this time. This is displayed in Table 1, showing that 34 rainfall events were recorded manually at Hart, compared to the Mesonet's recording of 112 days of rainfall.

All gauges were calibrated in 2021, prior to the first rainfall event, ensuring the volumetric capacity of water (mm) was consistent for measurement accuracy. Events under 0.4 mm were not recorded.

Rainfall at the Hart field site was mapped using a GIS program to display rainfall patterns for each event, through inverse distance weighted (IDW) interpolation maps (Figure 2).

The variability of autumn, winter, spring and summer rainfall, growing season rainfall (GSR), annual rainfall and individual rainfall events was measured.

Table 1. Growing season and annual rainfall summary for the 2022 season at Hart. Rainfall data was sourced from the Mid-North Mesonet.

	Rainfall (mm)	**Decile**
Annual rainfall	519	10
Growing season rainfall (GSR)	355	8
	Mesonet (rainfall days)	**Manual gauges** (recorded rainfall events)
Number of recorded rainfall events	112	34

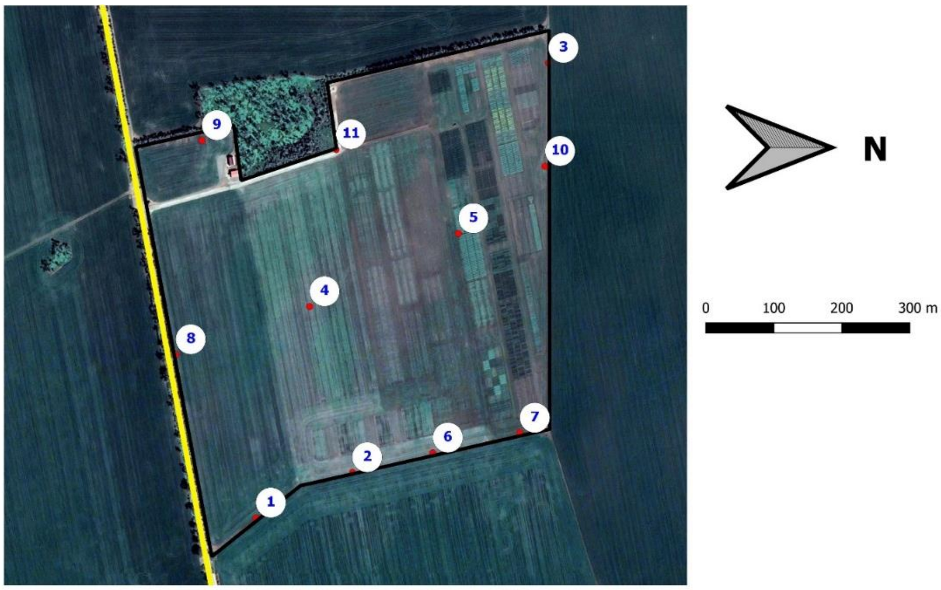


Figure 1. Location of manual rain gauges positioned across the Hart field site in 2022.

Results and discussion

Growing season and annual rainfall

During 2022, a total of 34 rainfall events were recorded, with 24 of these events occurring during the growing season. Annual rainfall at Hart in 2022 was 425 mm with a GSR of 288 mm across all 11 rain gauges. Growing season rainfall varied by 14.5 mm (5%) across all gauges (Figure 2). This volumetric difference is similar to what was observed in 2021, with 17 mm difference across the 40 ha site at Hart (Anderson & Allen 2021).

Annual rainfall varied by 21 mm (5%), with the highest amount of rainfall received in the south-west corner and northern fence line (Figure 3). The lowest amount of rainfall was recorded near the middle of the southern fence line.

The close proximity of high and low rainfall areas in 2022, continue to indicate high spatial variability of rainfall.

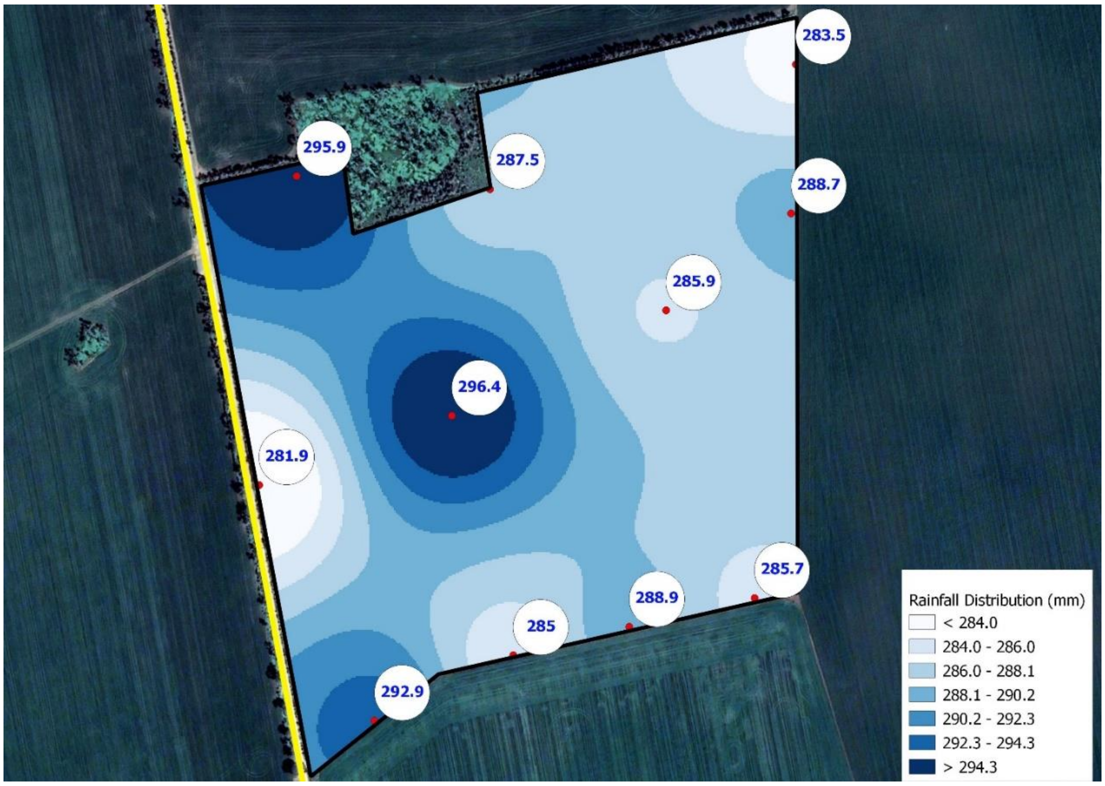


Figure 2. Distribution of recorded rainfall for the duration of the 2022 growing season (April – October) for each gauge at Hart.

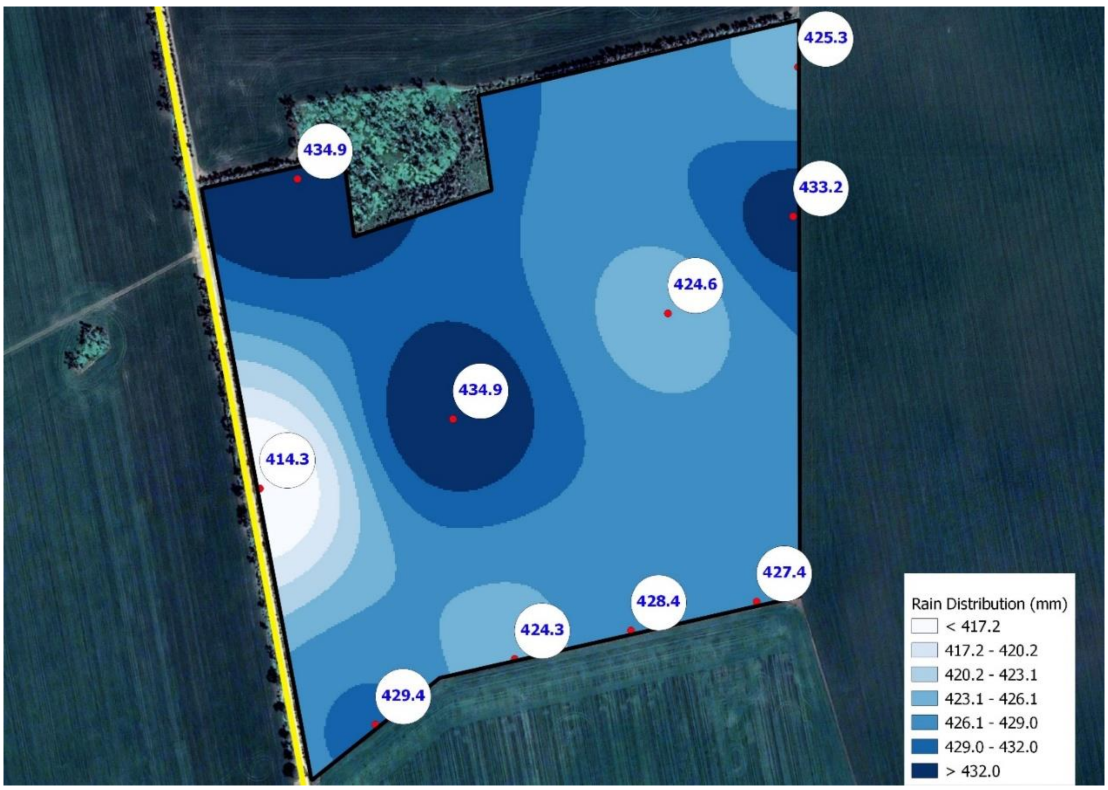


Figure 3. Distribution of recorded rainfall for 2022 for each gauge at Hart. Gauge 11 not present due to missing values.

Comparison of single rainfall events

A high coefficient of variation (CV%) was recorded for rainfall events of less than (<) 5 mm when compared to events over 5 mm.

This results in larger differences between rain gauges when smaller rainfall events are observed. This is supported by the percentage (%) difference between highest and lowest recorded amount in each rainfall event. Events that were < 5 mm varied by 12-48% between the highest and lowest recorded rainfall across gauges (data not shown). The variability of rainfall across gauges was lower in 2022 when compared to 2021. This was likely a result of an increase in average rainfall per event in 2022, averaging 12.7 mm compared to 7.8 mm in 2021.

Rainfall that was greater than (>) 5 mm had a lower difference (%) between high and low recordings with events averaging 15% between gauges compared to 31% when < 5 mm (data not shown).

When rainfall events of similar volume were compared, the spatial distribution of rainfall still varied greatly, as shown in Figure 4 and Figure 5. The rainfall patterns suggest that there are no paddock locations that consistently record higher levels of rainfall. Across both years of this trial, there has been no spatial trend observed, meaning assumptions of where rainfall is going to be higher cannot be made for Hart.

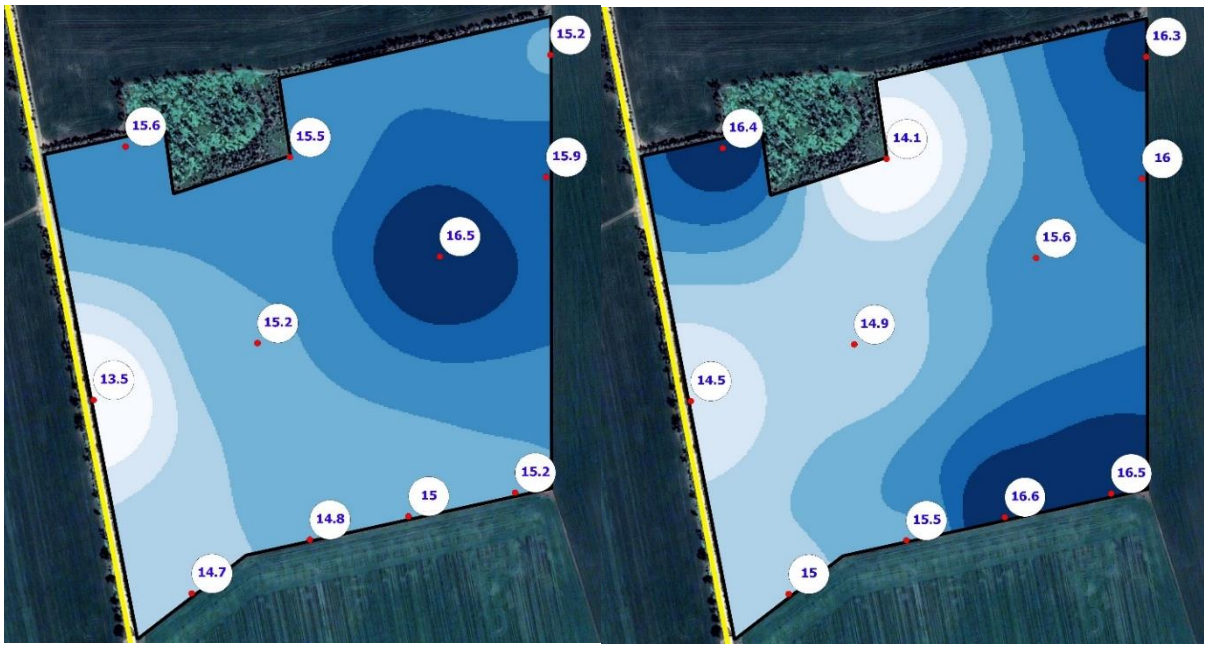


Figure 4. Rain distribution maps of two 15 mm rainfall events on June 27 (left) and December 23 (right) at Hart in 2022.

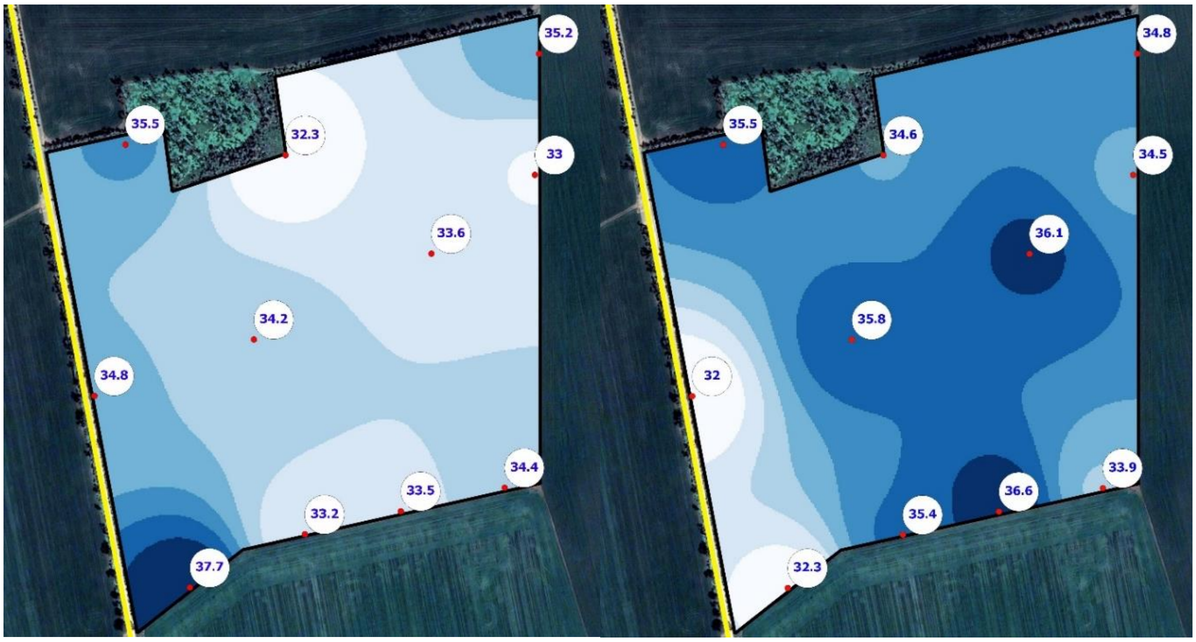


Figure 5. *Rain distribution maps of two 35 mm rainfall events on May 31 (left) and October 26 (right) at Hart in 2022.*

Rainfall variability across seasons

As expected, the volume of rainfall was different across seasons, with low recordings of 51 mm in autumn, and high rainfall of 246 mm in spring (Table 2).

Similar to 2021 observations, winter and spring had the most consistent distribution of rainfall with low CV% (variability) of 8.1 and 3.4 respectively. Summer months in 2022 also had consistent rain distribution with a CV% of 5.3 (Table 2).

As observed in 2021, autumn recorded a high rainfall CV% across the 11 gauges, suggesting that differences in rainfall across a paddock would be greater than in other seasons.

Table 2. Seasonal rainfall data including coefficient of variation (CV%), rainfall event average (mm), rainfall days and total seasonal rainfall (mm) for Hart in 2022. Rainfall data sourced from the Mid North Mesonet.

	Autumn	Winter	Spring	Summer
CV%	13.9	8.1	3.4	5.3
Event average	3.7	2.9	6.6	7.3
Rainfall days	14	41	37	14
Total season rainfall (mm)	**51.2**	**120.0**	**246.4**	**101.6**

Rainfall distribution for each season across the Hart field site was variable (Figure 6). There are no similarities between corresponding rainfall distribution maps in 2021 or 2022 (Anderson & Allen 2021). This suggests there are not predicable rainfall distribution patterns for each season at Hart.

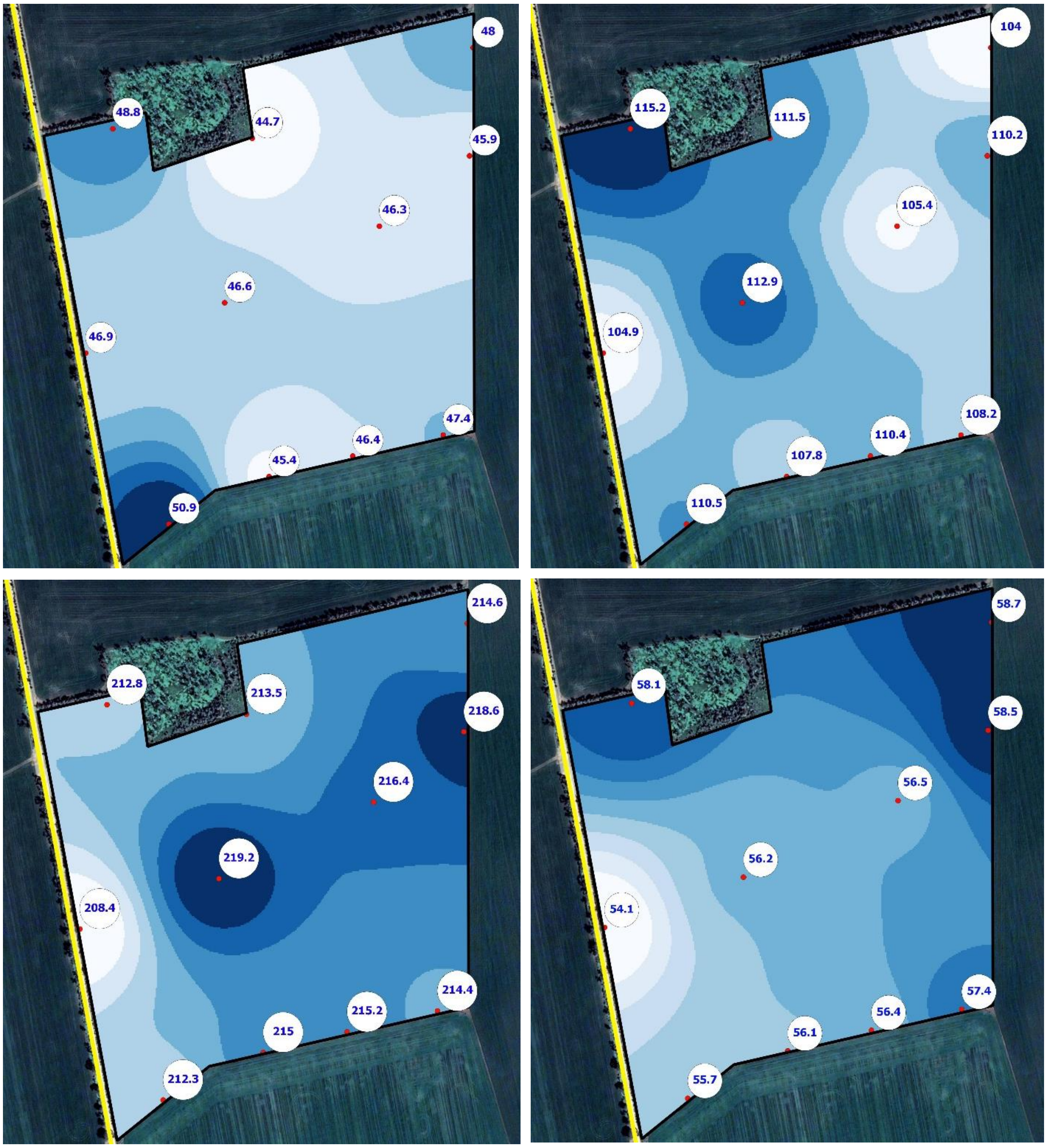


Figure 6. Rainfall distribution maps for autumn (top left), winter (top right), spring (bottom left) and summer (bottom right) at the Hart field site in 2022. Dark blue shading represents greater rainfall areas and white areas indicate lower rainfall.

Acknowledgements

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

This trial is funded by

References

Anderson D and Allen R 2021, 'Rainfall variability at Hart in 2021'
https://www.hartfieldsite.org.au/pages/resources/trials-results/2021-trial-results.php

Interpretation of statistical data

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

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

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

Interpretation of replicated results: an example

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

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

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

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

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

Disclaimer

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Comparison of wheat and durum wheat varieties

Rebekah Allen and Declan Anderson
Hart Field-Site Group

Key Findings

- Australian Premium Durum variety Patron was the highest yielding at Hart of 5.41 t/ha.
- Ballista, Catapult and Rockstar were the highest yielding Australian Hard varieties, ranging from 4.58 – 4.72 t/ha. Australian Prime Hard variety Sunblade CL Plus also performed well, yielding 4.85 t/ha.
- Scepter continues to perform well across multiple seasons at Hart.
- Brumby, Denison and LRPB Trojan were the highest yielding Australian Premium White varieties, yielding 4.54, 4.80 and 4.59 t/ha, respectively. Brumby also performed well in National Variety Trials across the Mid-North Region.
- Screenings (%) were very low, due to an excellent spring finish supporting wheat grain fill, however protein levels across all varieties trialed were low (>10.5%).

Introduction

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

Methodology

Plot size	1.75 m x 10.0 m	**Fertiliser**	Seeding: DAP (18:20) Zn 1% + Impact @ 80 kg/ha
Seeding date	May 5, 2022		July 22: Easy N (42.5:0) @ 70 L/ha
Location	Hart, SA		August 17: Easy N (42.5:0) @ 60 L/ha
Harvest date	December 1, 2022		
Previous Crop	Oaten hay		

The trial was a randomised block design with three replicates and 24 wheat varieties comprising of both bread wheat and durum. This trial was managed with the application of pesticides to ensure a weed, insect and disease-free canopy. All plots were assessed for grain yield (t/ha), protein (%), test weight (kg/hL) and screenings (%). The in-season nitrogen (N) applied targeted an average wheat grain yield of ~3.0 t/ha, however, wet spring conditions from August increased yield potential and the crop became N-limited. Available N at Hart pre-seeding (0-90 cm) was 74 kg/ha, following oaten hay in 2021.

New wheat lines trialed at Hart in 2022 were Reilly (BH120020S-11) and Patron (AGT109). Reilly is a new wheat released by BASF in 2022, available through Seednet for the 2023 growing season. Patron is a new durum wheat, also released in 2022 by AGT. Newer wheat varieties tested at Hart in 2021 include; Sunblade CL Plus (SUN968G) Anvil CL Plus (LPB17-6157), Calibre (RAC2721), Kingston (BSWDH04-062), Valiant CL Plus (IGW4502) and Brumby (IGW6683).

Results and discussion

Grain yield

The average wheat yield was 4.42 t/ha at Hart in 2022, with varieties ranging from 3.54 – 5.14 t/ha. Australian Premium Durum (ADR) variety Patron was the highest yielding at Hart of 5.41 t/ha. Bitalli and DBA-Aurora were also high yielding achieving 4.61 and 4.75 t/ha, respectively. Long-term yield data for durum at Hart also shows these two varieties have performed well in years trialed (Table 1 & Table 2).

Australian Prime Hard (APH) variety Sunblade CL Plus performed well, yielding 4.85 t/ha alongside Australian Hard varieties Ballista, Catapult and Rockstar, ranging from 4.58 – 4.72 t/ha. Sunblade CL Plus, Ballista and Rockstar were also ranked in the top ten yielding varieties at Turretfield, Spalding and Mintaro in National Variety Trials (GRDC National Variety Trials 2022). Long-term yield data at Hart shows that Scepter continues to perform well across multiple seasons, yielding similarly or above the annual trial average (Table 3). Newer varieties Sunblade CL Plus, Calibre and Brumby have also performed well across two seasons at Hart.

Brumby, Denison and LRPB Trojan were the highest yielding Australian Premium White (APW) varieties, yielding 4.54, 4.80 and 4.59 t/ha, respectively. Brumby performed well across the Mid-North in 2022 National Variety Trials at Turretfield, Spalding and Mintaro (GRDC National Variety Trials 2022). Long-term yield data for APW varieties still remains variable at Hart, however LRPB Trojan has performed well, yielding above the trial average in three out of five seasons.

Grain quality

Excellent spring rainfall was received at Hart in 2022, increasing crop yield potential, however the crop was N-limited, resulting in low protein (%) levels. Anvil CL Plus, Calibre, Grenade CL Plus, Hammer CL Plus, Scepter, Chief CL Plus and Razor CL Plus achieved the highest protein levels, however these were still low, ranging between 9.3 – 9.8%, meeting ASW1 receival standards (no minimum protein % level).

Valiant CL Plus had the highest test weight of 85.6 kg/hL. Similar to 2021 results, all varieties trialed were above 76 kg/hL, meeting maximum receival standards (Table 1). Screenings were also low, (<1%) due to an excellent spring finish supporting grain fill.

Table 1. Long term durum wheat variety performance at Hart from 2017 – 2021 (expressed as % trial average).

	% Trial average					Grain yield (t/ha)
Variety	**2017**	**2018**	**2019**	**2020**	**2021**	**2021**
Bitalliᶲ			99	103	101	1.55
DBA-Auroraᶲ	100	102	103	106	100	1.53
DBA Artemisᶲ			95	79	84	1.29
DBA Spesᶲ		102	105	104	107	1.64
DBA Vittaroiᶲ		104	96	99		
Hyperno	96	95	95			
Saintlyᶲ	100	90	97			
Westcourtᶲ			107	110	108	1.65
Trial average yield t/ha	**4.08**	**4.24**	**2.31**	**2.63**	**1.53**	
Sowing date	May 10	May 9	May 15	May 15	May 3	
Apr-Oct rain (mm)	356	191	160	162	2.32	
Annual rain (mm)	485	331	224	189	401	

Table 2. Grain yield (t/ha), protein (%), test weight (kg/hL) and screenings (%) for wheat varieties at Hart in 2022. Shaded values within each column show the highest performing varieties.

Quality	Variety	Grain yield t/ha	% of site average	Protein %	% of site average	Test Weight kg/hL	% of site average	Screenings %	% of site average
APH	Sunblade CL Plus	4.85	110	8.9	101	81.8	98	0.9	222
AH	Anvil CL Plus⦷ (LPB17-6157)	3.54	80	9.8	111	82.4	99	0.5	120
	Ballista⦷	4.72	107	8.8	99	83.1	100	0.7	159
	Catapult ⦷	4.58	104	8.2	93	83.6	101	0.4	90
	Calibre⦷	4.32	98	9.3	105	82.6	99	0.4	107
	Devil⦷	4.27	97	8.9	100	82.0	99	0.4	105
	Grenade CL Plus⦷	4.21	95	9.5	107	82.3	99	0.3	65
	Hammer CL Plus⦷	3.87	88	9.7	110	83.9	101	0.4	91
	Kingston⦷ (BSWDH04-062)	4.16	94	8.8	99	84.2	101	0.2	46
	LRPB Scout⦷	4.42	100	9.0	102	84.5	102	0.5	115
	Reilly⦷ (BH120020S-11)	4.47	101	9.2	104	84.5	102	0.5	110
	RockStar ⦷	4.65	105	8.1	91	82.5	99	0.5	118
	Scepter⦷	4.35	98	9.3	105	85.0	102	0.4	102
	Valiant CL Plus⦷ (IGW4502)	4.37	99	9.1	103	85.6	103	0.2	46
	Vixen⦷	4.20	95	9.3	105	81.1	98	0.3	82
	H1 receival standard			>13.0		>76		<5.0	
APW	Brumby⦷ (IGW6683)	4.54	103	8.3	94	81.13	98	0.5	116
	Chief CL Plus⦷	3.69	83	9.5	107	82.97	100	0.3	84
	Denison⦷	4.80	109	8.2	93	84.1	101	0.5	134
	Sheriff CL Plus⦷	4.19	95	9.0	101	84.57	102	0.2	56
	LRPB Trojan⦷	4.59	104	8.4	94	84.1	101	0.8	202
	APW1 receival standard			>10.5		>76		<5.0	
ASW	Razor CL Plus⦷	4.10	93	9.4	106	83.83	101	0.3	81
	ASW1 receival standard			NA		>76		<5.0	
ADR	DBA-Aurora⦷	4.75	107	8.9	101	80.8	97	0.5835	143
	Bitalli⦷	4.61	104	8.7	98	82.1	99	0.3	70
	Patron⦷ (AGTD109)	5.41	122	7.4	84	79.8	96	0.3	78
	DR1 receival standard			>13		>76		<5.0	
	Site Average	4.42	100	8.85	100	83.10	100	0.41	100
	LSD (P≤0.05)	0.32		0.50		0.59		0.14	

Table 3. Long term wheat variety performance at Hart (expressed as % trial average).

Quality	Variety	% Trial average					Grain yield (t/ha)
		2018	2019	2020	2021	2022	2022
APH	Sunblade CL Plus				105	111	4.85
AH	LRPB Anvil CL Plus				105	81	3.54
	Ballista			95	100	108	4.72
	Calibre				112	99	4.32
	Catapult		97	107	96	105	4.58
	Devil		104	109		98	4.27
	Grenade CL Plus	110	93	93	93	97	4.21
	Hammer CL Plus			106	108	89	3.87
	Kingston				101	95	4.16
	LRPB Scout	107	107	106	86	101	4.42
	Reilly					102	4.47
	RockStar		104	108	80	107	4.65
	Scepter	113	106	101	113	100	4.35
	Valiant CL Plus				93	100	4.37
	Vixen		111	109	130	96	4.20
APW	Brumby				115	104	4.54
	Chief CL Plus	87	85	113	102	85	3.69
	Cutlass	117	98	81	76		
	Denison				86	110	4.80
	LRPB Trojan	106	102	94	93	105	4.59
	Sheriff CL Plus		96	100	107	96	4.19
ASW	Razor CL Plus	104	109	98	111	94	4.10
ADR	DBA-Aurora					109	4.75
	Bitalli					106	4.61
	Patron					124	5.41
	Trial average yield t/ha	**2.13**	**1.50**	**2.50**	**2.03**	**4.40**	
	Sowing date	May 14	May 15	May 6	May 3	May 5	
	Apr-Oct rain (mm)	160	162	336	232	355	
	Annual rain (mm)	224	189	503	401	519	

Acknowledgements

The Hart Field-Site Group would like to acknowledge the generous support of our sponsors who provide funding that allows us to conduct this trial. Proceeds from Hart's ongoing commercial crop also support Hart's research and extension program. We would like to thank InterGrain, AGT, LongReach Plant Breeders, BASF and Seednet for providing seed to conduct this trial.

This trial is funded by HART

References

The GRDC National Variety Trials program (2022) https://nvt.grdc.com.au

Useful Resources

2023 South Australian Crop Sowing Guide (2022) https://grdc.com.au/resources-and-publications/all-publications/nvt-crop-sowing-guides/sa-crop-sowing-guide

Early sown winter and awnless wheats

Declan Anderson
Hart Field-Site Group

Key Findings

- Slower season varieties performed best in 2022 due to a wet spring, with Denison and LPB19-14343 the highest yielding varieties of 5.34 t/ha and 5.68 t/ha, respectively. Illabo, Catapult, RockStar, LRPB Orion and LRPB Dual were also high performing with an average yield of 5.06 t/ha.
- Time of sowing did not affect grain yield or hay production due to minimal rainfall between sowing dates. In 2020, there was sufficient rainfall between sowing times, resulting in a decrease in yield (0.35 t/ha) at the earlier sowing due to dry conditions at critical development times.
- Hay performance between awnless varieties was similar in 2022, with an average production of 7.67 t/ha. Dry spring conditions in 2021 saw LRPB Bale perform best with 5.98 t DM/ha produced. There was a wet finish in 2020, similar to 2022, that resulted in no difference in hay yield between awnless wheats.
- Grain quality varied between varieties with low protein (8.9 %), high test weights (82.4 kg/hL) and low screenings (0.5%). Protein was low due to under fertilisation, resulting in all varieties, excluding Orion, meeting ASW1 receival specifications.

Introduction

Winter wheats allow growers to sow a cereal program earlier in the growing season, utilising early April rainfall. Winter wheats can be sown earlier as they have a vernalisation (cold) requirement, which lengthens the crops growing season (Porker et al 2019). Due to this, winter wheats will still flower in the optimal window, whereas early sown spring wheats are at risk of frost damage as they will flower early.

Dual purpose crops such as awnless wheat varieties are a useful tool within cropping systems prone to frost damage as they can be utilised for grain or hay production. Awnless wheats produce a safer hay option due to the lack of awns; awns have the potential to injure animals consuming awned hay (Lyon 2021).

Trials investigating the performance of longer season spring wheats and winter wheats in the Mid-North were conducted from 2020 – 2022. The aim was to compare these varieties to Scepter wheat in its optimal flowering window (September 15-25) and evaluate newly released awnless varieties for hay and grain production.

Methodology

Plot size	1.75 m x 10.0 m	**Fertiliser**	Seeding: DAP (18:20) Zn 1% + Impact @ 80 kg/ha
Seeding date	TOS 1: April 22		June 22: Easy N (42.5:0) @ 70 L/ha
	TOS 2: May 13		August 17: Easy N (42.5:0) @ 60 L/ha
Crop History	Mulgara Oaten Hay	**Location**	Hart, SA
Harvest date	December 1, 2022		

The trial was a split plot design with three replicates, two times of sowing (TOS) and 12 wheat varieties. Seeding dates were chosen to represent the early sowing opportunity for winter and slow spring wheats on April 22, and the ideal sowing time of Scepter (May 13) to flower in the optimal flowering window (Hunt et al 2020). This trial was managed with the application of pesticides to ensure a weed, insect and disease-free canopy. All plots were assessed for grain yield (t/ha), protein (%), test weight (kg/hL) and screenings (%). Data was analysed using a split-plot ANOVA model in Genstat 22nd edition.

Awnless wheat varieties were also assessed for hay production by sampling 4 x 1 m section of row at watery ripe (GS71). Samples were oven dried at 60°C for 48 hours and weighed to assess hay production. Varieties that were included in this trial are listed in Table 1.

A pre-commercial testing line (V13121-030) by AGT was included in the trial due to its awnless and quick maturing characteristics. DS Bennett was not included into the 2022 trial due to very late maturing proving un-suitable to the medium rainfall regions of the Mid-North, like Hart. It was replaced with a quick winter variety (LPB19-14343), with maturity similar to Longsword, developed and undergoing testing by LongReach Plant Breeding.

Table 1. Summary of wheat varieties, including development and quality sown at Hart in 2022 (Schilling et al 2021).

Variety	Development	Quality	Awnless
Scepter	Mid spring	AH	N
RockStar	Mid – slow spring	AH	N
Nighthawk	Very slow spring	APW	N
LRPB Orion	Mid – slow spring	ASF	Y
LRPB Bale	Slow spring	APW	Y
LRPB Dual	Mid – slow spring	AH	Y
Valiant CL Plus	Mid – slow spring	AH	N
Catapult	Mid – slow spring	AH	N
Denison	Slow spring	APW	N
V13121-020	Quick spring*	-	Y
Illabo	Quick – mid winter	AH	N
LPB19-14343	Quick winter*	-	N

**Provisional development rating*

Results and discussion

Grain yield

Longer season wheat varieties were some of the best performing wheats in 2022 at Hart.

Denison and LPB19-14343 were the highest yielding varieties with grain yields of 5.34 t/ha and 5.68 t/ha, respectively (Figure 1). Illabo, Catapult, RockStar, LRPB Orion and LRPB Dual were also high performing with an average yield of 5.06 t/ha.

The 2022 growing season was characterised by a cold winter (daily average temperature of 10.9 °C), followed by a wet spring (246 mm). Winter wheat and longer season spring wheats were able to capitalise on the longer growing season and utilise the late spring moisture more effectively. The quick spring variety V13131-020 was the lowest yielding with a grain yield of 4.58 t/ha. This is due to its faster maturity not suiting dry conditions experienced in the winter months. LRPB Bale, Scepter, and Nighthawk also performed similarly to V13121-020 with yields ranging from 4.58 – 4.95 t/ha.

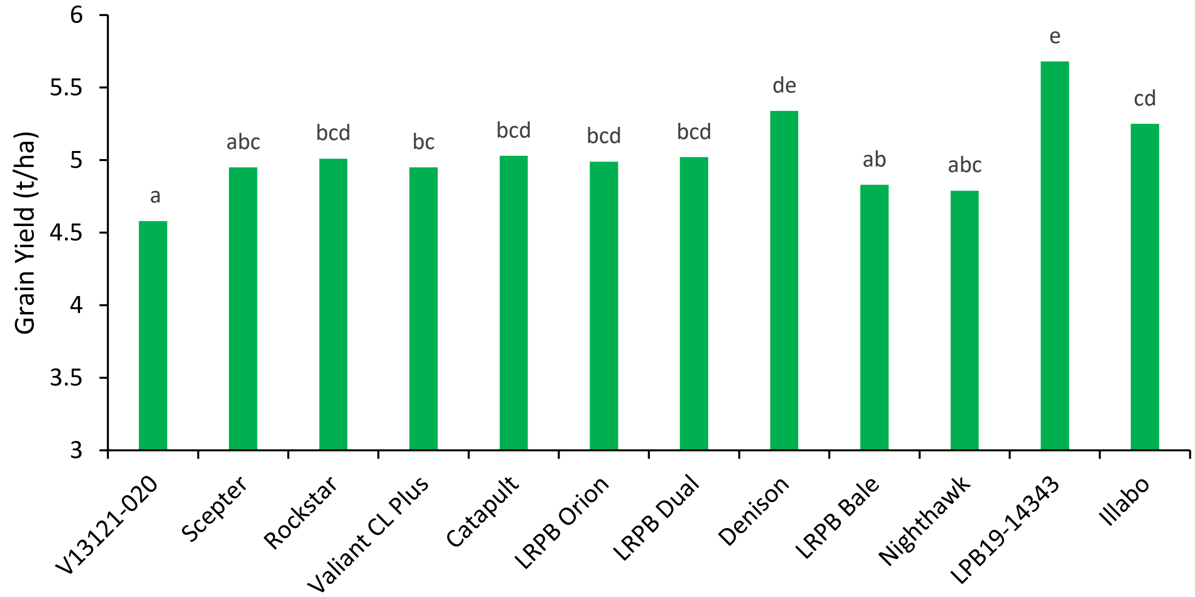

Figure 1. Wheat grain yield at Hart in 2022. Varieties are ordered from fastest to slowest maturity. Varieties with the same lettering are not significantly different.

Time of sowing

Time of sowing did not affect grain yield in 2022 (Table 2). Wheat grain yields were also similar across both times of sowing in 2021 (Anderson & Allen 2021). This was a result of marginal rainfall between the early and standard time of sowing, preventing early germination.

In 2020, there was over 50 mm of rainfall received between sowing times (April 20 – May 6) resulting in yield differences of 0.35 t/ha (Table 2). Sowing early in 2020 resulted in decreased grain yield due to very dry conditions across June and July (47 mm) causing significant crop stress for TOS 1 during the transitional phase at stem elongation, impacting grain yield potential. During this time TOS 2 was still tillering, reducing crop stress and rainfall from August 7 onwards relieved crop stress with 70 mm over 17 days.

Table 2. Summary of average wheat grain yield for TOS comparisons trialed at Hart from 2020 – 2022. Shaded values indicate the highest performing treatments. Varieties with the same letters are not significantly different.

Variety	**2020**		**2021**		**2022**	
	April 20	**May 6**	**April 19**	**May 3**	**April 22**	**May 13**
	Grain yield (t/ha)		Grain yield (t/ha)		Grain yield (t/ha)	
Scepter	1.65[f]	3.03[a]	2.18	2.28	5.08	4.82
RockStar	-	-	-	-	5.12	4.89
Nighthawk	2.28[cde]	1.97[def]	1.74	1.77	4.81	4.77
Valiant CL Plus	-	-	-	-	5.09	4.82
Catapult	2.13[def]	2.92[ab]	2.34	2.22	5.18	4.88
Denison	1.91[ef]	2.43[bcd]	2.18	2.30	5.22	5.45
Illabo	1.65[f]	2.00[def]	2.05	1.82	5.29	5.21
LPB19-14343	-	-	-	-	5.70	5.65
LRPB Orion	2.06[de]	2.00[def]	1.41	1.46	5.22	4.76
LRPB Bale	1.98[def]	2.04[def]	1.75	1.8	4.94	4.71
LRPB Dual	2.02[def]	2.64[abc]	1.94	1.99	5.20	4.84
DS Bennett	2.19[cde]	2.25[cde]	1.94	1.69	-	-
V13121-020	-	-	-	-	4.68	4.49
Average yield	**1.99[a]**	**2.34[b]**	**1.95**	**1.93**	**5.13**	**4.94**
LSD (P≤0.05)	**0.17 (0.49 in each TOS)**		**NS**		**NS**	

Grain quality

All varieties, excluding Orion, were classified as ASW1 due to low protein levels in 2022. The awnless testing line V13121-020 recorded the highest protein of 10.1% (Table 3). Protein levels for all remaining varieties were lower, ranging from 8.2 – 9.5%.

Test weight was high for most varieties, with Scepter, Valiant CL Plus and LPB19-14343 performing well with test weights of 84.6, 84.4, and 84.2 kg/hL respectively. The only variety to receive a low test weight was Orion (75.9), just below minimum receival standards for SFE1 of 76 kg/hL. Screenings were low across all varieties with an average of 0.46%.

Table 3. Summary of grain quality and maximum receival standards for all wheat varieties trialed at Hart in 2022. Shaded values show the highest performing varieties. Values with the same letter are not significantly different.

Quality	**Variety**	**Protein** (%)	**Test weight** (kg/hL)	**Screenings** (%)
AH	Scepter	9[ef]	84.6[g]	0.43[cd]
	Illabo	8.9[de]	81.2[b]	0.35[bc]
	Catapult	8.3[ab]	82.8[d]	0.56[ef]
	RockStar	8.2[a]	82.1[c]	0.58[fg]
	Valiant CL Plus	8.7[cde]	84.4[g]	0.24[a]
	LRPB Dual	9.4[g]	83.4[de]	0.48[de]
H1 receival standard		>13.0	>76	<5.0
APW	Nighthawk	9.2[fg]	83.7[ef]	0.31[ab]
	LRPB Bale	9.4[g]	80.7[b]	0.77[h]
	Denison	8.4[abc]	83.6[e]	0.67[gh]
APW1 receival standard		>10.5	>76	<5.0
ASF	LRPB Orion	8.2[a]	75.9[a]	0.42[cd]
SFE1 receival standard		<9.5	>76	<5.0
Unclassified	V13121-020	10.1[h]	81.7[c]	0.34[abc]
	LPB19-14343	8.6[bcd]	84.2[fg]	0.38[bcd]
LSD (P≤0.05)		**0.34**	**0.57**	**0.10**

Hay yield

Dry matter production at watery ripe (GS71) was similar for all varieties, ranging from 7.23 t/ha to 8.01 t/ha (Figure 2). Hay yields measured in 2020 were also similar for varieties trialed.

A wet spring was present in both 2020 and 2022 seasons, suggesting that hay production (t/ha) would be similar between varieties in wet spring finishes under similar agronomic conditions. A dry spring finish in 2021 resulted in differences between awnless wheats with LRPB Bale the highest performer at 5.98 t/ha (Figure 2).

Time of sowing has had no effect on hay yield for awnless wheats across three growing seasons at Hart (data not shown).

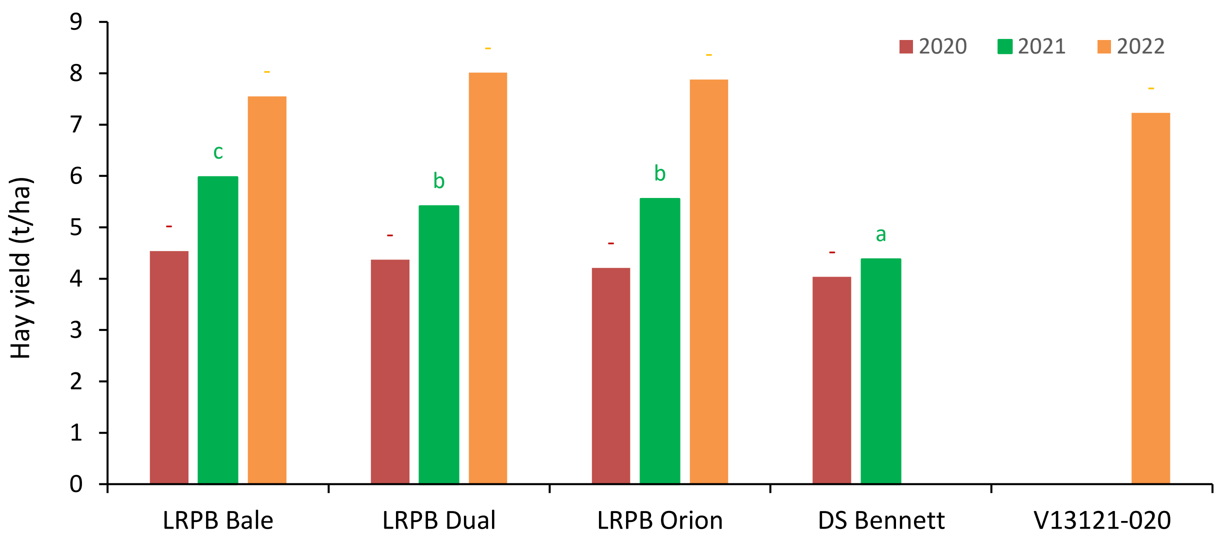

Figure 2. Summary of the average hay yield for each awnless wheat variety trialed at Hart from 2020-2022. Hay yield data for 2020 and 2022 is not significant.

Acknowledgements

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

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

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

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Comparison of barley varieties

Declan Anderson
Hart Field-Site Group

Key Findings

- The average barley yield at Hart was 5.99 t/ha, with RGT Planet and Zena CL performing the best with yields of 7.13 t/ha and 7.02 t/ha, respectively.
- Spartacus CL and Maximus CL met Malt 1 specifications in the 2022 season.
- Beast, Commodus CL, Cyclops, and Laperouse (all pending malt accreditation) met Malt 1 standards for protein (%), screenings (%), retention (%) and test weight (kg/hL).
- Screenings, retention and test weight met the equivalent to Malt 1 receival standards for all varieties.

Introduction

To compare the performance of new barley varieties alongside current industry standards.

Methodology

Plot size	1.75 m x 10.0 m	**Fertiliser**	Seeding: DAP (18:20) Zn 1% + Impact @ 80 kg/ha
Seeding date	May 5, 2022		July 22: Easy N (42.5:0) @ 70 L/ha
Location	Hart, SA		August 17: Easy N (42.5:0) @ 60 L/ha
Harvest date	November 17, 2022		
Crop history	Mulgara Oaten Hay		

The trial was a randomised block design with three replicates and 15 barley varieties. This trial was managed with the application of pesticides to ensure a weed, insect and disease-free canopy. All plots were assessed for grain yield (t/ha), protein (%), test weight (kg/hL), screenings (2.2 mm screen) and retention (2.5 mm screen). Data was analysed using a one-way ANOVA model in Genstat 22nd edition.

New varieties trialed at Hart in 2022 include Combat (IGB1944) and Zena CL (IGB20125T) by InterGrain, as well as Titan AX (AGTB0325) by AGT. All varieties have been released for the 2023 growing season.

Results and discussion

Grain yield

Barley at Hart yielded an average of 5.99 t/ha in 2022 (Table 1). The longer season barley varieties were better suited to the seasonal conditions as they were able to utilise late season rains and cool conditions to maximise yield. RGT Planet and Zena CL (mid maturing varieties) were the highest yielding of 7.13 and 7.02 t/ha, respectively (Table 1). Combat (mid maturity) and Minotaur (mid-slow maturity) were also high yielding varieties of 6.71 and 6.4 t/ha, respectively.

Quick maturing varieties Laperouse, Compass, Maximus CL and Spartacus CL were lower yielding at Hart, ranging from 5.2 – 5.47 t/ha. Fast maturing varieties did not suit the conditions experienced in 2022. Spartacus CL was also low yielding in 2021.

The highest yielding malt variety was RGT Planet (7.13 t/ha), followed by Leabrook (5.74 t/ha). Malt varieties of Compass, Maximus CL and Spartacus yielded similarly. A number of varieties currently undergoing malt accreditation also showed excellent yield potential at Hart; newly released variety Zena CL was the highest yielding variety at 7.02 t/ha, followed by Cyclops (6.4 t/ha), and Minotaur of 6.07 t/ha (Table 1).

The newly released variety Combat was the highest yielding feed barley at Hart in 2022. Rosalind and Fathom were also high yielding. Historic data shows that both Rosalind and Fathom consistently perform well at Hart (Table 2).

RGT Planet, Zena CL, Combat and Minotaur were also ranked in the top ten varieties at Spalding, Turretfield, and Salter Springs (GRDC National Variety Trials sites 2022).

Grain quality

Test weights were high for all varieties trialed at Hart in 2022, with all above 65 kg/hL, meeting BAR 1 and Malt 1 receival standards. Laperouse, although lower yielding, recorded the highest test weight of 70.1 kg/hL (Table 1).

Screenings were very low in 2022 with a trial average of 0.86%. This is significantly lower than in 2021, where screenings ranged from 3.8 – 15.7% with the dry finish at Hart (Allen 2022). A cool and wet finish experienced at Hart, allowed varieties to increase yield potential by maximising grain fill, however this likely attributed to reduced protein % levels. All varieties trialed met receival specifications.

Grain retention (%) in 2022 was high, averaging 96%. Many varieties performed well, including Laperouse, Compass, Titan AX, Leabrook, Minotaur, Beast and Combat.

The average barley protein (%) level at Hart averaged 9%. Maximus CL (10%), Spartacus CL (10%) and Beast (9.8%) performed well. Compass, Leabrook, RGT Planet and Zena CL (IGB20125T) did not meet Malt 1 receival standards for grain protein. Lower protein levels observed across the trial are likely a cause of limiting nitrogen levels in addition to above average rainfall leading into grain fill.

Spartacus CL and Maximus CL met all specifications for Malt 1 receival standards at Hart in 2022.

Table 1. Grain yield (t/ha), protein (%), test weight (kg/hL) and screenings (%) and retention for barley varieties at Hart in 2022. Shaded values within each column show the highest performing varieties.

Quality	Variety	Grain yield t/ha	% of site average	Protein %	% of site average	Test weight kg/hL	% of site average	Screenings %	% of site average	Retention %	% of site average
Feed	Fathom	6.05^{d}	101	9.6	107	67.5^{bcd}	99	0.65^{ab}	76	95.6	100
	Rosalind	6.03^{d}	101	9.2	102	69.0^{g}	102	0.74^{bc}	87	96.0	100
	Combat (IGB1944)	6.71^{f}	112	8.5	94	66.4^{a}	98	0.48^{a}	56	96.8	101
	Titan AX (AGTB0325)	5.77^{c}	96	9.0	100	68.4^{ef}	101	0.85^{c}	99	97.3	101
	Bar 1 Receival Standards			NA		>62.5		<15.0%		NA	
Malt	Compass	5.41^{ab}	90	8.7	97	67.6^{cd}	99	0.63^{ab}	74	97.5	102
	Leabrook	5.74^{c}	96	8.9	99	67.3^{bcd}	99	0.65^{ab}	76	97.2	101
	Maximus CL	5.44^{ab}	91	10.0	111	69.5^{g}	102	1.29^{de}	151	94.7	99
	RGT Planet	7.13^{g}	119	7.6	84	67.9^{de}	100	0.76^{bc}	89	95.6	100
	Spartacus CL	5.47^{ab}	91	10.0	111	68.9^{fg}	101	1.38^{de}	161	91.9	96
	Malt 1 Receival Standards			9-12%		>65		<7.0%		>70%	
Pending malt accreditation	Beast	5.75^{c}	96	9.8	109	67.7^{d}	100	0.72^{bc}	84	97.0	101
	Commodus CL	5.67^{bc}	95	9.2	102	67.0^{ab}	99	1.22^{d}	143	95.6	100
	Cyclops	6.07^{d}	101	9.0	100	67.7^{d}	100	1.42^{e}	166	93.8	98
	Laperouse	5.24^{a}	87	9.0	100	70.1^{h}	103	0.48^{a}	56	97.9	102
	Minotaur	6.40^{e}	107	8.6	96	67.0^{abc}	99	0.84^{c}	98	97.1	101
	Zena CL (IGB20125T)	7.02^{g}	117	7.9	88	67.5^{bcd}	99	0.77^{bc}	90	95.9	100
	Site Average	**5.99**	**100**	**9.00**	**100**	**67.97**	**100**	**0.86**	**100**	**96.0**	**100**
	LSD (P≤0.005)	0.26		0.30		0.62		0.19		1.19	

Values with the same letter are not significantly different.

Table 2. Long term barley variety performance at Hart for 2018-2022 (expressed as % trial average).

		% Trial average					Grain yield (t/ha)
Quality	**Variety**	**2018**	**2019**	**2020**	**2021**	**2022**	**2022**
Feed	Fathom	109	104	112	107	101	6.05
	Hindmarsh	100	103				
	Rosalind	102	107	100	105	101	6.03
	Combat (IGB1944)					112	6.71
	Titan AX (AGTB0325					96	5.77
Malt	Commander	104	93	95			
	Compass	105	106	99	112	90	5.41
	La Trobe	99	107	94			
	Leabrook			107	107	96	5.74
	Maximus CL		102	95	96	91	5.44
	RGT Planet	97	101	111	86	119	7.13
	Spartacus CL	98	100	89	83	91	5.47
Pending malt accreditation	Beast			99	111	96	5.75
	Commodus CL				100	95	5.67
	Cyclops				103	101	6.07
	Laperouse			105	112	87	5.24
	Minotaur				101	107	6.40
	Zena CL (IGB20125T)					117	7.02
	Average yield (t/ha)	**2.86**	**2.25**	**3.18**	**2.61**	**5.99**	
	Sowing date	May 14	May 15	May 16	May 3	May 5	
	April - Oct (mm)	160	162	355	232	355	
	Annual rainfall (mm)	224	189	503	401	519	

Acknowledgements

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

This trial is funded by HART

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Comparison of canola varieties; including genetically modified options

Rebekah Allen
Hart Field-Site Group

Key findings

- Canola varieties performed exceptionally well at Hart in 2022, yielding 2.55 – 3.29 t/ha resulting from above average rainfall.
- Oil content (%) was high across the trial, achieving > 49%, leading to oilseed premiums for growers.
- The highest yielding GM varieties were; Pioneer 44Y30 RR (3.29 t/ha), InVigor LR (3.15 t/ha), InVigor R 4520 (3.17 t/ha) and dual tolerance variety Nuseed Emu TF (3.13 t/ha).
- New conventional variety Outlaw yielded similarly to current commercial varieties Nuseed Diamond and Nuseed Quartz, achieving an average of 3.0 t/ha.
- Triazine tolerant varieties also yielded well ranging between 2.55 – 3.03 t/ha. The highest yielding varieties were HyTTec Trophy, InVigor T 4510, RGT Capacity TT, SF Dynatron TT, RGT Baseline and testing line SFR65-064TT.
- All canola varieties were profitable at Hart in 2022, with gross margins ranging from \$1,244 – \$1,610 per hectare. Gross margin and yield data from 2021 shows the importance of variety selection on return (\$/ha) with a number of varieties performing well in lower rainfall years at Hart.

Introduction

In 2021, South Australian mainland growers saw the 16-year moratorium on genetically modified (GM) crops lifted for commercial use. The addition of glyphosate and glufosinate tolerant technologies in canola (including dual tolerance), provide additional varietal options for mainland growers with in-crop herbicide registrations (Group 9 & 10) new to broadacre agriculture.

An ongoing variety trial compares the performance of new canola varieties, including genetically modified (GM) options; Roundup Ready®, TruFlex® and LibertyLink®, alongside current conventional, Triazine Tolerant (TT) and Clearfield® (CL) varieties.

Methodology

Plot size	2.0 m x 10.0 m	**Fertiliser**	Seeding: DAP (18:20) Zn 1% + Impact @ 80 kg/ha
Seeding date	June 9, 2022		July 22: Easy N (42.5:0) @ 70 L/ha
Location	Hart, SA		Aug 17: Easy N (42.5:0) @ 90 L/ha
Harvest date	December 1, 2022	**Soil available N**	62 kg N/ha (depth to 90 cm)
Previous crop	Oaten hay		

In 2022 there were 28 canola varieties trialed at Hart, each technology was set up as a randomised block design with three replicates. The trial was managed with the appropriate application of pesticides to ensure a weed, insect and disease-free canopy. All plots were assessed for crop establishment (plants/m^2), NDVI (Normalised Difference Vegetation Index) to measure crop vigour, flowering date (50% flower), crop yield (t/ha) and oil content (%). Canola gross margins were also calculated for the 2021 and 2022 seasons.

Results and discussion

Oilseed yield and oil content

Canola varieties yielded exceptionally well at Hart in 2022, with yields ranging between 2.55 – 3.29 t/ha. This was a result of above average annual and growing season rainfall and was in contrast to 2020, where canola yields were below average, achieving 0.66 – 1.26 t/ha.

New conventional variety Outlaw yielded similarly to current commercial varieties, Nuseed Diamond and Nuseed Quartz, achieving an average of 3.0 t/ha. Outlaw was a new variety trialed at Hart and is an early-maturing open pollinated (OP) variety. Oil content for these three conventional varieties was high ranging from 49.4 – 50.2%.

Triazine tolerant varieties also yielded well ranging between 2.55 – 3.03 t/ha. The highest yielding varieties were HyTTec Trophy, InVigor T 4510, RGT Capacity TT, SF Dynatron TT, RGT Baseline and testing line SFR65-064TT yielding an average of 2.97 t/ha. Similar to conventional varieties, oil content was high, ranging from 48.7 – 50.2%.

Yield performance for new genetically modified varieties was excellent, achieving yields above 3 t/ha. The highest yielding GM varieties were; Pioneer 44Y30 RR (3.29 t/ha), InVigor LR (3.15 t/ha), InVigor R 4520 (3.17 t/ha) and dual tolerance variety Nuseed Emu TF (3.13 t/ha). Pioneer 44Y30 RR and InVigor LR also achieved very high oil content > 50%, similarly to Hyola 410XX and Hyola Garrison XC.

All canola varieties were profitable at Hart in 2022, with gross margins ranging from $1,244 – $1,610 per hectare (excluding oil premiums) (Table 3). It was evident that seasonal conditions in 2022 were favourable for canola production, with decile 8 growing season rainfall (355 mm) and decile 10 annual rainfall (519 mm) contributing to grain yield potential. At Hart in 2021, rainfall was below average for most months (excluding July and late August), contributing to yield reduction through reduced soil moisture and nitrogen, contributing to crop stress. Gross margins and yield data from 2021 show the importance of variety selection on return ($/ha) with a number of varieties performing well in lower rainfall years at Hart, and more broadly across the Mid-North region (Table 3).

Flowering

Field trials conducted across five years (2014 – 2018) through the GRDC Optimised Canola Profitability project have shown that the optimum start of flowering (OSF) date for canola at Hart is from July 25, with a large OSF window up to 37 days. This means it is ideal for canola to start flowering between July 25 and August 31 to minimise heat and water stress (Lilley 2018), however flowering dates will vary depending on crop phenology of varieties (time from sowing to flowering).

The first varieties to flower at Hart prior to August 31, 2021 were earlier maturing varieties Nuseed Diamond, HyTTec Velocity, InVigor R 4520P, Nuseed Emu TF and 43Y92 CL from late August (Figure 1).

Table 1. Summary of oilseed yield (t/ha) and oil content (%) for canola varieties trialed at Hart in 2022. Shaded values in each column show the highest performing varieties in each technology.

Technology	Variety	Yield (t/ha)	% of average	Oil content (%)	% of average
Conventional	Outlaw⒫	2.96	99	50.2	101
	Nuseed® Quartz	2.99	100	49.4	99
	Nuseed® Diamond	3.04	101	49.5	100
	Average	**3.00**	**100**	**49.7**	**100**
	LSD (P≤0.05)	**NS**		**NS**	
Triazine tolerant & dual triazine and imidazolinone tolerant varieties (CT)	ATR-Bluefin⒫	2.55	89	49.3	100
	ATR-Bonito⒫	2.69	94	50.2	102
	Hyola® Blazer TT	2.88	100	49.4	101
	Hyola® Enforcer CT	2.80	97	48.3	98
	HyTTec® Trophy	2.94	102	48.1	98
	HyTTec® Velocity	2.81	98	49.1	100
	InVigor® T 4510	2.91	101	48.8	99
	Renegade TT ⒫	2.89	101	49.1	100
	RGT Capacity™ TT	3.03	106	49.5	101
	SF Dynatron TT	3.00	104	49.4	101
	RGT Baseline	2.99	104	49.1	100
	SFR65-064TT	2.99	104	48.7	99
	Average	**2.87**	**100**	**49.08**	
	LSD (P≤0.05)	**0.12**		**NS**	
Genetically modified	Pioneer® 44Y27 RR	3.01	99.26	49.33	99
	Pioneer® 44Y30 RR	3.29	108.64	50.10	101
	Hyola® 410XX	2.77	91.40	50.73	102
	Hyola® Battalion XC	2.79	92.13	49.40	99
	Hyola® Garrison XC	2.91	96.22	50.67	102
	InVigor® LR	3.15	103.92	50.50	101
	InVigor® R 4520	3.17	104.61	48.60	98
	Nuseed® Emu TF	3.13	103.29	49.83	100
	Nuseed® Raptor TF	3.04	100.52	49.10	99
	Average	**3.03**	**100**	**49.81**	**100**
	LSD (P≤0.05)	**0.21**		**0.87**	
Imidazolinone tolerant varieties	Pioneer® 43Y92 CL	2.80	95.19	50.07	100
	Pioneer® 44Y94 CL	3.21	109.20	50.23	100
	Pioneer® 45Y95 CL	3.08	104.61	49.23	98
	Hyola® Equinox CL	2.68	91.00	51.10	102
	Average	**2.94**	**100**	50.16	**100**
	LSD (P≤0.05)	**0.18**		0.54	

Imidazolinone tolerant varieties = Clearfield® technology (CL)

Table 2. Long term yield data for canola varieties at Hart from 2021 – 2022.

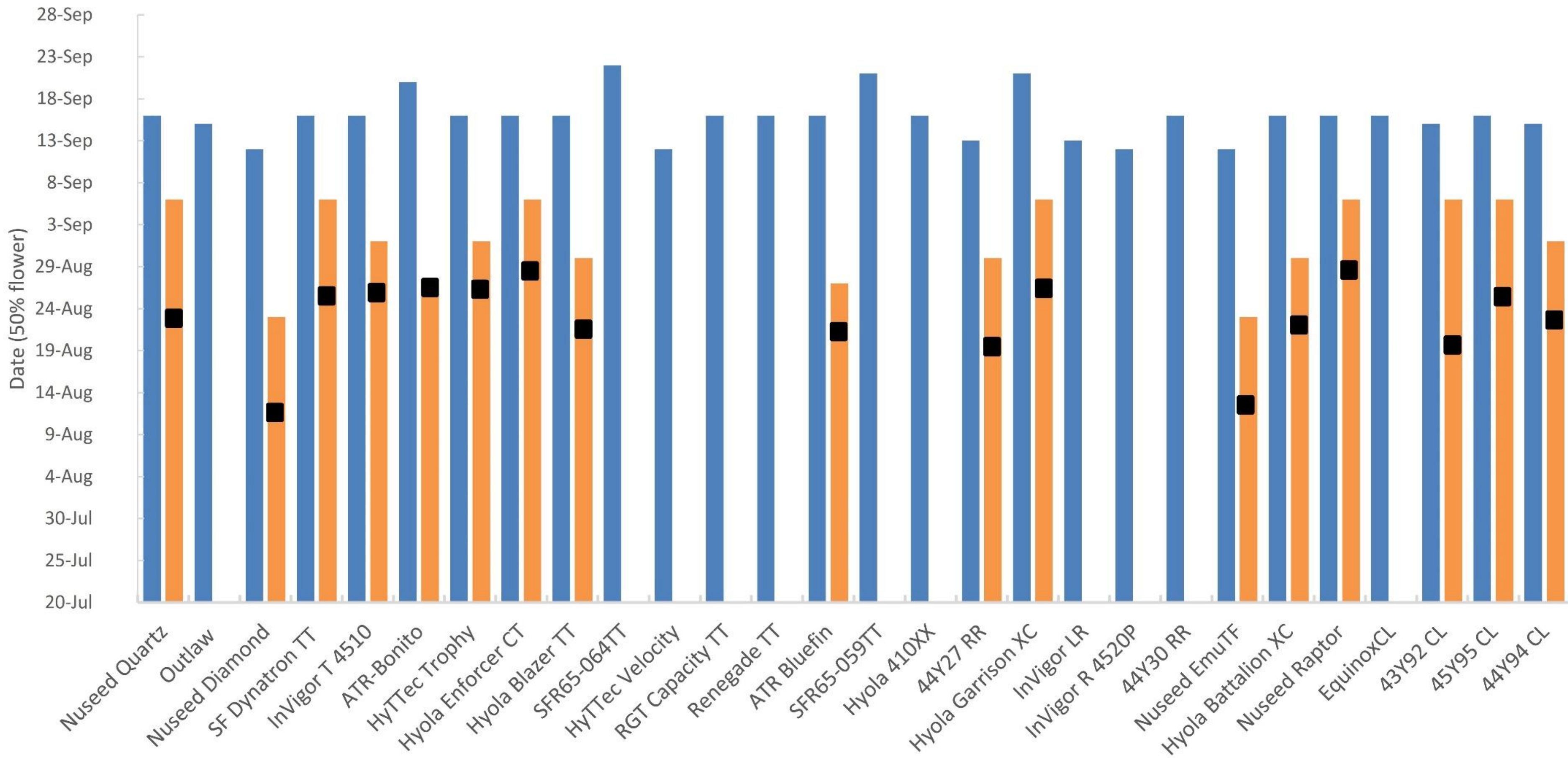
		% Trial average		Yield (t/ha)
Technology	**Variety**	**2021**	**2022**	**2022**
Conventional	Outlaw		99	2.96
	Nuseed® Quartz	98	100	2.99
	Nuseed® Diamond	102	101	3.04
	Average	**100**	**100**	**3.00**
Triazine tolerant (TT) & dual triazine and imidazolinone tolerant varieties (CT)	ATR-Bluefin	72	89	2.55
	ATR-Bonito	78	94	2.69
	Hyola® Blazer TT	108	100	2.88
	Hyola® Enforcer CT	107	97	2.80
	HyTTec® Trophy	97	102	2.94
	HyTTec® Trifecta	99		
	HyTTec® Trident	120		
	HyTTec® Velocity		98	2.81
	InVigor® T 4510	123	101	2.91
	Renegade TT		101	2.89
	RGT Capacity™ TT	95	106	3.03
	SF Dynatron TT	105	104	3.00
	SF Spark	97		
	RGT Baseline		104	2.99
	SFR65-064TT		104	2.99
	Average	**100**	**100**	**2.87**
Genetically modified	Pioneer® 44Y27 RR	114	99	3.01
	Pioneer® 44Y30 RR		109	3.29
	Pioneer® 45Y28 RR	115		
	Hyola® 530 XT	71		
	Hyola® 410XX	95	91	2.77
	Hyola® Battalion XC	88	92	2.79
	Hyola® Garrison XC	98	96	2.91
	InVigor® LR		104	3.15
	InVigor® R 4520P		105	3.17
	InVigor® R 4022P	102		
	Nuseed® Emu TF	113	103	3.13
	Nuseed® Raptor TF	105	100	3.04
	Average	**100**	**100**	**3.03**
Imidazolinone tolerant varieties	Pioneer® 43Y92 CL	100	95	2.80
	Pioneer® 44Y94 CL	110	109	3.21
	Pioneer® 45Y95 CL	96	105	3.08
	Hyola® Equinox CL		91	2.68
	Saintly	108		
	Banker CL	86		
	Average	**100**	**100**	**2.94**
	Sowing date	May 3 (dry)	June 9	
	Apr-Oct ran (mm)	231	355	
	Annual rain (mm)	401	519	

Table 3. Gross margins for trialed conventional, Roundup Ready®, TruFlex®, CL and TT canola technologies. Input costs and sale price sourced from: Farm Gross Margin and Enterprise Planning Guide, 2022.

			Partial gross margin $/ha	
Technology	**Variety**	**2022 Grain yield (t/ha)**	**2021**	**2022**
Conventional	Outlaw	2.96		$ 1,478
	Nuseed® Quartz	2.99	$ 190	$ 1,500
	Nuseed® Diamond	3.04	$ 223	$ 1,537
Triazine Tolerant	ATR-Bluefin	2.55	-$ 105	$ 1,169
	ATR-Bonito	2.69	-$ 68	$ 1,470
	Hyola® Blazer TT	2.88	$ 78	$ 1,411
	Hyola® Enforcer CT	2.80	$ 72	$ 1,353
	HyTTec® Trophy	2.94	$ 24	$ 1,455
	HyTTec® Velocity	2.81		$ 1,360
	InVigor T® 4510	2.91	$ 153	$ 1,433
	Renegade TT	2.89		$ 1,419
	RGT Capacity™ TT	3.03	$ 13	$ 1,521
	SF Dynatron TT	3.00	$ 62	$ 1,499
	RGT Baseline	2.99		$ 1,492
	SFR65-064TT	2.99		$ 1,492
Genetically modified	Pioneer® 44Y27 RR	3.01	$ 135	$ 1,413
	Pioneer® 44Y30 RR	3.29		$ 1,610
	Hyola® 410XX	2.77	$ 32	$ 1,244
	Hyola® Battalion XC	2.79	$ 2	$ 1,258
	Hyola® Garrison XC	2.91	$ 52	$ 1,342
	InVigor ®LR	3.15		$ 1,512
	InVigor® R 4520	3.17		$ 1,526
	Nuseed® Emu TF	3.13	$ 130	$ 1,497
	Nuseed® Raptor TF	3.04	$ 86	$ 1,434
Imidazolinone tolerant varieties	Pioneer® 43Y92 CL	2.8	$ 186	$ 1,335
	Pioneer® 44Y94 CL	3.21	$ 250	$ 1,635
	Pioneer® 45Y95 CL	3.08	$ 158	$ 1,540
	Hyola® Equinox CL	2.68		$ 1,247

**This data should be used a guide and is based on 2021 and 2022 forecasted pricing only.*

Figure 1. Flowering dates (50% flower) for canola varieties trialed at Hart in 2021 – 2022. The black squares (■) indicate start of flowering dates for canola trialed in 2021.



Acknowledgements

The Hart Field-Site Group would like to acknowledge SAGIT for funding this trial. We would also like to thank BASF, Nuseed, Pioneer® Seeds, SeedForce and Pacific Seeds for providing canola seed.

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Useful Resources

Canola Flowering calculator
https://www.canolaflowering.com.au/

Comparison of lentil and field pea varieties

Rebekah Allen
Hart Field-Site Group

Key findings

- Grain yields for lentil varieties at Hart in 2022 were high, ranging from 4.31 – 6.04 t/ha.
- The highest yielding lentil varieties were GIA thunder (GIA2002L), testing line CIPAL2122 and PBA Jumbo2, achieving 6.64, 6.04 and 5.88 t/ha, respectively.
- PBA Jumbo2, GIA Thunder (GIA2002L) and PBA Highland have consistently performed well across a number of seasons at Hart.
- Field pea grain yields achieved a trial average of 3.63 t/ha at Hart in 2022. The top eight varieties achieved between 3.60 – 4.07 t/ha.
- Kaspa field pea continues to yield well at Hart across a number of seasons, consistently yielding above the trial average.

Introduction

To compare the performance of newly released pulse varieties alongside current commercial standards.

Methodology

Plot size (field pea)	2.0 m x 10.0 m	**Fertiliser**	MAP (10:22) + 2% Zn @ 80 kg/ha
Plot size (lentil)	1.75 m x 10.0 m		
Seeding date	June 9, 2022		
Field pea harvest date	November 29, 2022		
Lentil harvest date	December 14, 2022		
Location	Hart, SA		

Two trials were designed as randomised block designs with three replicates for lentil and field pea varieties. Eleven field pea varieties were trialed, including a new testing line GIA2202P. Thirteen lentil varieties were trialed, including newly released GIA Thunder, GIA Sire, GIA Metro and GIA Lightning and testing line CIPAL2122. Trials were managed with the application of pesticides to ensure a weed, insect and disease-free canopy. All plots were assessed for grain yield (t/ha) and analysed as a one-way ANOVA in Genstat 22nd Edition.

Results and discussion

Lentil

Grain yields for lentil varieties trialed at Hart in 2022 were high, ranging from 4.31 – 6.04 t/ha. The highest yielding varieties were GIA thunder (GIA2002L), testing line CIPAL2122 and PBA Jumbo2, achieving 6.64, 6.04 and 5.88 t/ha, respectively (Table 1). GIA Sire and GIA Metro were the lowest yielding lentil varieties at Hart in 2022, however in addition to these varieties having imidazolinone-tolerance, GIA Sire also has improved tolerances to clopyralid (sulfonylurea soil residues) with GIA

Metro having tolerances to metribuzin herbicide. Therefore, reductions in grain yield could be expected (GRDC, 2022). Long term yield data shows that PBA Jumbo2, GIA Thunder (GIA2002L) and PBA Highland have performed well across a number of seasons at Hart (Table 2). New varieties GIA Lightning and CIPAL2122 performed well in 2022 and will continue to be evaluated at Hart.

Table 1. Lentil grain yields at Hart in 2022. Values shaded within each column show the highest performing varieties.

Lentil variety	Grain yield (t/ha)
PBA Kelpie XTⓓ	5.12^{bcd}
PBA Hallmark XTⓓ	5.36^{b-e}
PBA Hurricane XTⓓ	5.68^{de}
PBA Highland XTⓓ	5.63^{cde}
PBA Jumbo2ⓓ	5.88^{ef}
GIA Leaderⓓ	5.69^{de}
GIA Thunderⓓ (GIA2002L)	6.64^{f}
GIA Sireⓓ (GIA1703L)	4.31^{a}
GIA Metroⓓ (GIA2004L)	4.33^{a}
PBA Boltⓓ	4.86^{ab}
PBA Blitzⓓ	4.88^{abc}
GIA Lightningⓓ (GIA2003L)	5.67^{de}
CIPAL2122	6.04^{ef}
Average grain yield	**5.42**
LSD (P≤0.05)	**0.43**

Table 2. Long term yield data for lentil varieties at Hart 2020 – 2022.

	% of trial average			**Grain yield** (t/ha)
Variety	**2020**	**2021**	**2022**	**2022**
PBA Kelpie XTⓓ	106	82	94	5.12
PBA Highland XT	100	99	104	5.63
PBA Jumbo2ⓓ	104	110	108	5.88
PBA Hallmark XT	95	97	99	5.36
GIA Thunderⓓ (GIA2002L)		113	123	6.64
GIA Leaderⓓ	98	103	105	5.69
PBA Hurricane XTⓓ	91	95	105	5.68
GIA Sireⓓ (GIA1703L)			80	4.31
GIA Metroⓓ (GIA2004L)			80	4.33
PBA Boltⓓ			90	4.86
PBA Blitzⓓ			90	4.88
GIA Lightningⓓ (GIA2003L)			105	5.67
CIPAL2122			111	6.04
Average grain yield (t/ha)	**1.62**	**1.30**	**5.42**	
Sowing date	May 18	May 18	June 9	
April - Oct (mm)	355	232	355	
Annual rainfall (mm)	503	401	519	

Field pea

Above average rainfall at Hart improved field pea yields in 2022, with a trial average of 3.63 t/ha. This was a minimum increase of 2.02 t/ha when compared to recent seasons at Hart (2020 – 2021). Field pea yields ranged from 3.06 – 4.07 t/ha, with many varieties yielding well.

The highest performing varieties for grain yield at Hart were Kaspa, PBA Oura, PBA Butler, PBA Wharton, PBA Percy, PBA Taylor, PBA Pearl and testing line GIA2202P, ranging from 3.60 – 4.07 t/ha. Long term data shows that Kaspa continues to perform well at Hart across a number of seasons, with Butler performing well in two out of three years. New testing line GIA2202P will continue to be evaluated at Hart, yielding 110% of the average trial yield in the first year of evaluation.

Table 3. Field pea grain yields at Hart from 2020 – 2022. Values shaded within each column show the highest performing varieties.

Field pea variety	2022
GIA Kastarⓓ	3.12^{a}
GIA Ourstarⓓ	3.06^{a}
Kaspaⓓ	3.86^{bc}
PBA Ouraⓓ	3.66^{abc}
PBA Butlerⓓ	4.07^{c}
PBA Whartonⓓ	3.61^{abc}
PBA Gunyahⓓ	3.36^{ab}
PBA Percy	3.60^{abc}
PBA Taylorⓓ	3.80^{bc}
PBA Pearl	3.83^{bc}
GIA2202P	3.99^{bc}
Average grain yield	**3.63**
LSD (P≤0.05)	**0.39**

Table 4. Long term yield data for field pea varieties at Hart 2020 – 2022.

	% of trial average			**Grain yield** (t/ha)
Variety	**2020**	**2021**	**2022**	**2022**
GIA Kastarⓓ	98	88	86	3.12
GIA Ourstarⓓ	111	93	84	3.06
PBA Whartonⓓ	83	98	99	3.61
PBA Butlerⓓ	94	108	112	4.07
PBA Ouraⓓ	101		101	3.66
Kaspaⓓ	112	113	106	3.86
PBA Gunyahⓓ			93	3.36
PBA Percy			99	3.60
PBA Taylorⓓ			105	3.80
PBA Pearl			106	3.83
GIA2202P			110	3.99
Average grain yield (t/ha)	**1.38**	**1.61**	**3.63**	
Sowing date	May 18	May 18	June 9	
April - Oct (mm)	355	232	355	
Annual rainfall (mm)	503	401	519	

Acknowledgements

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

This trial is funded by HART

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

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Economic benefits of nitrogen fixation from legumes in subsequent season crops

Declan Anderson and Rebekah Allen
Hart Field-Site Group

Key findings

- Vetch brown manure fixed the most nitrogen (N) into the soil with a pre-seeding soil N of 107 kg/ha, an increase of 37.9 kg N/ha from 2021. Poor legume growth in 2021 resulted in no increase in soil N from grain legume treatments.
- Barley (5.73 t/ha) and wheat (6.10 t/ha) yielded similarly across all 2021 treatments. Grain quality was also similar in 2021. Protein was low for wheat (10.1%) and barley (10.9%) due to under fertilisation. Test weights were high, and screenings were acceptable.
- Timok vetch had the highest two-year partial gross margin in wheat and barley with $2,202 and $1,777/ha respectively. Brown manured vetch provided the lowest return in both wheat ($1,804/ha) and barley ($1,306/ha) due to no income in the first year and minimal benefit from increased N fixation.

Introduction

Nitrogen is a fundamental element in cropping systems, contributing to vital plant functions of crop growth and development (Leghari 2016). Forms of nitrogen are available from atmospheric, biological and organic fixation of N, therefore appropriate N management practices are important to increase soil N and minimise input costs of N fertilisers for cereal and oilseed crops (Leghari 2016).

Legume crops have been used to fix N into soils for many years to reduce the cost of fertiliser inputs, however, not all legume crops are capable of fixing the same amount of soil N (Farquharson et al 2022). Nitrogen fixation is also affected by biomass production with larger crops typically fixing more N (Seymour et al 2015).

In recent seasons, N based fertilisers including urea and diammonium phosphate (DAP) have increased in cost, putting significant pressure on growers to manage the application of granular fertilisers more efficiently. It has also influenced grower's decision-making when considering an increase in primary production area sown to legume crops.

This two-year trial investigated N fixation of legumes in the medium rainfall zone of the Mid-North region and the economic benefits in a subsequent season's crop (wheat or barley).

Methodology

2021		**2022**	
Seeding date	May 18, 2021	**Seeding date**	June 10, 2022
Crop type	Grain legumes	**Crop type**	Cereal phase
Basal fertiliser	MAP (10:22) + 2% Zn @ 80kg/ha	**Basal fertiliser**	DAP (18:20) + 1% Zn + Impact @ 80 kg/ha
2021 harvest date	November 30, 2021	**2022 harvest date**	December 14, 2022

The trial was a split plot design with three replicates and five treatments. It was managed with the application of pesticides to ensure a weed, insect and disease-free canopy. Plots were assessed for crop biomass (t DM/ha) at hay cutting (50% podding), grain yield (t/ha) and harvest biomass (t DM/ha) in 2021. Plot assessments in 2022 involved pre-seeding soil N (kg N/ha), NDVI (Normalised Difference Vegetation Index) as a measure of crop vigour, grain yield (t/ha) and a partial gross margin ($/ha). Data was analysed using a split plot ANOVA model in Genstat 22nd edition.

Five legume treatments were sown in 2021; Timok vetch, PBA Hallmark XT lentil, PBA Butler field pea and PBA Samira faba bean. A vetch brown manure treatment was also included and was terminated on September 1, 2021 using RoundUp Ultra®MAX + Lontrel® Advanced, followed by a double knock of SpraySeed® on September 29. Genesis 090 chickpea was removed from analysis in 2021 as poor establishment in that year would have influenced available soil moisture and available N for the following year's crop.

The starting soil N in 2021 was 68.7 kg N/ha. In 2022, legume treatments were over-sown with Scepter wheat or Compass barley. The targeted wheat grain yield for wheat and barley in 2022 was 3 t/ha, equating to approximately 120 kg N/ha (based on N efficiency of 40 N/t). Granular urea was applied to all cereal plots, targeting 120 kg/ha N.

Table 1. Pre-seeding N level (kg/ha) in 2022 for each legume treatment and the average amount of N applied (kg/ha) to reach 120 kg N/ha target.

Crop type	**Average N pre-seeding (2022)** (kg/ha)	**Average N applied** (kg N/ha)	**Granular urea applied** (kg/ha)
Lentil (Hallmark XT)	50.5	69.5	151.2
Field pea (Butler)	55.3	64.7	140.6
Faba bean (Samira)	67.8	52.2	113.5
Vetch (Timok)	67.4	52.6	114.3
Vetch brown manure (Timok)	106.6	13.4	29.1

Results and discussion

Legume yields in 2021

Dry conditions in 2021 resulted in below average grain yields for all legumes at Hart. Lentil was the lowest yielding legume in 2021, averaging 0.67 t/ha. Faba bean, field pea and vetch performed similarly, with yields of 1.09 t/ha, 1.12 t/ha and 1.06 t/ha, respectively (Figure 1).

The vetch brown manure treatment was terminated prior to seed-set.

Field pea and vetch had higher levels of biomass at hay cutting, producing 4.26 and 3.91 t DM/ha respectively (Table 2). At harvest, all varieties produced similar levels of crop biomass, therefore minimal differences in fixed soil N would be expected (Farquharson et al 2022).

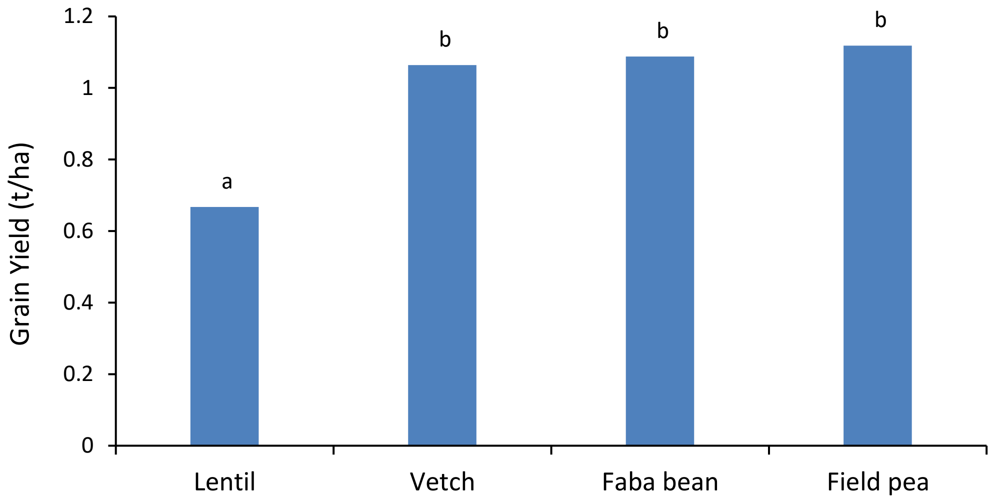

Figure 1. Grain yields at Hart in 2021 for grain legume crops.

Table 2. Biomass production (t/ha) for legume varieties at Hart in 2021. Varieties for each cut timing with the same letter are not significantly different. Shaded values indicate the highest performing treatment.

Variety	**2021 Biomass Production**	
	Hay cut (t/ha)	**Harvest Cut** (t/ha)
Lentil	2.18[a]	4.52
Faba bean	2.99[ab]	5.65
Vetch	3.91[bc]	4.20
Field pea	4.26[c]	5.20
LSD (P≤0.05)	**1.23**	**NS**

Soil N fixation

Crops with greater biomass typically fix more N into the soil (Farquharson et al 2022). Biomass production in a drier year, as observed at Hart in 2021, was low, therefore N fixation was reduced. Similar or decreased levels of soil N in grain legume treatments, when compared to background levels measured in 2021 (Figure 2), were a result of grain removal and low levels of N fixation in-season due to lower yield potential. The only legume treatment which increased soil N was the vetch brown manure of 106.6 kg N/ha prior to seeding in 2022. This was an increase of 37.9 kg N/ha, when compared to 2021 pre-seeding levels, as a result of no N removal from the terminated vetch.

Faba beans are capable of fixing approximately 27 kg of N per tonne of biomass produced, whereas lentils and field peas are capable of fixing approximately 24 kg of N for every tonne of biomass produced (Farquharson et al 2022). These values can change depending on the growing season and performance of varieties. A trial in the Riverine planes observed vetch fixing higher levels of N per tonne of biomass when compared to faba bean and field pea (Glover et al 2012).

Pre-seeding N did not account for crop residue that would contribute N during the growing season.

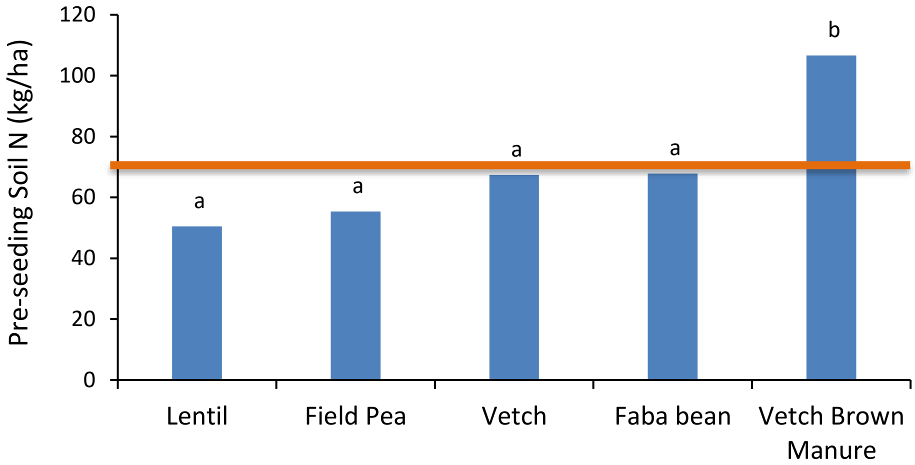

Figure 2. Pre-seeding soil N level at Hart in 2022. Pre-seeding soil N in 2021 is represented by the orange line (68.7 kg N/ha).

2022 crop yield

At Hart in 2022, no yield differences were observed for cereal crops, with wheat yields ranging from 6.06 - 6.15 t/ha and barley from 5.45 – 5.94 t/ha (data not shown). This was expected as each plot was fertilised in-crop with granular urea to 120 kg N/ha. The vetch brown manure treatment could contribute to crop yield increases with early termination, resulting from higher available soil water if seasonal conditions were dry (Ferrier et al 2013).

2022 grain quality

Grain quality for wheat was similar with protein (%), test weight (kg/hL) and screenings of 10.1%, 85.8 kg/hL, and 3.5%, respectively. All treatments met ASW1 receival standards. Barley quality was also similar for protein and retention (Table 2). Test weight and screenings were variable, resulting from previous legume treatments. Barley sown after vetch was observed to have lower test weight and higher screenings, and sown after the vetch brown manure treatment, it recorded a lower test weight. Differences observed for these two treatments were negligible and did not affect receival standards, with all treatments meeting Malt 1 requirements.

Table 2. Grain quality characteristics for Compass barley following legume treatments at Hart in 2022. Shaded values indicate best performing treatments. Values with the same letter are not significantly different.

2021 treatment	**Protein** (%)	**Test Weight** (kg/hL)	**Retention** (%)	**Screenings** (%)
Lentil	11.3	68.2^{abc}	96.8	0.9^{a}
Field pea	10.7	68.6^{bc}	97.4	0.7^{a}
Vetch	11.3	67.6^{a}	96.7	1.1^{b}
Faba bean	10.4	68.6^{c}	97.6	0.6^{a}
Vetch brown manure	11.0	67.9^{ab}	97.0	0.8^{a}
LSD (P≤0.05)	**NS**	**0.63**	**NS**	**0.24**

Gross margin analysis

The legume rotation producing the highest two-year partial gross margin for wheat and barley was vetch, with returns of $2,202/ha and $1,777/ha, respectively (Figure 4). This was due to higher grain yield and prices for vetch in 2021.

Barley and wheat sown after vetch brown manure resulted in the lowest two-year partial gross margin with cumulative returns of $1,306/ha and $1,804/ha, respectively (Figure 4). This was expected as there was no income during the 2021 season. Alternative uses of vetch, such as grazing, were not included in the partial gross margin analysis.

The advantage of a brown manure vetch prior to wheat or barley was a 40% ($112/ha) and 45% ($147/ha) reduction in urea cost (Table 3 & 4). This would also provide secondary benefits in years where access to fertiliser or labour is limited. Low lentil yields in 2021 also resulted in a lower two-year partial gross margin, performing similar to vetch brown manure.

Brown manured vetch also offers a high level of weed control in preparation for subsequent years' crops. In high weed pressure paddocks, the partial gross margin would be affected due to a reduction in grain yield.

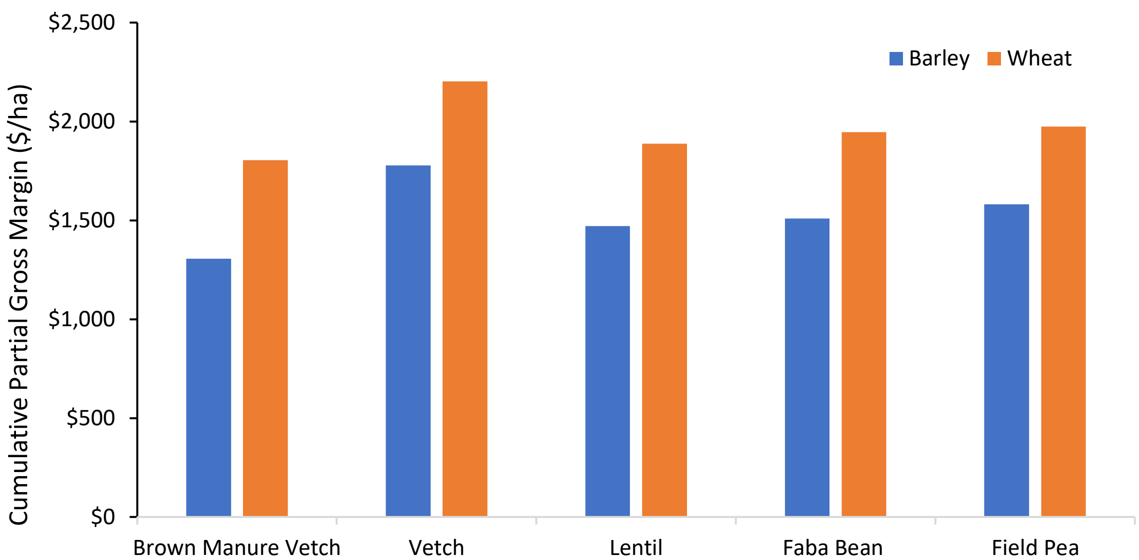

Figure 4. Cumulative partial gross margin analysis ($/ha) for grain legume crops, followed by wheat or barley at Hart. The partial gross margin includes pesticide and fertiliser inputs and seed costs. Operational, contracting and insurance costs were not accounted for. Grain prices for 2021 in addition to seed, pesticide, basal fertiliser and urea costs were based on estimates from the 2021 and 2022 Farm Gross Margin Guide. Barley and wheat prices for 2022 were based on cash prices available at Viterra Snowtown on December 14. ASW wheat was $376/t and Malt 1 barley was $298/t.

The partial gross margin presented is based on one year of legume and cereal data only and is likely to vary depending on seasonal conditions.

Table 3. Partial gross margin ($/ha) for legume crop and Scepter wheat crop at Hart. The 2022 grain price was based on ASW1 at Snowtown on December 14. The 2021 and 2022 Gross Margin and Enterprise Planning Guides were used to estimate input costs.

		Vetch brown manure	Vetch	Lentil	Faba Bean	Field Pea
Income	2021 Yield (t/ha)	0	1.03	0.58	0.91	0.92
	Price ($/t)	$ -	$ 500	$ 600	$ 400	$ 380
	2022 Yield (t/ha)	6.09	6.06	6.09	6.12	6.15
	Price ($/t)	$ 376	$ 376	$ 376	$ 376	$ 376
	Total ($/ha)	$ 2,290	$ 2,794	$ 2,638	$ 2,665	$ 2,662
2021 Expenses	Seed Cost	$ 38	$ 38	$ 32	$ 70	$ 57
	Sowing Fert.	$ 48	$ 48	$ 48	$ 48	$ 48
	Pesticides	$ 74	$ 66	$ 175	$ 139	$ 86
	2021 Total ($/ha)	$ 159	$ 152	$ 255	$ 258	$ 191
2022 Expenses	Seed Cost	$ 45	$ 45	$ 45	$ 45	$ 45
	Sowing Fert.	$ 104	$ 104	$ 104	$ 104	$ 104
	Pesticides	$ 178	$ 178	$ 178	$ 178	$ 178
	Urea	$ -	$ 113	$ 169	$ 135	$ 171
	2022 Total ($/ha)	$ 327	$ 439	$ 496	$ 461	$ 497
Final Partial GM ($/ha)		**$ 1,804**	**$ 2,202**	**$ 1,887**	**$ 1,946**	**$ 1,973**

Table 4. Partial gross margin ($/ha) for legume crop and Compass barley at Hart. The 2022 grain price was based on Malt 1 at Snowtown on December 14. The 2021 and 2022 Gross Margin and Enterprise Planning Guides were used to estimate input costs.

		Vetch Brown Manure	Vetch	Lentil	Faba Bean	Field Pea
Income	2021 Yield (t/ha)	0	1.09	0.75	1.27	1.32
	Price ($/t)	$ -	$ 500	$ 600	$ 400	$ 380
	2022 Yield (t/ha)	5.88	5.94	5.76	5.45	5.63
	Price ($/t)	$ 298	$ 298	$ 298	$ 298	$ 298
	Total ($/ha)	$ 1,752	$ 2,315	$ 2,166	$ 2,132	$ 2,179
2021 Expenses	Seed Cost	$ 38	$ 38	$ 32	$ 70	$ 57
	Sowing Fert.	$ 48	$ 48.00	$ 48	$ 48	$ 48
	Pesticides	$ 74	$ 66	$ 175	$ 139	$ 86
	2021 Total ($/ha)	$ 159	$ 152	$ 255	$ 258	$ 191
2022 Expenses	Seed Cost	$ 60	$ 60	$ 60	$ 60	$ 60
	Sowing Fert.	$ 104	$ 104	$ 104	$ 104	$ 104
	Pesticides	$ 86	$ 86	$ 86	$ 86	$ 86
	Urea	$ 37	$ 137	$ 191	$ 115	$ 157
	2022 Total ($/ha)	$ 287	$ 386	$ 440	$ 365	$ 407
Final Partial GM ($/ha)		**$ 1,306**	**$ 1,777**	**$ 1,471**	**$ 1,509**	**$ 1,581**

Conclusion

Urea input was reduced when vetch was brown manured at Hart in 2021 with cost reduced by 40-45% ($112-147/ha), although overall gross margins were similar between legume crops. Due to seasonal conditions, grain legumes did not increase soil N at Hart.

Vetch grain production prior to a cereal crop produced the highest two-year partial gross margins across wheat and barley due to good prices. All legume treatments provided profitable options for growers, even with low grain yields in 2021. Brown manured vetch also provided a profitable option for growers with the added benefit of improved weed control.

The results presented cover two-years of data only and are influenced by seasonal conditions.

Acknowledgements

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

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

We would like to thank the numerous growers who donated seed to conduct this trial.

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Optimising vetch grazing and hay production

Declan Anderson and Rebekah Allen
Hart Field-Site Group

Key findings

- Studenica, Timok and RM4 produced the highest grazing biomass (kg DM/ha) across two seasons at Hart.
- RM4 and Capello produced the best quality feed, with Timok, RM4 and Jumbo2 producing the best quality hay when measured in 2021.
- RM4, Morava and Capello produced superior hay yields in 2022 of 6.95, 6.04 and 6.02 t DM/ha, respectively.
- Vetch performance is highly influenced by both variety selection and seasonal conditions.
- Studenica, Timok and RM4 have shown to be high yielding across multiple seasons when trialed at Hart.
- Time of sowing did not influence vetch production at Hart in 2022, however dry sowing in 2021, as a result of infrequent rainfall events prior to the season break, was shown to reduce crop establishment to 44%.

Introduction

Vetch is a low input crop commonly grown across the Mid-North region of SA for grazing and hay end-uses within mixed farming systems, providing a legacy effect of nitrogen fixation for subsequent crops.

Decision making based around variety selection and sowing time, can greatly impact the potential $/ha return from a vetch crop. Optimising production will be important to increase the lasting benefit and return of vetch as a rotation option within farming systems.

There are three species of vetch grown in Australian farming systems. Common Vetch *(Vicia sativa)* is mostly grown in dryland mixed farming systems due to low hard seededness levels and high grain and hay production. Woolly Pod Vetch *(Vicia villosa)* and Purple Vetch *(Vicia benghalensis)* are typically grown in livestock systems and in high rainfall regions due to their hard seededness for grazing purposes and waterlogging tolerance (GRDC 2018). Breeding efforts in the last decade for woolly-pod vetch have resulted in the commercialisation of RM4. This variety has reduced hard seededness in addition to improved establishment and vigour when compared to previous woolly-pod vetches (Matic 2016). These traits allow RM4 to be better suited to dryland mixed farming systems, when compared to older varieties.

This trial aims to assess the performance of vetch varieties across two times of sowing (TOS) to optimise vetch grazing and hay production. Data presented has been collected over two growing seasons; 2021 and 2022.

Methodology

Plot size	1.75 m x 10.0 m	**Fertiliser**	DAP (18:20) + 1% Zn + Impact @ 80 kg/ha
2021 **Seeding date**	April 19, 2021	**Crop history**	Mulgara Oaten Hay
2022 **Seeding dates**	TOS 1: April 22 TOS 2: June 9	**Location**	Hart, SA

The trial was a split-plot design with three replicates, two times of sowing (TOS) and six varieties. Trials were managed with the application of pesticides to ensure a weed, insect and disease-free canopy. All plots were assessed for grazing and hay production (t DM/ha). Data was analysed using a split-plot ANOVA model in Genstat 22nd edition.

Common vetches are widely grown across most cropping regions and varieties trialed in 2022 include Studenica, Timok and Morava which have a very early, mid and late maturities, respectively (Table 1). The woolly-pod vetches trialed were RM4 and Capello which are typically later maturing and have been developed for forage and hay production. Grain produced cannot be fed to livestock due to high toxin levels (Nagel et al 2021). Care should be taken when grazing woolly-pod vetch once pods have formed, but should not be grazed prior to 10-nodes (GRDC 2018).

A lentil hay option trialed in 2021 was included as a comparison in 2022. PBA Jumbo2 was selected due it's medium - tall height, better suited for hay production (Day and Blake 2022).

The recommended seeding rate varied for each vetch type, however a target of 70 plants/m^2 is ideal (Nagel et al 2022). For common vetches, this results in a seeding rate of approximately 50 kg/ha and 40 kg/ha for the woolly-pod vetches. PBA Jumbo2 was sown to a target density of 120 plants/m^2 as the recommended sowing rate (GRDC 2017).

Observations in 2021 suggest that delaying seeding until either adequate soil moisture was available, or prior to a significant rain event, could be beneficial in improving establishment and therefore crop production. This resulted in the inclusion of two TOS in the 2022 trial; standard practice; mid-late April and late seeding into soil moisture. The late TOS was sown on June 9 after a season break of 37 mm rainfall on May 31. All plots emerged on June 12.

Table 1. Maturity characteristics (Nagel et al 2020) and cut dates for all varieties sown at Hart in 2022.

Variety	Maturity	Hay cut date
Studenica	Very early	October 6
Timok	Mid	October 6
PBA Jumbo2	Mid	October 6
Morava	Late	October 17
RM4	Mid	October 28
Capello	Late	October 28

Grazing cuts were completed on all vetch plots on August 26, 2022 (10 weeks after emergence).

Results and discussion

Grazing performance

Observed trends show there are high performing varieties for grazing options in the medium rainfall region of the Mid-North. RM4, Timok and Studenica were the highest performing varieties in 2021 and 2022. In 2022, these varieties produced 913, 891 and 850 kg DM/ha, respectively. Morava yielded equally, producing 980 kg DM/ha (Figure 1). Timok regularly performs well due to very high dry matter production, while Studenica also performs well at grazing due to superior winter growth and increased vigour (Nagel et al 2022).

Overall, Timok and Studenica have yielded consistently well as a grazing option across two seasons at Hart. When comparing woolly-pod vetch varieties, RM4 was the best performing variety at grazing with high levels of biomass production and excellent feed quality characteristics (Anderson & Allen 2021).

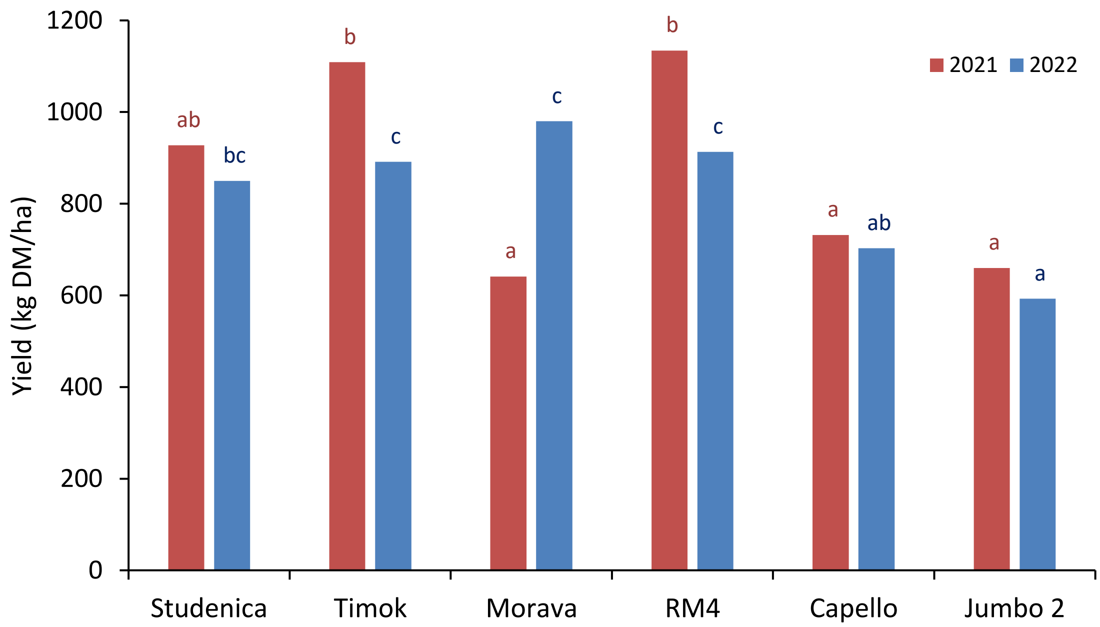

Figure 1. Biomass production (kg DM/ha) at grazing for each variety trialed at Hart in 2021 and 2022. Varieties with the same letters are not significantly different from each other. Significance levels are for comparison within each individual season only.

PBA Jumbo2 produced low biomass in both years, displaying its un-suitability for early grazing. Capello was also lower performing across two seasons due to low biomass production, however it did produce high quality feed, similar to RM4 in 2021 (Anderson & Allen 2021). Woolly-pod vetch like Capello is typically known for their poorer performance to early grazing with the exception of RM4 having improved early grazing performance due to recent breeding efforts (GRDC 2018).

Hay performance

Performance of vetch varieties varied across the two years trialed due to diverse seasonal conditions. A dry finish and minimal soil moisture in 2021 saw varieties yield similarly, with an average hay production of 2.3 t DM/ha (Table 2). Conditions in 2022 were cool and wet later into the growing season, allowing longer season varieties like Morava, RM4 and Capello to capitalise on additional soil moisture, yielding 6.04, 6.95 and 6.02 t DM/ha, respectively (Table 2). The shorter season varieties Studenica, Timok and Jumbo2 lentils were limited in production by their maturity length as they were unable to benefit from late season rainfall.

Although RM4 is noted as mid-maturing, woolly-pod vetch is typically later maturing than common vetch, resulting in RM4 yielding exceptionally well.

Table 2. Hay production of vetch and lentil varieties at Hart in 2021 and 2022. Values shaded blue indicate best performing varieties. Varieties with the same letters are not significantly different.

Variety	Hay Yield (t DM/ha)	
	2021	**2022**
Studenica	1.91	4.60[a]
Timok	2.30	5.50[ab]
Morava	2.24	6.04[bc]
RM4	2.59	6.95[c]
Capello	2.37	6.02[bc]
Jumbo2	2.39	4.97[ab]
Average	**2.30**	**5.68**
LSD (P≤0.05)	**NS**	**1.135**

In 2021, hay quality was measured for all varieties trialed. Stand-out varieties included RM4, Timok and Jumbo2 (Anderson & Allen 2021). RM4 and Timok had increased fibre digestibility (NDFDom30 of 41.05%) and protein levels (19.5%). Jumbo2 lentil had increased digestibility and greater energy density. Hay quality for vetch varieties was not measured in 2022.

Time of sowing

Emergence was negatively impacted in 2021 due to small and infrequent rainfall events occurring post-sowing. Crop establishment in 2021 averaged 44% and was visually inconsistent. Sowing date did not affect crop establishment in 2022 due to negligible rainfall between both TOS. As a result, TOS 1 did not germinate until the season break arrived. Establishment was not affected.

Acknowledgements

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

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

We would like to thank the Australian National Vetch Breeding Program (ANVBP) and SARDI Clare for providing seed to conduct this trial.

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Benefits of long coleoptile wheat

Declan Anderson and Rebekah Allen
Hart Field-Site Group

Key findings

- Marginal summer rainfall leading into the 2022 season at Hart resulted in dry conditions, and marginal soil moisture at depth.
- Commercial wheat varieties with longer coleoptiles had improved crop establishment when sown deep, with Bale (133 plants/m^2) and Calibre (130 plants/m^2) having better crop establishment when compared to Scepter (118 plants/m^2).
- Results show that pre-breeding line Mace18 had reduced yield when sown at standard depth (40 mm) after the season break on May 30. This result was also observed at other trial locations (Rebetzke et al 2022) with the reason currently unknown.
- Yield losses were observed for Mace and Scout when sown deep, showing that the Rht18 gene in these varieties provides benefits, allowing growers to sow deeper.
- In years where small and infrequent rainfall events occur, standard sowing (40 mm) may reduce establishment when crops are sown early in drier conditions. Long coleoptile wheats can reduce this risk by deeper sowing into subsoil moisture when conditions are favourable.

Introduction

Deep sowing is a technique that can be used by growers to place seeds into soil moisture lower in the profile or improve pre-emergent herbicide crop safety (Porker & Wheeler 2012). Most commercially available wheat varieties have shorter coleoptile lengths (5-7 cm) and reduced establishment can result if sown too deep (Pumpa et al 2013). Wheats with longer coleoptile sheaths have the ability to protect the seedling when sown deeper (>50 mm), resulting in a reduction of crop establishment. Long coleoptile wheat varieties could allow growers to sow seed further away from pre-emergent herbicide bands without reducing crop establishment (Porker & Wheeler 2012) or risking potential yield loss.

Two trials were conducted at Hart in 2022:

1. Comparing crop safety and yield impacts of current wheat varieties with varying coleoptile lengths.
2. Assessing the performance of current and pre-breeding wheat lines from CSIRO (+/- Rht18 gene) when sown at standard depth (40 mm) or deep (120 mm).

Methodology

Plot size	1.75 m x 10.0 m	**Fertiliser**	Seeding: DAP (18:20) Zn 1% + Impact @ 80 kg/ha
Seeding date	June 10, 2022		July 22: Easy N (42.5:0) @ 70 L/ha
Location	Hart, SA		August 17: Easy N (42.5:0) @ 60 L/ha
Harvest date	December 15, 2022		
2021 crop	Mulgara Oaten Hay		

Trial 1 was a split-split plot design with three replicates, three wheat varieties, three pre-emergent herbicides and two sowing depths. Varieties selected for this trial were based on their variation in coleoptile length (Table 1); Scepter (medium – short), Calibre (medium – long), and LRPB Bale (long). The pre-emergent herbicides used in this trial were Sakura®, Luximax® and Overwatch®. Assessments for this trial include plant establishment (plants/m^2), NDVI (Normalised Difference Vegetation Index), grain yield (t/ha), and grain quality. Data was analysed using a split-split plot ANOVA model in Genstat 22nd edition.

Trial 2 was a split plot design with three current commercial varieties, three pre-breeding lines (+Rht18 breeding gene) and two sowing depths (Table 2). Assessments include plant establishment (plants/m^2), NDVI (Normalised Difference Vegetation Index), plant height (cm), grain yield (t/ha), and grain quality. Data was analysed using a split-split plot ANOVA model in Genstat 22nd edition.

Table 1. Treatments for Trial 1; variety x herbicide x sowing depth sown at Hart in 2022.

Variety	Pre-emergent herbicide	Sowing depth
Scepter	Sakura	40 mm (standard)
Calibre	Luximax	120 mm (deep)
LRPB Bale	Overwatch	

Table 2. Treatments for Trial 2; new genetics x sowing depth sown at Hart in 2022. Mace18, Scout18 and Yitpi18 contain the Rht18 dwarfing gene.

Variety	Sowing depth
Mace	40 mm (standard)
Mace18	120 mm (deep)
Scout	
Scout18	
Yitpi	
Yitpi18	

Results and discussion

2022 Sowing conditions

Due to a late season break (May 30) and minimal rainfall over summer and autumn months, trials were sown in June. Long coleoptile wheats allow growers to sow earlier into subsoil moisture, however as the Hart site has a heavy soil type (clay loam), dry conditions were not favourable to sow deep and would have resulted in poor seed-soil contact.

Results from Trial 2 primarily show the effects of sowing pre-breeding wheat (+Rht18 genes) at a standard sowing time at two depths compared to commercial varieties Mace, Scout and Yitpi.

Variety x herbicide x sowing depth

There was a plant establishment penalty observed across all varieties sown at depth when compared to standard sowing depth, however, less so for those with a longer coleoptile. Bale and Calibre performed best at depth with plant establishment of 133 and 130 plants/m^2, respectively. Crop establishment between all varieties sown at standard sowing depths was similar.

Grain yield was not affected by sowing depth, with the trial averaging 3.95 t/ha (Table 3).

Scepter was expected to display yield losses when sown at depth. Previous growth chamber research conducted at Waite, SA (Bruce 2017) showed that coleoptile length can increase under cold conditions (peak length at 15 degrees), so results highlight the possibility that coleoptile length can increase in cold environments.

Grain quality was variable among treatments with differences in protein (%), test weight (kg/hL) and screenings (%). Protein was higher when crop was deep sown, averaging 10.3%, while standard depth sowing averaging 9.1% (Table 3). Screenings were affected by variety selection, with the awnless variety Bale recording the highest level of screenings. Screenings were also high for Bale when sown deep. Test weight was variable between treatments with varying responses amongst varieties.

Table 3. Grain yield and quality of wheat varieties at standard or deep sowing for the variety x herbicide x sowing depth trial. Shaded values indicate best performing treatments. Values with the same letters are not significantly different.

Sowing Depth	Variety	Yield (t/ha)	Protein (%)	Test Weight (kg/hL)	Screenings (%)
Standard	Scepter	4.31	8.8	85.5[d]	3.2[a]
	Calibre	4.48	8.7	82.9[b]	3.3[a]
	Bale	3.84	9.9	82[b]	4.9[b]
Deep	Scepter	3.69	10.2	86.2[d]	2.9[a]
	Calibre	3.92	9.6	84.0[c]	3.6[ab]
	Bale	3.47	11.00	79.1[a]	6.4[c]
LSD (P≤0.05)		**NS**	**NS**	**1.03**	**1.39**

Pre-emergent herbicide selection had little effect on crop establishment or grain yield at Hart in 2022 and no crop damage was observed in any treatment.

Grain yield was positively influenced by pre-emergent herbicide treatment; with plots treated with Overwatch and Luximax recording high yields of 3.97 and 3.98 t/ha, respectively. Plots treated with Sakura were lower yielding with yields of 3.91 t/ha. The lower yields were likely not due to herbicide damage from Sakura. Herbicide damage is more likely to occur when crops are sown at a standard depth and no damage was observed at Hart.

New genetics x sowing depth

The inclusion of the new dwarfing gene Rht18 improved crop establishment at deep sowing for Mace18 and Scout18 (Figure 2). Yitpi18 was observed to have similar establishment to commercial wheat Yitpi without the Rht18 gene, when sown deep. This is a result of Yitpi having a longer coleoptile and would emerge better when sown deep compared to other varieties. Differences would likely be observed if deeper seeding depth was trialed.

At a standard sowing depth of 40 mm, emergence between varieties +/- Rht18 gene was similar.

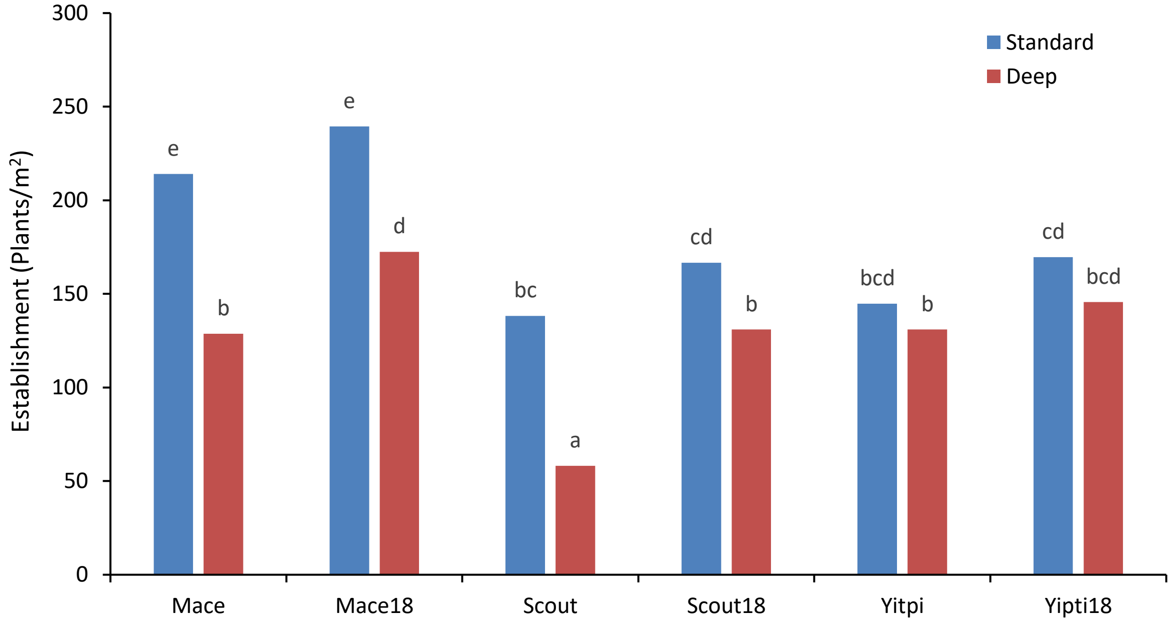

Figure 2. Establishment (plants/m^2) of wheat varieties trialed in the variety x sowing depth. Varieties with the same letter are not significantly different.

When sown at standard depth, Mace, Scout, Yitpi and Yitpi18 were the highest yielding wheats with an average yield of 4.09 t/ha (Figure 3).

Scout18 and Mace18 provided yield benefits over commercial varieties Mace and Scout when sown deep. This was not observed for Yitpit18 which yielded similarly to commercial variety Yitpi. This is a result of this variety having a longer coleoptile. Yield differences may be observed if Yitpi and Yitpi18 were sown deeper than 120 mm.

Pre-breeding wheat lines of Scout18 and Yitpi18, with the Rht18 gene, were sown at a standard depth, achieving similar yield outcomes to commercial varieties Yitpi and Scout. This suggests that if seasonal conditions that allow early sowing into subsoil moisture are not met, growers can still sow these varieties in May in favourable seeding conditions with no yield penalty.

Results show that pre-breeding line Mace18 had reduced yield when sown at standard depth (40 mm) after the season break on May 30. This result was also observed at other trial locations (Rebetzke et al 2022) with the reason currently unknown. Yield losses were observed for Mace and Scout when sown deep, showing that the Rht18 gene in these pre-breeding varieties provides benefits, allowing growers to sow deeper. In years where small and infrequent rainfall events occur; standard sowing (40 mm) may reduce establishment when crops are sown early in drier conditions. Long coleoptile wheats can reduce this risk by deeper sowing into subsoil moisture when conditions are favourable.

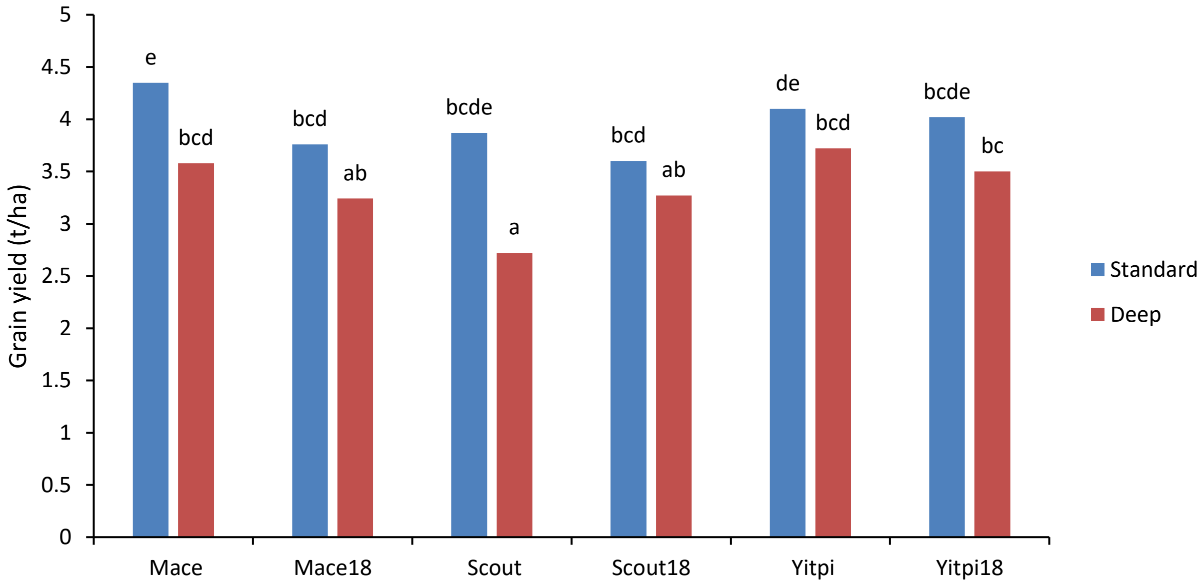

Figure 3**.** *Grain yield at standard or deep sowing for the new genetics x sowing depth trial. Values with the same letters are not significantly different.*

When assessing new pre-breeding genetic lines across two sowing depths, differences were observed for protein (%), test weight (kg/hL) and screenings (%).

Protein increased slightly when sown deep, averaging 11.1%, compared to 10% at standard sowing (Table 4). The increase in grain protein from deep sowing resulted in a higher receival grade of APW, when compared to the ASW receival grade at standard sowing. Screenings were also higher at deep sowing averaging 3.2% when compared to 2.7% for standard sowing. Variety selection affected test weight and screenings across sowing depths, with only select varieties experiencing changes in test weight and screenings (Table 4).

Table 4. Grain quality of wheat varieties at standard or deep sowing for the new genetics x sowing depth trial. Shaded values indicate best performing treatments. Values with the same letters are not significantly different.

Sowing Depth	**Variety**	**Protein** (%)	**Test Weight** (kg/hL)	**Screenings** (%)
Standard	Mace	9.9	85.6^{g}	2.4^{ab}
	Mace18	10.2	83.2^{ef}	1.9^{a}
	Scout	9.1	83.5^{ef}	3.2^{cde}
	Scout18	11.1	78.6^{b}	2.0^{a}
	Yitpi	9.7	83.1^{e}	3.6^{e}
	Yitpi18	9.8	81.2^{cd}	3.0^{cd}
Deep	Mace	11.0	85.5^{g}	2.8^{bc}
	Mace18	11.4	83.9^{ef}	2.3^{a}
	Scout	10.7	84.3^{f}	4.5^{f}
	Scout18	11.4	76.0^{a}	2.3^{ab}
	Yitpi	11.2	81.6^{d}	3.5^{de}
	Yitpi18	10.8	80.2^{c}	3.7^{e}
LSD (P≤0.05)		**NS**	**1.13**	**0.52**

Coleoptile length between varieties

Variation in coleoptile lengths between wheat varieties is highlighted below in Figure 4. The first wheats released with the Rht18 gene were LRPB Bale and LRBP Dual with Bale recording the longest coleoptile length (120 mm). Dual also contains the Rht12 gene for dwarfing, explaining the difference in coleoptile length between the two. Yitpi is also known for having a long coleoptile length, recording 116 mm.

Under laboratory conditions, commonly grown wheat varieties Scepter and Vixen have shorter coleoptile lengths of 90 mm and 86 mm. Other varieties that produced short coleoptiles were Sunblade CL Plus and Beckom with lengths of 61 mm and 74 mm respectively.

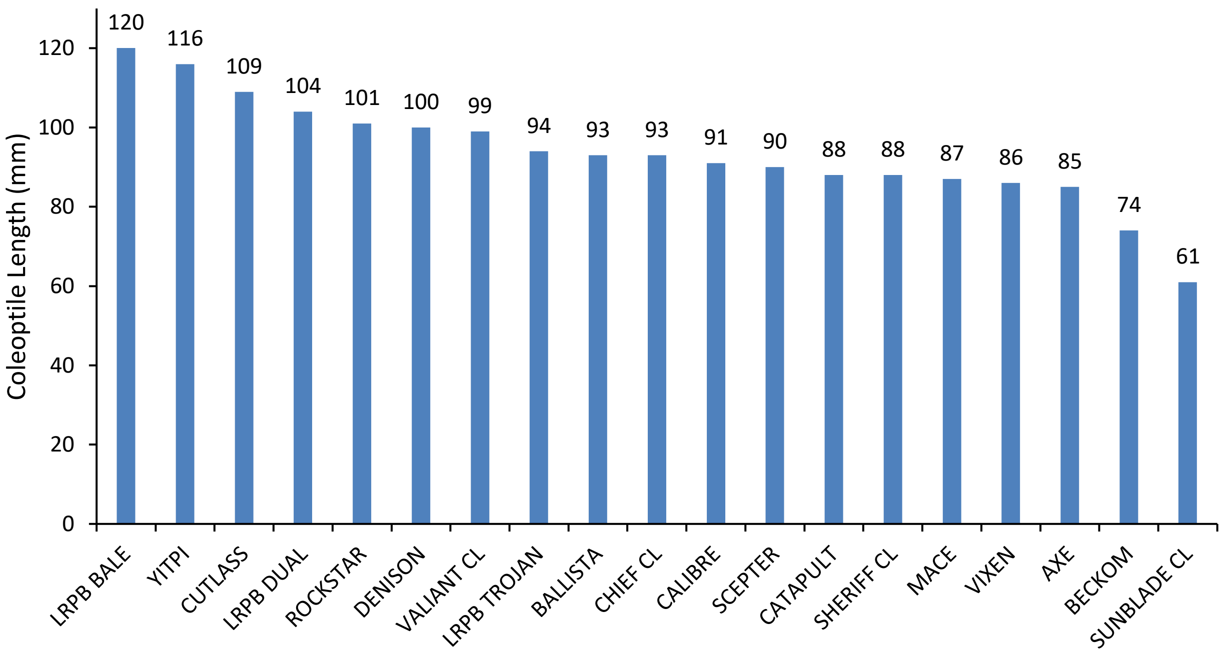

Figure 4. Summary of lab recorded wheat coleoptile lengths (mm) at 200°Cd. Data was supplied by Mitchell Eglinton and Longreach Plant Breeders as part of their coleoptile screening data. Data has not been analysed.

Acknowledgements

This trial is funded by HART

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We would like to thank Longreach Plant Breeders, AGT and Greg Rebetzke for supplying seed to conduct this trial.

We would also like to thank Mitchell Eglinton and Longreach Plant breeders for supplying wheat coleoptile length data.

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Oaten hay variety response to nitrogen and early seeding; a three-year summary

Courtney A. E. Peirce[1,2], Rebekah Allen[3], Melissa McCallum[1] and Rhiannon K. Schilling[1,2,4]

[1]South Australian Research and Development Institute (SARDI), [2]The University of Adelaide, [3]Hart Field-Site Group, [4]Flinders University

Key findings

- Hay yields were consistently improved from early May sowing due to crops maximising access to available soil water in challenging seasons at Hart.
- Interactions between sowing date and variety were inconsistent for hay quality, however sowing earlier did reduce some measures of hay quality.
- Low rates of nitrogen (N) fertiliser (30 - 60 kg N/ha depending on the season) provided the most benefit for hay yields across these trials. Responses in higher rainfall years are expected to favour greater N inputs.
- Hay yield responses for varieties were similar, with seasonal conditions favouring mid-maturing varieties.
- Varieties did not respond differently to applied N however, caution should be taken in interpreting N response from the SA trial series alone, due to consecutive dry seasons limiting soil N mineralisation for the crop.

Introduction

The National Hay Agronomy (NHA) project was a four-year investment, funded by AgriFutures Australia, with trials conducted across South Australia, Western Australia, New South Wales and Victoria from 2019 – 2021. These trials investigated the agronomic management of oats through variety selection, nutrition, and time of sowing strategies and their influence on hay yield and quality. This article will summarise the key results from the 2019 to 2021 trials at the Hart field site, focusing on nine oaten hay varieties, two sowing dates and three applied N rates.

Methodology

Each trial from 2019 to 2021 investigated two times of sowing (TOS); early and late May, with three N rates; 30, 60 and 90 kg N/ha and nine oat varieties. The varieties grown at Hart in 2019 were Brusher, Carrolup, Durack, Forester, Koorabup, Mulgara, Williams, Wintaroo and Yallara. In 2020 and 2021 Vasse replaced Forester, due to this variety having a very long season maturity, leading to poor performance at Hart and more broadly across the national program. Trials were established as replicated split-split plot designs and were managed to ensure a weed, insect and disease-free canopy with pesticide application as necessary. A summary of plot size, seeding dates, seeding fertiliser and starting soil N at 0-60 cm is provided in Table 1.

Nitrogen treatments were applied as split applications with two thirds at seeding and one third at early tillering. This aimed to achieve good early vigour, plant establishment and thin stems. Plant establishment counts were conducted in June for each TOS with seed rates targeting 320 plants/m^2. Seeding densities were calculated based on grain weight and germination to ensure the target seeding rate was reached for each variety in each year.

Table 1. Summary of agronomic details for trials conducted in 2019 to 2021.

2019			
Plot size	1.75 m x 10.0 m	**Fertiliser**	Seeding: DAP (18:20) + Impact @ 60 kg/ha
Seeding date	May 3 and June 5		
Location	Hart, SA	**Starting soil N (0-60cm)**	26 kg N/ha
2020			
Plot size	1.75 m x 10.0 m	**Fertiliser**	Seeding: DAP (18:20) + Impact @ 60 kg/ha
Seeding date	May 6 and May 25		
Location	Hart, SA	**Starting soil N** (0-60cm)	53 kg N/ha
2021			
Plot size	1.75 m x 10.0 m	**Fertiliser**	Seeding: DAP (18:20) + Impact @ 70 kg/ha
Seeding date	May 3 (effective May 10) and June 1	**Starting soil N** (0-60cm)	88.5 kg N/ha
Location	Hart, SA		

Measurements

Plant height (cm) and lodging assessments (scale = 1 – 9, 9 no lodging) were conducted prior to hay cutting. Oaten hay development was monitored by assessing Zadoks crop growth stage (GS) from booting (GS 43-49) until top florets were watery ripe (GS71). Once the middle florets were at watery ripe, hay cuts were taken 15 cm from the ground in each plot (4 x 1 m row). Samples were dried in an oven at 60°C for at least 48 hours or until dry and weighed to calculate hay yield (t/ha). Samples were ground to < 1 mm and hay quality characteristics including Acid Detergent Fibre (% ADF), Neutral Detergent Fibre (% NDF), Crude Protein (% CP), Water-Soluble Carbohydrates (% WSC), digestibility (% IVD) and colour measured by Minolta *a* (data not shown) were measured using the National Oat Breeding NIR calibration. Stem thickness was measured by digital calipers of the squashed internode at the base of the cut stem and leaf greenness of dried plant samples was measured using a SPAD-502 Plus chlorophyll meter.

Yield and quality data was analysed using GenStat V19, and statistical comparisons between treatments were made with Least Significant Difference (LSD) of p=0.05. In the tables, best performing varieties or treatments are highlighted in orange. These are calculated as all treatments within LSD of the best performing treatment.

Hay quality descriptors

Acid Detergent Fibre (ADF %) estimates the least-digestible fraction of hay (cellulose and lignin) and for top quality export hay should be less than 32%. Neutral Detergent Fibre (NDF %) estimates the structural carbohydrates of the hay and is negatively correlated with animal intake so as NDF increases the amount of hay an animal will consume decreases. Ideally NDF will be less than 55-57% for top quality export hay. Digestibility (IVD %) estimates the percentage of hay that can be readily broken down in the rumen and high-quality hay will have a value of at least 58%. Crude Protein (CP %) consists of both true protein and non-protein N in hay and is an important parameter for developing rations. For export quality oaten hay, CP % should be in the 4-10% range. Water Soluble Carbohydrates (WSC %) are aligned with the palatability and sweetness of the hay as they are sugars that can be rapidly fermented in the rumen. High quality export oaten hay will have WSC greater than 18%. The indicative values provided for hay quality are a guide as outlined in the Producing Quality Oat Hay, AEXCO (2016), but each exporter has their own quality targets depending on their end customers and markets.

Climate during growing season

Due to dry seasonal conditions at Hart in 2019 and 2021, establishment of the early sown plots occurred on marginal soil moisture. In 2019 there was sufficient soil moisture and subsequent rainfall after sowing for both TOS 1 and TOS 2 to germinate. In 2021, TOS 1 oat varieties were sown dry ahead of a rain event on May 10 however only 9 mm fell over the three days and germination was uneven. Therefore, supplementary irrigation of 10 mm in-furrow was applied on May 17 by dripper irrigation. In 2020, higher than average summer and April rainfall meant stored soil moisture was sufficient for germination.

The 2019 season at Hart was characterised by a very dry summer, average May and June rainfall which allowed plant establishment, followed by a spring drought. The site only received 161 mm of growing season rainfall (GSR) from May to October, and 188 mm annual rainfall. This resulted in a decile one year, and very low hay yields for the season. Hart's average GSR is 300 mm with an annual rainfall of 400 mm.

In 2020, Hart experienced a wet season, receiving a decile 7 GSR of 335 mm and a decile 9 annual total of 502 mm. This was comparatively better than 2019, however, rainfall in 2020 was not evenly distributed throughout the year. Higher than average rainfall during summer and April meant stored soil moisture was available to the crop at seeding. Below average rainfall was received in May, and this continued throughout winter with a June/July combined rainfall of 38 mm. The trial presented symptoms of water and N stress with slow biomass accumulation during this dry winter period. Warm conditions also caused rapid progression through plant growth stages, resulting in varieties reaching watery ripe on the same date. Although spring rainfall was above average with 209 mm falling from August to the end of October, it was too late to be beneficial to hay production but did assist grain fill (data not shown).

Leading into the 2021 season, the Mid-North region, including Hart, was dry, resulting in limited soil moisture prior to seeding with a late season break of 19 mm occurring on May 25. Rainfall over the winter months was average to above average before a dry start to spring and then very wet November. Overall, GSR rainfall for 2021 was at a decile 3 (231 mm), with a decile 5 year for annual rainfall of 401 mm. The variation in rainfall distribution across the three years for GSR and annual rainfall should be taken into consideration when interpreting the findings of this research.

Results and Discussion

Varieties

Across three seasons at Hart, hay yields were influenced by variety selection (Tables 2 – 4). In the 2019 and 2021 seasons, an interaction between variety and TOS was observed for hay yield (Tables 5 and 7). In 2021, average hay yields for varieties ranged from 3.4 – 4.8 t/ha (Table 4). Yallara and Wintaroo were high yielding, achieving average hay yields across the two sowing dates of above 4.5 t/ha. These two varieties have consistently yielded well across three seasons. In 2020, in addition to Yallara and Wintaroo, Brusher and Carrolup, both mid-maturing varieties and Durack, a quick variety, were also high yielding at Hart (Table 3).

Varieties with a quick to mid-maturity consistently yielded well in trials at Hart due to their suitability to shorter, drier and warmer environments. In contrast, Forester in 2019 and Vasse in 2020 and 2021 have performed poorly across the trial program due to their slower development speed. Forester struggled to flower in 2019 with TOS 2 becoming necrotic in the boot, whilst Vasse struggled to get full panicle emergence and flowered in the boot in 2020 and 2021. This indicates neither of these varieties are suited to the shorter growing season at Hart.

Table 2. Effects of variety, sowing date and nitrogen for a range of hay yield and quality traits at Hart in 2019. The best performing varieties for key traits are highlighted in orange.

	Z71 relative to Carrolup (days)	Plant height (cm)	Hay yield (t/ha)	Stem diameter (mm)	ADF (%)	NDF (%)	CP (%)	IVD (%)	Lignin (%)	WSC (%)
Brusher	+5	35	3.1	3.5	23.0	45.1	9.1	73.5	3.4	29.2
Carrolup	18-Sep	31	2.9	3.2	23.6	42.8	10.0	73.7	3.8	30.8
Durack	-6	32	3.0	3.5	24.5	46.0	9.1	71.2	4.1	28.6
Koorabup	+3	30	3.0	3.4	24.1	46.0	9.0	72.2	3.7	28.7
Mulgara	+2	39	3.3	3.8	24.6	45.3	8.9	72.8	3.8	26.5
Forester	+43	25	1.5	3.3	22.4	40.9	8.8	79.4	2.3	34.8
Williams	+3	29	3.2	3.5	23.7	45.6	10.0	72.4	3.6	26.5
Wintaroo	+7	37	3.2	4.0	24.6	47.6	8.2	71.6	3.9	25.7
Yallara	+2	37	3.2	3.7	22.7	42.1	8.5	73.6	3.4	33.4
Average	**+0**	**33**	**2.9**	**3.5**	**23.7**	**44.6**	**9.1**	**73.4**	**3.6**	**29.7**
Significance (V)	-	***	***	***	***	***	***	***	***	***
LSD (p≤0.05)	-	*3*	*0.1*	*0.2*	*0.7*	*1.3*	*0.4*	*1.0*	*0.2*	*2.1*
TOS1 - 3 May	+0	37	3.5	4.0	23.6	43.3	8.0	73.5	3.6	33.0
TOS2 - 5 June	+0	29	2.3	3.1	23.8	45.9	10.2	73.2	3.5	26.5
Significance (TOS)	-	***	**	***	*n.s.*	**	***	*n.s.*	*n.s.*	***
LSD (p≤0.05)	-	*2*	*0.4*	*0.2*	-	*1.1*	*0.6*	-	-	*0.7*
30 kg N/ha	+0	33	2.5	3.4	24.2	45.3	7.9	72.5	3.6	31.0
60 kg N/ha	+0	33	3.0	3.6	23.4	44.2	9.1	73.5	3.5	30.2
90 kg N/ha	+0	32	3.1	3.6	23.4	44.3	10.2	74.1	3.6	28.0
Significance (N)	-	*n.s.*	***	***	***	***	***	***	**	***
LSD (p≤0.05)	-	-	*0.1*	*0.1*	*0.2*	*0.5*	*0.2*	*0.5*	*0.1*	*0.9*
Significance (N x V)	-	*n.s.*	***	*n.s.*	*n.s.*	*n.s.*	**	*n.s.*	*n.s.*	*n.s.*

Significance: n.s. not significant; * p≤0.05, ** p≤0.01, *** p≤0.001ADF: acid detergent fibre, NDF: neutral detergent fibre, CP: crude protein, IVD: in vitro digestibility, WSC: water soluble carbohydrates

Table 3. Effects of variety, sowing date and nitrogen for a range of hay yield and quality traits at Hart in 2020. The best performing varieties for key traits are highlighted in orange.

	Z71 relative to Carrolup (days)	Plant height (cm)	Hay yield (t/ha)	Stem diameter (mm)	ADF (%)	NDF (%)	CP (%)	IVD (%)	Lignin (%)	WSC (%)
Brusher	+0	66	3.5	4.3	27.6	48.7	10.1	68.9	3.9	25.9
Carrolup	18-Sep	56	3.4	4.0	27.6	47.6	10.3	68.7	3.8	25.9
Durack	-7	57	3.1	4.4	28.4	50.9	11.1	65.9	4.3	21.4
Koorabup	+0	55	3.0	4.2	28.4	50.1	10.5	67.3	4.1	23.5
Mulgara	+0	60	3.0	4.4	28.3	49.3	10.7	68.5	4.0	23.9
Vasse	+5	46	2.3	3.7	30.0	53.8	11.9	68.5	4.4	15.3
Williams	+0	49	2.9	4.5	28.1	50.2	11.7	67.7	4.2	21.2
Wintaroo	+0	60	3.2	4.3	27.5	48.9	10.4	68.9	3.9	24.1
Yallara	+0	55	3.2	4.2	27.0	47.4	10.4	69.0	3.7	25.9
Average	**+0**	**56**	**3.1**	**4.2**	**28.1**	**49.7**	**10.8**	**68.2**	**4.0**	**23.0**
Significance (V)	-	***	***	*n.s.*	***	***	***	***	***	***
LSD (p≤0.05)	-	*3*	*0.4*	-	*0.8*	*1.2*	*0.5*	*1.2*	*0.2*	*1.1*
TOS1 - 6 May	+0	63	3.5	4.4	28.4	49.8	10.1	67.1	4.2	24.3
TOS2 - 25 May	+0	49	2.7	4.1	27.8	49.5	11.5	69.2	3.9	21.7
Significance (TOS)	-	*	*n.s.*	*n.s.*	*	*n.s.*	*	**	**	*
LSD (p≤0.05)	-	*10*	-	-	*0.3*	-	*1.2*	*1.2*	*0.1*	*2.0*
30 kg N/ha	+0	56	3.1	4.2	28.2	49.6	10.0	67.9	4.0	24.8
60 kg N/ha	+0	56	3.1	4.2	28.1	49.7	10.9	68.1	4.0	22.7
90 kg N/ha	+0	56	3.1	4.2	28.0	49.6	11.6	68.5	4.0	21.5
Significance (N)	-	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	***	*n.s.*	*n.s.*	***
LSD (p≤0.05)	-	-	-	-	-	-	*0.3*	-	-	*0.6*
Significance (N x V)	-	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*

Significance: n.s. not significant; * p≤0.05, ** p≤0.01, *** p≤0.001

ADF: acid detergent fibre, NDF: neutral detergent fibre, CP: crude protein, IVD: in vitro digestibility, WSC: water soluble carbohydrates

Variation in cutting dates across 2019 and 2020 was narrow, with varieties progressing quickly to watery ripe due to water stress. The mild spring conditions in 2021 resulted in cutting dates across a 6-week period for varieties and sowing dates (Figure 1). Yallara, sown early on May 3, was the highest yielding variety (6.0 t/ha).

Table 4. Effects of variety, sowing date and nitrogen for a range of hay yield and quality traits at Hart in 2020. The best performing varieties for key traits are highlighted in orange.

	Z71 relative to Carrolup (days)	Plant height (cm)	Lodging (9-0)	Hay yield (t/ha)	Stem diameter (mm)	ADF (%)	NDF (%)	CP (%)	IVD (%)	Lignin (%)	WSC (%)
Brusher	+0	63	8.4	4.2	5.0	26.4	48.8	10.6	69.7	4.4	21.1
Carrolup	23-Sep	58	8.6	4.1	5.0	27.5	48.4	11.0	67.3	4.6	19.3
Durack	-6	58	9.0	4.2	4.8	27.3	48.3	9.8	66.9	4.8	22.6
Koorabup	-3	56	9.0	3.9	5.1	27.4	47.2	12.0	68.9	4.0	18.8
Mulgara	+0	63	8.7	4.2	5.2	26.5	46.3	10.9	70.6	4.0	21.9
Vasse	+16	47	8.1	3.4	4.9	25.2	45.4	10.7	74.4	3.6	23.8
Williams	+6	52	8.5	4.2	5.2	27.2	49.3	11.4	67.7	4.2	17.6
Wintaroo	+7	61	8.7	4.5	5.3	26.6	46.5	9.9	70.4	4.0	22.4
Yallara	-2	63	8.9	4.8	5.1	25.9	46.4	9.5	69.0	4.6	24.9
Average	**+0**	**58**	**8.7**	**4.2**	**5.1**	**26.7**	**47.4**	**10.6**	**69.4**	**4.2**	**21.4**
Significance (V)	-	***	**	***	*n.s.*	***	***	***	***	***	***
LSD (p≤0.05)	-	*4*	*0.4*	*0.4*	-	*0.7*	*1.3*	*0.7*	*1.2*	*0.3*	*1.2*
TOS1 - 3 May	+0	66	8.8	5.0	5.9	27.6	48.4	10.0	67.4	4.7	21.0
TOS2 - 1 June	+0	50	8.6	3.3	4.2	25.7	46.4	11.3	71.5	3.8	21.8
Significance (TOS)	-	***	*n.s.*	**	**	*	*	*	**	**	*n.s.*
LSD (p≤0.05)	-	*5*	-	*0.9*	*0.6*	*1.5*	*1.8*	*1.0*	*2.3*	*0.4*	-
30 kg N/ha	+0	59	8.8	4.2	5.1	26.8	47.8	9.6	68.7	4.5	22.6
60 kg N/ha	+0	57	8.6	4.2	5.0	26.6	47.2	10.7	69.7	4.2	21.4
90 kg N/ha	+0	56	8.6	4.1	5.1	26.6	47.1	11.6	69.9	4.0	20.2
Significance (N)	-	***	***	*n.s.*	*n.s.*	*n.s.*	*	***	***	***	***
LSD (p≤0.05)	-	*1*	*0.1*	-	-	-	*0.6*	*0.3*	*0.6*	*0.1*	*0.7*
Significance (N x V)	-	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*

Significance: n.s. not significant; * p≤0.05, ** p≤0.01, *** p≤0.001

ADF: acid detergent fibre, NDF: neutral detergent fibre, CP: crude protein, IVD: in vitro digestibility, WSC: water soluble carbohydrates

Variety selection influenced hay quality, although across all three seasons quality traits were high (Table 2 – 4). Stem diameter and greenness (SPAD; data not shown), were an exception with differences observed in 2019 only.

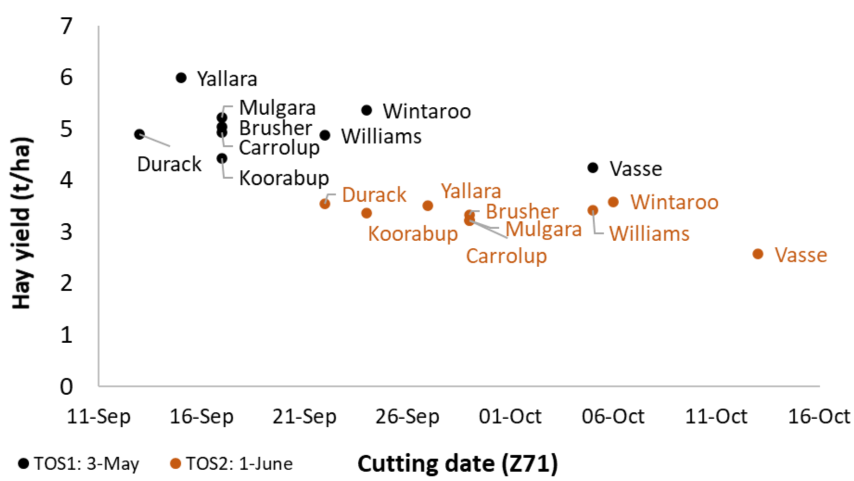

Figure 1. Hay yield by cutting date for early May and early June planting at Hart in 2021.

Time of sowing

Sowing date across three years of trials consistently influenced hay yield and quality. Hay yields were maximised from early May sowing (Tables 2 – 4) in two out of three seasons at Hart. In 2020, hay yields were increased due to early sowing (data not shown). Earlier sowing in all three years resulted in taller plants with a positive relationship between hay yield and plant height across the varieties. It should be noted that there was no lodging in 2019 and 2020, with minimal lodging in 2021. The positive relationship between hay yield and plant height may not be maintained for all varieties in seasons where there is significant lodging.

Hay quality was very good at Hart meeting export quality due to dry seasonal conditions and lower hay yields. Earlier sowing, however, did reduce hay quality across most of the measured traits in all three seasons (Tables 2 – 4). Stem diameter was thin (<6 mm) but thicker from earlier sowing in all three years. Digestibility (IVD%) and CP (%) were lower from earlier sowing in all three years. Fibre fraction ADF (%) was higher from earlier sowing in 2020 and 2021 but NDF (%) was inconsistently influenced by sowing date across the three seasons. Lignin (%) was higher from earlier sowing in 2020 and 2021 however WSC (%) was higher for earlier sowing in 2019 and 2020 but not affected by sowing date in 2021.

Variety x time of sowing

Varieties responded differently to sowing date for hay yield in two out of three years and some hay quality traits across all three years (Tables 5 – 7). However, due to the inconsistencies between years, no clear conclusions can be made from the SA trial series alone on the interaction that variety and sowing date have on hay quality.

Caution should be taken regarding this observation due to the short height of Vasse from later sowing resulting in some stem diameter measurements taken above the top node rather than the internode. Only small and insignificant differences occurred in 2021 with all varieties having thinner stems from later sowing (Table 7).

Table 5. Interaction between variety and sowing date for hay yield and quality traits at Hart in 2019. The best performing variety x sowing date combinations are highlighted in orange.

	Z71 relative to Carrolup (days)	Plant height (cm)	Hay yield (t/ha)	ADF (%)	NDF (%)	CP (%)	IVD (%)	Lignin (%)	WSC (%)
Brusher	+2	38	3.8	22.1	42.7	7.8	74.6	3.0	34.6
Carrolup	11-Sep	37	3.3	23.7	42.3	9.0	72.7	3.9	32.1
Durack	-6	38	3.7	25.2	45.5	8.2	69.6	4.3	30.8
Koorabup	+2	34	3.6	24.3	45.6	8.1	73.0	3.8	30.1
Mulgara	+0	44	3.9	24.3	43.3	8.0	73.6	3.8	34.5
Forester	+44	27	1.9	21.6	38.7	7.3	79.5	2.2	39.8
Williams	+2	32	3.3	23.8	45.1	8.6	72.4	3.7	28.5
Wintaroo	+7	43	3.9	24.1	45.2	7.0	72.8	3.8	31.0
Yallara	+0	41	3.8	23.0	41.4	7.8	73.7	3.6	35.6
TOS1		**37**	**3.5**	**23.6**	**43.3**	**8.0**	**73.5**	**3.6**	**33.0**
Brusher	+7	32	2.4	23.9	47.5	10.4	72.3	3.8	23.8
Carrolup	26-Sep	25	2.6	23.4	43.4	11.0	74.8	3.7	29.6
Durack	-6	26	2.4	23.9	46.5	10.0	72.8	4.0	26.3
Koorabup	+4	27	2.4	23.9	46.5	9.9	71.4	3.6	27.4
Mulgara	+4	35	2.6	24.9	47.4	9.8	72.1	3.8	25.2
Forester	+42	23	1.1	23.2	43.1	10.3	79.4	2.4	29.8
Williams	+4	26	2.0	23.5	46.1	11.4	72.4	3.5	24.4
Wintaroo	+7	32	2.5	25.0	50.0	9.5	70.3	3.9	20.3
Yallara	+4	33	2.6	22.5	42.7	9.2	73.5	3.2	31.2
TOS2		**29**	**2.3**	**23.8**	**45.9**	**10.2**	**73.2**	**3.5**	**26.5**
Significance (TOS X V)	-	*	***	***	**	**	***	***	***
LSD (p≤0.05)	-	*4*	*0.43*	*0.9*	*1.9*	*0.7*	*1.7*	*0.2*	*2.8*
LSD (p≤0.05) - same TOS	-	*4*	*0.20*	*0.9*	*1.8*	*0.5*	*1.4*	*0.2*	*2.9*

Table 6. Interaction between variety and sowing date for significant hay quality traits at Hart in 2020. The best performing variety x sowing date combinations are highlighted in orange.

	Z71 relative to Carrolup (days)	Plant height (cm)	Stem diameter (mm)	ADF (%)	CP (%)	IVD (%)	Lignin (%)	WSC (%)
Brusher	+0	74	4.3	28.4	9.0	67.2	4.1	27.3
Carrolup	16-Sep	63	4.1	27.9	9.7	67.8	3.9	27.1
Durack	-9	60	4.4	28.3	10.4	65.2	4.2	23.7
Koorabup	+0	62	4.2	28.9	10.0	66.1	4.2	24.1
Mulgara	+0	70	4.5	29.0	9.7	66.7	4.3	25.3
Vasse	+6	48	4.5	29.0	11.3	68.7	4.5	18.3
Williams	+0	57	4.6	28.8	11.2	66.2	4.5	21.5
Wintaroo	+0	70	4.6	28.1	9.6	67.5	4.1	25.0
Yallara	+0	60	4.1	27.0	10.2	68.6	3.7	26.2
TOS1		**63**	**4.4**	**28.4**	**10.1**	**67.1**	**4.2**	**24.3**
Brusher	+0	58	4.3	26.9	11.3	70.7	3.7	24.5
Carrolup	21-Sep	49	3.9	27.3	11.0	69.7	3.8	24.7
Durack	-4	54	4.4	28.5	11.9	66.7	4.4	19.2
Koorabup	+0	47	4.2	28.0	11.0	68.4	4.0	23.0
Mulgara	+0	50	4.3	27.7	11.8	70.3	3.8	22.4
Vasse	+3	45	2.9	30.9	12.5	68.2	4.4	12.3
Williams	+0	41	4.5	27.4	12.3	69.2	3.9	20.9
Wintaroo	+0	51	4.1	27.0	11.1	70.3	3.7	23.2
Yallara	+0	50	4.2	26.9	10.6	69.5	3.6	25.5
TOS2		**49**	**4.1**	**27.8**	**11.5**	**69.2**	**3.9**	**21.7**
Significance (TOS X V)	-	***	***	**	*	*	*	***
LSD (p≤0.05)	-	*4*	*0.2*	*0.5*	*1.2*	*1.8*	*0.3*	*1.0*
LSD (p≤0.05) - same TOS	-	*2*	*0.1*	*0.5*	*0.7*	*1.7*	*0.3*	*0.8*

Table 7. Interaction between variety and sowing date for significant hay yield and quality traits at Hart in 2021.The best performing variety x sowing date combinations are highlighted in orange.

	Z71 relative to Carrolup (days)	Plant height (cm)	Lodging (9-0)	Hay yield (t/ha)	Stem diameter (mm)	ADF (%)	NDF (%)	IVD (%)	Lignin (%)	WSC (%)
Brusher	+0	72	9.0	5.0	6.0	28.2	50.9	66.0	5.1	20.1
Carrolup	17-Sep	65	9.0	4.9	5.9	28.7	50.4	64.2	5.0	17.1
Durack	-4	71	9.0	4.9	5.7	27.6	48.3	65.8	5.3	25.0
Koorabup	+0	63	9.0	4.4	5.8	29.1	50.3	65.7	4.5	15.5
Mulgara	+0	70	9.0	5.2	6.2	28.1	47.7	67.8	4.6	20.2
Vasse	+18	53	7.2	4.3	5.3	25.9	46.2	72.2	3.9	23.4
Williams	+5	58	9.0	4.9	6.2	27.4	47.8	68.1	4.3	19.6
Wintaroo	+7	68	8.6	5.4	5.9	26.9	46.0	70.0	4.1	23.2
Yallara	-2	71	9.0	6.0	6.1	26.9	47.9	66.4	5.2	24.7
TOS1		**66**	**8.8**	**5.0**	**5.9**	**27.6**	**48.4**	**67.4**	**4.7**	**21.0**
Brusher	+0	53	7.9	3.3	4.0	24.7	46.7	73.4	3.6	22.2
Carrolup	29-Sep	50	8.2	3.2	4.1	26.3	46.4	70.3	4.1	21.5
Durack	-7	46	9.0	3.5	3.9	27.0	48.3	68.0	4.3	20.1
Koorabup	-5	49	9.0	3.4	4.4	25.8	44.1	72.2	3.5	22.0
Mulgara	+0	55	8.3	3.2	4.1	24.8	44.8	73.5	3.5	23.5
Vasse	+14	41	9.0	2.6	4.4	24.6	44.5	76.6	3.2	24.2
Williams	+6	46	8.1	3.4	4.2	27.0	50.8	67.3	4.1	15.7
Wintaroo	+7	53	8.9	3.6	4.7	26.3	47.0	70.7	3.9	21.6
Yallara	-2	54	8.8	3.5	4.2	24.9	45.0	71.5	4.0	25.1
TOS2		**50**	**8.6**	**3.3**	**4.2**	**25.7**	**46.4**	**71.5**	**3.8**	**21.8**
Significance (TOS X V)	-	*	***	*	*	***	***	***	***	***
LSD (p≤0.05)	-	*6*	*0.6*	*0.9*	*0.7*	*1.6*	*2.2*	*2.5*	*0.2*	*2.1*
LSD (p≤0.05) - same TOS	-	*5*	*0.6*	*0.5*	*0.6*	*1.0*	*1.8*	*1.8*	*0.2*	*1.7*

In 2019 Durack had lower ADF % from delayed sowing compared to earlier sowing whilst Brusher and Forester had lower ADF from earlier sowing. In 2020 most varieties had lower ADF from delayed sowing except Vasse which was lower in the earlier sowing. Durack and Yallara maintained the same ADF across both sowing dates. In 2021, most varieties had lower ADF from later sowing except Durack, Vasse, Williams and Wintaroo which did not respond to sowing date.

In 2019 all varieties had increased CP% from later sowing (likely due to the lower overall hay yields) although some varieties (Brusher, Forester and Williams) had slightly larger increases in response to delayed sowing. Likewise in 2020, all varieties except Koorabup, Vasse, Williams and Yallara increased CP% from later sowing.

In 2019 NDF % increased from delayed sowing for Brusher, Mulgara, Forester and Wintaroo whilst in 2021 all varieties decreased NDF % from delayed sowing except for Williams where it increased and Durack and Wintaroo where there was no response to sowing date.

In 2019 digestibility (IVD%) was higher from earlier sowing for Brusher and Wintaroo whilst it was lower for Durack and Carrolup and did not respond for all other varieties. In 2020, Durack, Vasse and Yallara maintained digestibility across sowing dates whilst all other varieties had higher digestibility from later sowing. In 2021, Williams and Wintaroo maintained digestibility across sowing dates whilst all other varieties had higher digestibility from later sowing.

In 2019 the lignin content of most varieties did not respond to sowing date or was slightly lower from delayed sowing except for Brusher whilst in both 2020 and 2021 all varieties had either the same or lower lignin contents from delayed sowing.

In 2019, WSC decreased with delayed sowing in all varieties except Carrolup and Koorabup which maintained WSC across the two sowing dates. In 2020, the same trend occurred except the varieties Williams and Yallara maintained WSC across the two sowing dates. In 2021 the varieties responded differently with Brusher, Carrolup, Koorabup and Mulgara having higher WSC from delayed sowing. Williams and Durack had lower WSC from delayed sowing and Vasse, Wintaroo and Yallara maintained WSC across the two sowing dates.

Nitrogen management

Responses to N were not consistently experienced across all three years except for an increase in CP % and a decrease in WSC %. In 2020, no other responses to N occurred (Table 2). In 2019 and 2021, leaf greenness (SPAD, data not shown) and digestibility (IVD %) increased with applied N whilst NDF % decreased. Other responses to an increase in applied N were only experienced in one out of the three years (Tables 1-3). This result was expected due to the low in-season rainfall experienced across the trial series in SA. Applications of high rates of N will not be available to the crop without sufficient in-season rainfall to aid N mineralisation. It should also be noted that the soil starting N increased year on year.

There were minimal N x variety interactions across the three seasons with only hay yield and crude protein in 2019 having significant differences. In both these cases, the interaction was driven by the lack of response of Forester to applied N and caution should be taken with this variety due to its unsuitability at the Hart field site as already discussed. As varieties responded the same to applied N, we would suggest future work does not need to focus on the interaction of variety and N rate.

Conclusion

The 2019 to 2021 seasons at Hart were not typical seasons with either below average rainfall or rainfall occurring too late to be beneficial to a hay crop. As a result, caution should be taken in making statewide assumptions from these three trials. Due to the dry growing seasons, there was minimal lodging and in all three years there was a benefit from earlier sowing to maximise biomass accumulation and subsequent hay yields. Hay quality across all three years was good and early to mid-maturity varieties performed well. As a result of these environmental conditions, varieties did not respond differently to applied N but in the best year (2021), Yallara was a clear best performer for hay yield whilst maintaining quality when sown early.

Acknowledgments

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Evaluating the benefits of multi-species cropping; a four-year summary

Rebekah Allen[1], Terry Rose[2]

[1]Hart Field-Site Group, [2]Southern Cross University

Key findings

- Pulse productivity and performance through intercropping practices at Hart, SA was decreased in most cases when compared to monocrop (sole crop) systems across a number of growing seasons from 2019 – 2022.
- Intercropping treatments at Hart in 2022 had land equivalent ratio (LER) values ranging from 0.81 – 1.07. This indicates that overall, grain yield was reduced when two crop species were grown together, compared to their sole crops. Canola + vetch (LER = 1.07) was the only intercropping treatment to achieve a land equivalent ratio (LER) greater than 1.
- The reason for lower LER values at Hart in 2022 compared to other studies in the region (Roberts et al. 2017) are not known, however, in addition to the soils and climate of a region, factors including row intercrop planting configurations and the compatibility of the cultivars grown can affect yield outcomes.
- Soil water dynamics, including infiltration and uptake, measured by soil moisture probes were similar for all intercrop and monocrop treatments across four years of trials. No residual effects were observed in subsequent year's crops.

Introduction

Intercropping is a system resulting in two or more species sown and harvested together (Parvin 2020). This method has been adopted by a small number of Australian growers and is generally utilised within dryland broadacre cropping systems. An intercropping system recognised as a suitable option for many years is canola and field pea, otherwise known as 'peaola' (Kirkegaard 2019). Potential benefits from these systems include reduced input costs, rotational benefits, and soil improvement (Fletcher 2020). Companion cropping is also a form of multi-species cropping where crops are sown together, however one species is terminated either by grazing or herbicide use (Fletcher 2020). This concept could provide complementary benefits to a 'cash crop' through improved nutrition by nitrogen fixation, soil structure or weed suppression (Kirkegaard 2019). Common companion cropping mixes are currently wheat sown as a mixed row (Figure 1) with a legume; vetch, faba bean or field pea.

The aim of this four-year trial series was to assess the feasibility of integrating multi-species crops through intercropping strategies in current winter rotations. Intercropping systems and their impact on subsequent years' cereal crops was investigated.

Methodology

Intercropping trials were split-plot designs with three replicates and six crop treatments in 2019 and twelve crop treatments from 2021 – 2022.

Pulse and oilseed intercropping and monocrop (sole crop) treatments trialed from 2019 – 2020;

1. Canola (Stingray TT)
2. Field pea (Wharton)
3. Chickpea (Genesis090)
4. Linseed (Croxton)
5. Peaola; canola + field pea
6. Chickpea + linseed

Pulse and oilseed intercropping and monocrop treatments trialed from 2021 – 2022;

1. Canola (HyTTec Trophy)
2. Field pea (Wharton)
3. Chickpea (Genesis090)
4. Faba bean (Bendoc)
5. Lentil (Hallmark XT)
6. Vetch (Timok)
7. Peaola
8. Chickpea + canola
9. Faba bean + canola
10. Lentil + canola
11. Vetch + canola
12. Faba bean + lentil

A standard knife-point press wheel plot seeder was modified and used to sow the monocrop and intercrop treatments 8 rows wide (Table 1 & 2). The intercrop plots were sown in a double skip arrangement resulting in two rows of each crop sown together (Figure 1). All plots were assessed for soil water, crop biomass at anthesis (t/ha), harvest index (HI), grain yield (t/ha), 1000 grain weight (g) and land equivalent ratio (LER).

Anthesis cuts were completed by sampling 4 rows x 1 m sections in two areas of the plot. All samples were oven dried at 60°C for 48 hours and weighed. At harvest, whole plot grain samples were retained. Grain yield for intercropping treatments was then calculated by separating seed with a sieve and weighing, to calculate individual crop yield.

Table 1. Seeding and harvest operations for intercropping trials at Hart from 2019 – 2020.

2019	**Plot size**	4.2 m x 36.0 m	**Crop type**	Pulse and oilseed
	Seeding date	May 28, 2019	**Fertiliser**	MAP (10:22) + 2% Zn @ 75 kg/ha
	Location	Hart, SA		Urea (46:0) @ 100 kg/ha (canola
	Harvest date	November 26, 2019		and peaola only) Aug 6
2020	**Plot size**	4.2 m x 36.0 m	**Crop type**	Cereal phase
	Seeding date	May 5, 2022	**Fertiliser**	Seeding: DAP (18:20) Zn 1% + Impact @ 80 kg/ha
	Location	Hart, SA		
	Harvest date	December 14, 2020		July 2: Easy N (42.5:0) @ 80 L/ha
2020**	**Plot size**	2.2 m x 10.0 m	**Crop type**	Pulse and oilseed
	Seeding date	May 5, 2022	**Fertiliser**	MAP (10:22) + 2% Zn @ 80 kg/ha
	Location	Hart, SA		Urea (46:0) @ 100 kg/ha (canola
	Harvest date	December 14, 2020		and peaola only)

***A complimentary trial was implemented to further assess monocrop and intercrop combinations.*

Table 2. Seeding and harvest operations for intercropping and cereal trials at Hart in 2022.

2021	**Plot size**	2.2 m x 10 m	**Crop type**	Pulse and oilseed
	Seeding date	June 10, 2021	**Fertiliser**	MAP (10:22) + 2% Zn @ 80 kg/ha
	Location	Hart, SA		Urea (46:0) @ 50 kg/ha (sole canola and canola intercropping plots)
	Harvest date	N/A		
2022	**Plot size**	2.2 m x 10 m	**Crop type**	Cereal phase
	Seeding date	June 16, 2022	**Fertiliser**	Seeding: DAP (18:20) Zn 1% + Impact @ 80 kg/ha
	Location	Hart, SA		July 22: Easy N (42.5:0) @ 70 L/ha
	Harvest date	December 14, 2022		August 17: Easy N (42.5:0) @ 60 L/ha
2022**	**Plot size**	2.2 m x 10 m	**Crop type**	Pulse and oilseed
	Seeding date	June 16, 2022	**Fertiliser**	MAP (10:22) + 2% Zn @ 80 kg/ha
	Location	Hart, SA		Urea (46:0) @ 100 kg/ha (sole canola and canola intercropping plots)
	Harvest date	December 1, 2022		

***Yield and quality data could not be analysed from intercropping trials at Hart in 2021. This was due spring weather events causing significant crop damage prior to harvest. This trial was replicated in 2022.*

In 2019 and 2021, all trial plots were over-sown to Scepter wheat to assess carry over effects from previous monocrop and intercrop treatments on a subsequent year's cereal crop. All cereal plots were assessed for soil water, early crop vigour using NDVI (Normalised Difference Vegetation Index), grain yield (t/ha), protein (%), test weight (kg/hL) and screenings (2.2 mm screen). All trials were managed with the application of pesticides to ensure a weed, insect and disease-free canopy.

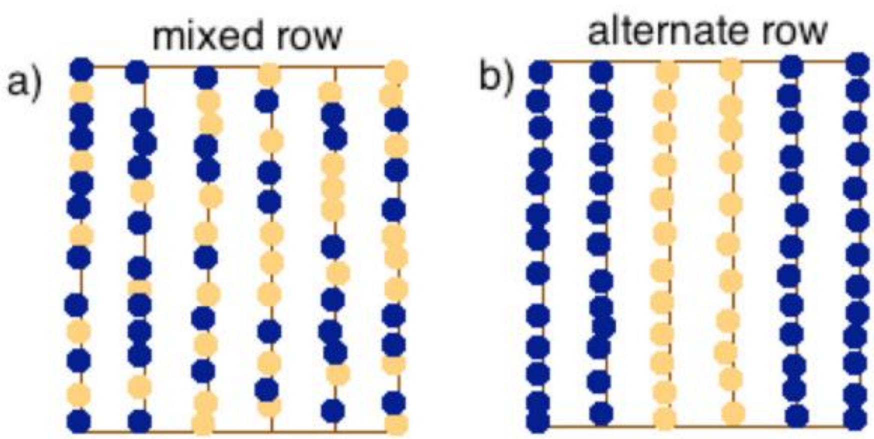


Figure 1. Sowing orientation of two crops (crop A = blue dot, crop B = orange dot) showing mixed row intercropping (left) and alternate row or 'double skip' row arrangement. Figure sourced from Roberts P, 2020.

Soil water assessments

Soil moisture probes were installed on June 5, 2019. The configuration of the capacitance probes was EnviroPro 80 cm EP100GL-08's and contained sensors at 10 cm intervals, starting at 15 cm through to 85 cm. A total of 15 moisture probes were installed in all treatments (excluding linseed monocrop) and replicates and soil moisture was monitored from June 2019 – November 2020. Moisture probes were again installed July 2021 and soil moisture measured until November 2022. A total of 18 moisture probes were installed for canola, field pea, chickpea, peaola, faba bean + canola and canola + chickpea plots.

Land equivalent ratio (LER)

Land equivalent ratio values were calculated to measure intercropping productivity relative to monocrop treatments. The LER is expressed as: LER = (intercrop yield A / sole yield A) + (intercrop yield B / sole yield B). An LER value of 1.0 means the productivity of the intercrop was equivalent to the monocrop. An LER value of > 1.0 means the intercropping treatments are more productive than the monocrop and is referred to as 'over-yielding' (Parvin 2020).

Results and discussion

Crop biomass

In 2019, NDVI was highest for linseed (followed by canola), indicating it had superior vigour and ground cover. Other treatments including chickpea + linseed and peaola produced similar canopy cover (Parvin 2020) but was lower than linseed. At pod fill, chickpea and linseed produced similar biomass to their intercrop, however sole field pea produced greater biomass when compared to the intercropping treatment. This is likely a result of canola having reduced biomass in dry growing season conditions. When crop biomass was measured at anthesis in 2022, all canola intercropped with a pulse produced similar biomass to the sole canola treatment, averaging 4.91 t/ha. Sole legume crops also provided greater biomass when compared to intercropping legume treatments (P value = <0.001).

Grain yield

The performance of intercrop and monocrop treatments at Hart from 2019 – 2022 were similar, even across varying seasonal conditions. In 2019, grain yields for monocrop and intercrop treatments were below average, resulting from decile 1 conditions (Figure 2). The LER for chickpea + linseed (0.79) and peaola (0.96) was < 1 (Parvin 2020), indicating a reduction in both grain yield and crop productivity for these systems under dry conditions (Figure 3). In 2020, peaola performed similarly with an LER of 0.96, however chickpea + linseed had a marginal increase, with an LER of 1.0. Overall, monocrop yields were higher in 2020, however similar results were observed between intercrops. This was initially understood to be a result of below average rainfall in winter months, contributing to an increase in crop competition for stored soil moisture (data not shown). However, results from 2022 indicate intercrop yields may be reduced, even under favourable conditions in the medium rainfall zone of the Mid-North.

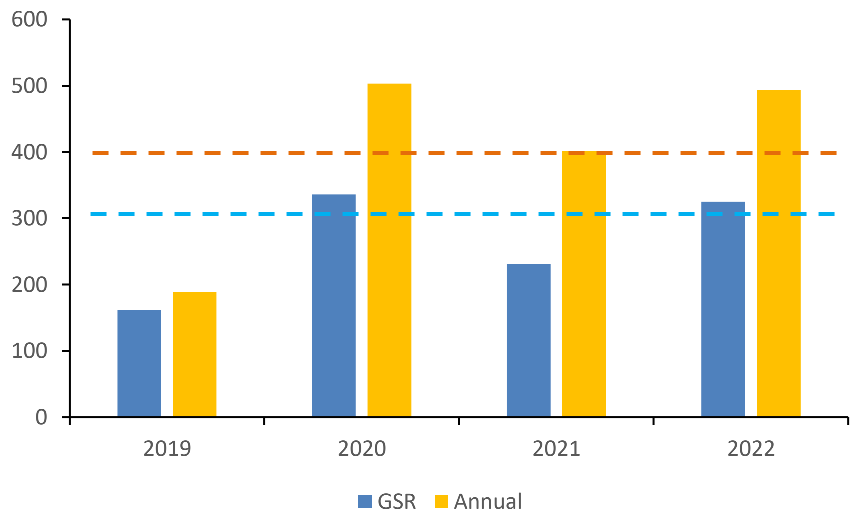


Figure 2. Average annual and growing season rainfall (GSR) at Hart 2019 – 2022. The blue dashed line is Hart's average GSR (300 mm). The orange dashed line is average annual rainfall (400 mm).

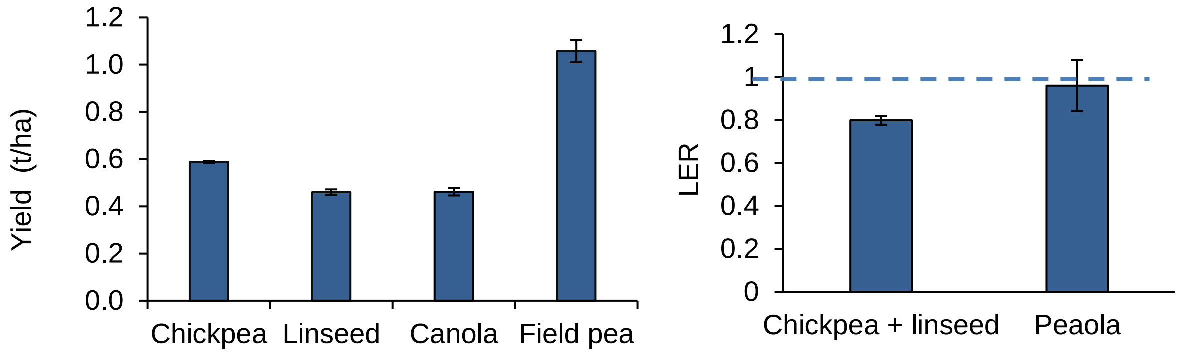


Figure 3. Grain yield of monocrops (left) and LER of intercrops (right) at Hart in 2019. The dashed blue line displays an LER value of 1.0. This figure has been adapted from Parvin, 2020.

At Hart in 2022, excellent grain yields were noted for monocrops, with canola yielding 1.95 t/ha and pulses between 2.65 – 4.06 t/ha. Canola yield was reduced when intercropped with field pea, vetch, lentil, faba bean or chickpea, indicating reduced productivity from the intercrop system (Figure 4). Canola intercropped with legume treatments provided grain yields between 1.05 – 1.38 t/ha.

Pulse and legume sown as a sole crop outperformed all comparative intercropping treatments (Figure 5). Legume treatments intercropped with canola yielded only 26 – 42% on the sole crop yield (Table 3). Chickpea and lentil production was also significantly reduced when intercropped with canola, yielding only 0.74 – 0.95 t/ha, indicating these crop types have reduced crop competition. Similar results were observed in a study conducted in 2019, showing no yield benefits were observed by intercropping chickpea with canola or linseed (P Roberts 2020).

When intercropped together, faba bean and lentil provided similar yields to their comparative monocrop treatments (data not shown). Anecdotal evidence suggests that intercropping these two species together provides ground cover benefits in low rainfall areas.

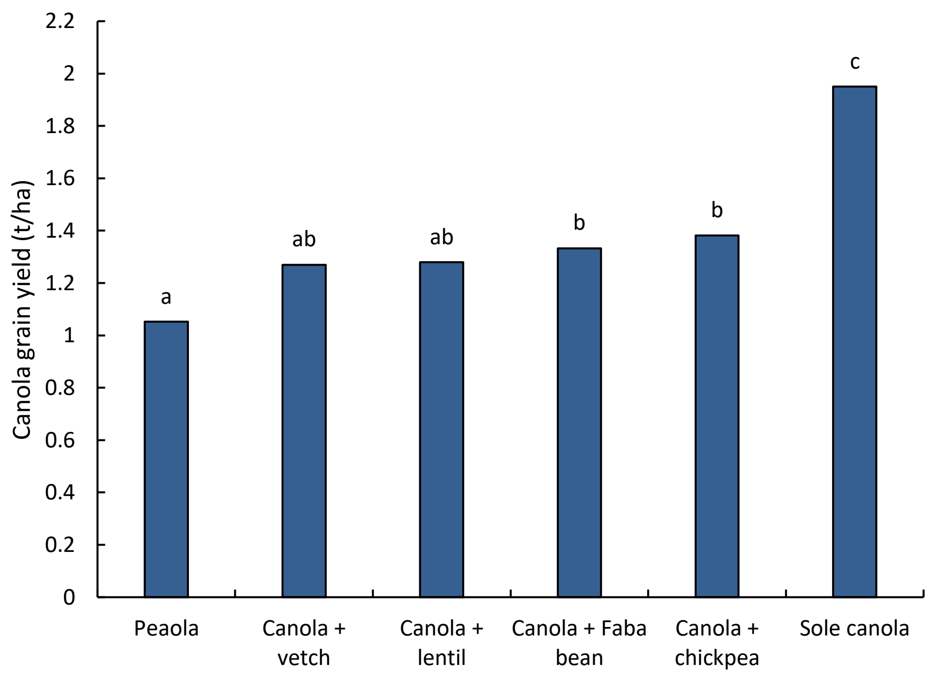


Figure 4. Grain yield of sole (monocrop) canola (t/ha) in comparison to canola intercropped with field pea, vetch, lentil, faba bean or chickpea at Hart in 2022. Columns with the same letters are not significantly different (P value = 0.002).

Table 3. Grain yield (t/ha), yield difference (t/ha) and % yield for crop types in comparison to their monocrop treatment at Hart in 2022.

Intercropping treatment	Crop type	Yield (t/ha)	Yield difference (t/ha) to comparative sole crop	% Yield (expressed as % of comparative monocrop average)	% of total intercrop yield
Peaola	Canola	1.05	-0.90	54	49.2
	Field pea	1.09	-1.71	39	50.8
Chickpea + canola	Chickpea	0.74	-2.15	26	34.8
	Canola	1.38	-0.57	71	65.2
Faba bean + canola	Faba bean	1.33	-0.58	33	50.8
	Canola	1.29	- 0.66	66	49.2
Lentil + canola	Lentil	0.95	-2.96	24	42.7
	Canola	1.28	- 0.67	66	57.3
Vetch + canola	Vetch	1.10	-1.55	42	46.5
	Canola	1.27	0.22	65	53.5
Faba bean + lentil	Faba bean	1.92	-2.14	47	59.4
	Lentil	1.31	-2.60	33	40.6

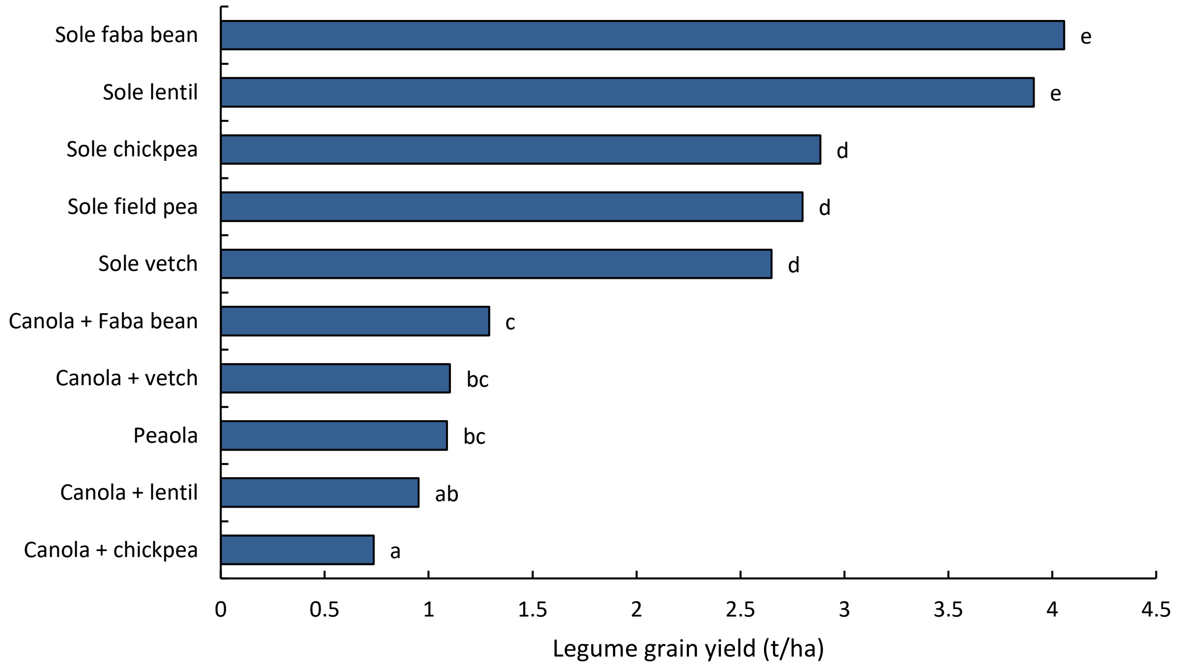


Figure 5. Grain yield of sole legumes (t/ha) and legumes intercropped with canola. Bars with the same letters are not significantly different (P value = <0.001).

In 2022, harvest index (HI), was similar for canola sown either as monocrop or intercrop, indicating that the ratio of harvested seed weight to total above ground biomass was similar for all treatments. Faba bean and vetch performed similarly to their comparative intercrop, with a HI of 0.61 and 0.52 respectively (total grain yield = 52 – 61% of total crop biomass). Sole field pea, lentil and chickpea had a higher HI when compared to intercrop treatments, indicating a higher amount of grain (t/ha) was produced these sole treatments, this trend is also observed in yield data (Figure 5).

Grain quality

Canola oil (%) was high across all treatments at Hart in 2022, ranging from 47.8 – 49.43%, however differences across monocrop and intercrop treatments were observed (P value = 0.03). The sole canola treatment, canola + lentil, canola + faba bean and canola + chickpea had the highest oil cotent, with an average of 48.9%. Although faba bean yield was reduced through intercroppping, seed size increased when intercropped with canola. Chickpea seed size was also reduced by 8% when intercropped due to poor crop competition when sown with a secondary crop species. All other crop types performed similarly to their comparative monocrop in 2022 (data not shown).

LER

Intercropping treatments at Hart in 2022 had LER values ranging from 0.81 – 1.07. This indicates that grain yield was reduced when two crop species were grown together, compared to their sole crops (Figure 6). The only treatment to provide yield increases with an LER > 1 was the canola and vetch intercropping treatment. Other studies from the region have typically found LER values of 1.1 to 1.8 for various canola-legume combinations (Roberts et al. 2017), which is typical of findings from overseas temperate cropping systems (Dowling et al. 2021). The reason for lower LER values at Hart in 2022 compared to other studies in the region (Roberts et al. 2017) are not known, however, in addition to the soils and climate of a region, factors including row intercrop planting configurations and the compatibility of the cultivars grown can affect yield outcomes.

If consistent yield benefits from intercropping cannot be achieved, other benefits will be needed to compensate for the increased complexity of operations. Future studies should examine the potential for reductions in nitrogen fertiliser use or fungicide use in intercropping systems, and any soil legacy effects that may improve subsequent cereal crop yields.

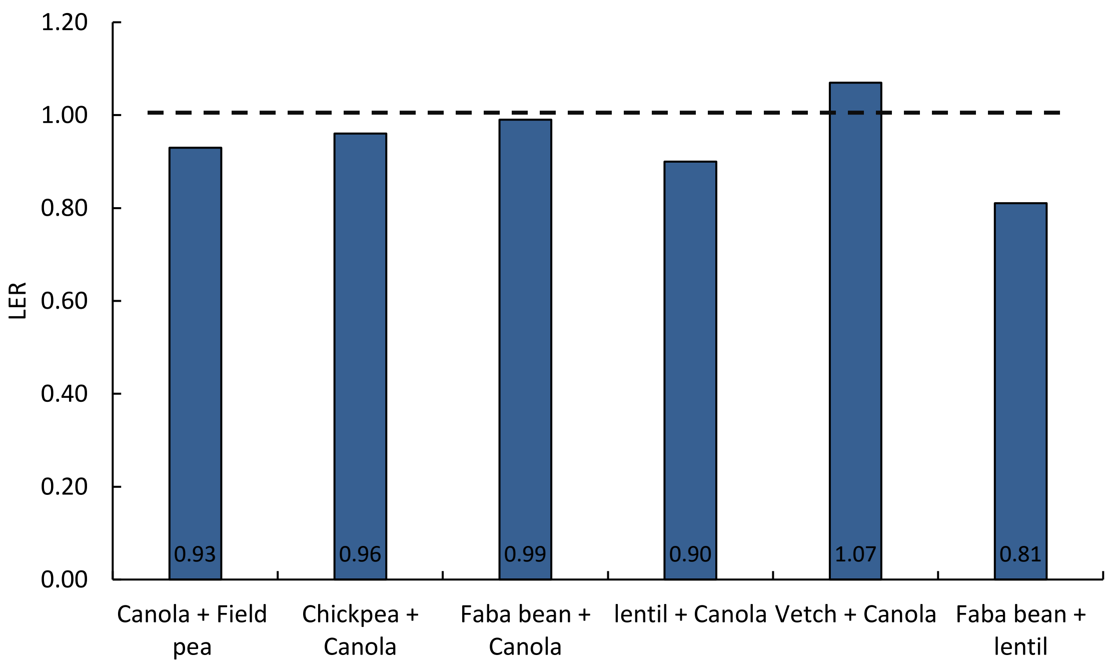


Figure 6. Land equivalent ratio (LER) of intercrop treatments at Hart in 2022. The dashed line displays an LER value of 1.0 (representing sole crop treatments).

Wheat grain yield and NDVI

Wheat grain yields at Hart in 2020 were similar for all previous intercrop and monocrop treatments. This indicates intercropping treatments did not increase wheat grain yield relative to the individual crops (Parvin 2020). This result was also observed at Hart in 2022, with an average wheat yield of 3.5 t/ha. Grain quality was also similar across all treatments. No differences in wheat vigour, measured as NDVI, were observed (P=0.113) in 2022, resulting from intercrop or monocrop treatments.

Soil water

In 2019, there were minimal differences in soil water for all crop types (data not shown). The intercropping treatments were able to draw down and access more soil water in late winter months, however once the profile was full, similar observations for water dynamics were observed. This was an unexpected result due to varying root dynamics of selected crop types. In the consecutive year's wheat crop, no difference in residual soil moisture was observed. (Parvin 2020). Despite wetter seasonal conditions at Hart in 2021, similar soil water use was observed for all monocrop and intercrop treatments measured (Figure 7).

Water use trends were similar in the 2022 cereal phase for all monocrop and intercrop treatments, suggesting no residual effects from the previous season's pulse crops influenced infiltration. There is evidence to suggest chickpea roots did not penetrate as far into soil as other pulse treatments, as it was the only crop to not show root activity at 55 cm.

Figure 7. Soil water content measured by capacitance probes (EnviroPro 80 cm EP100GL-08) presented as the average for (top to bottom) for canola + faba bean, field pea, canola, canola + chickpea, chickpea and peaola treatments at Hart in 2021.

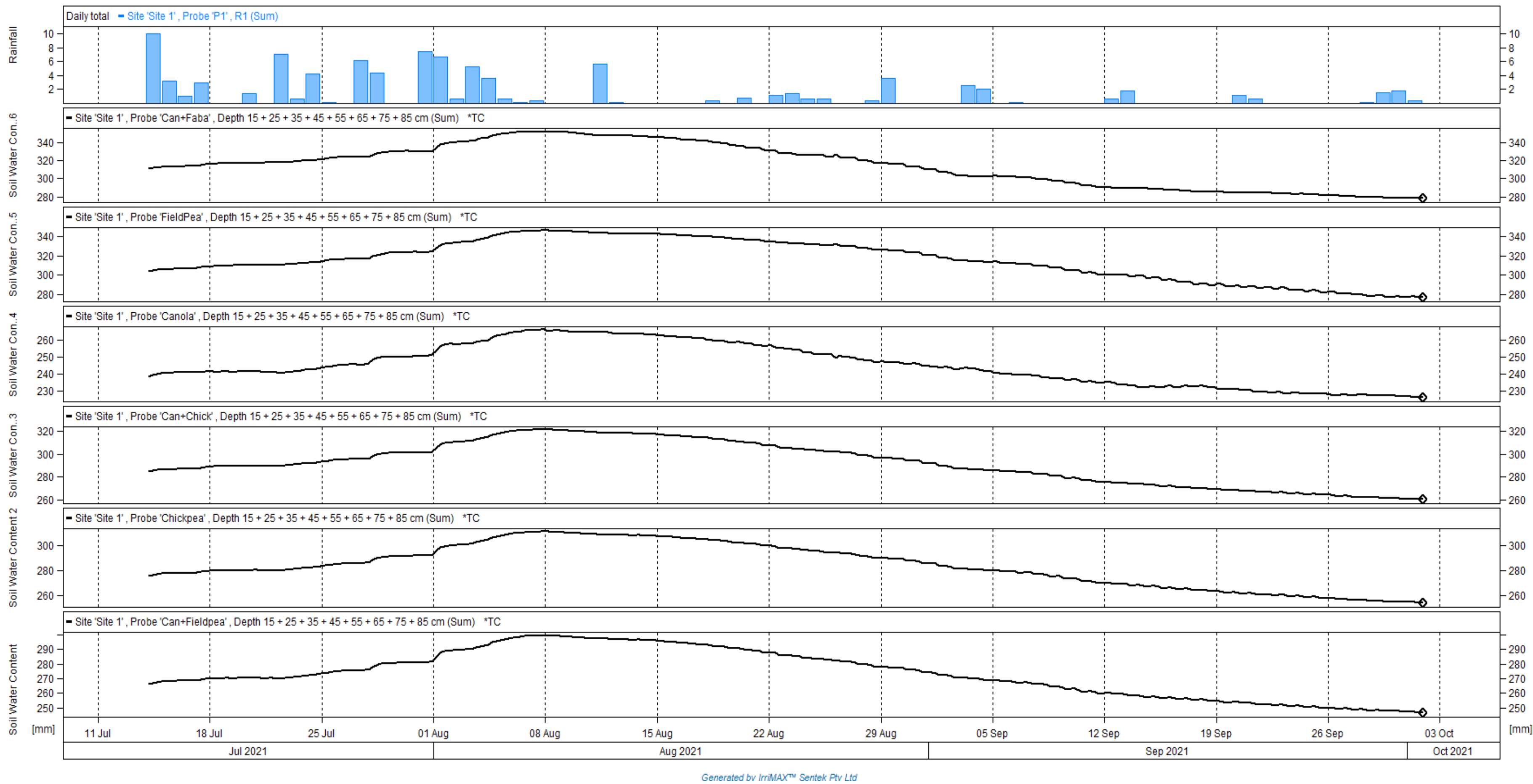
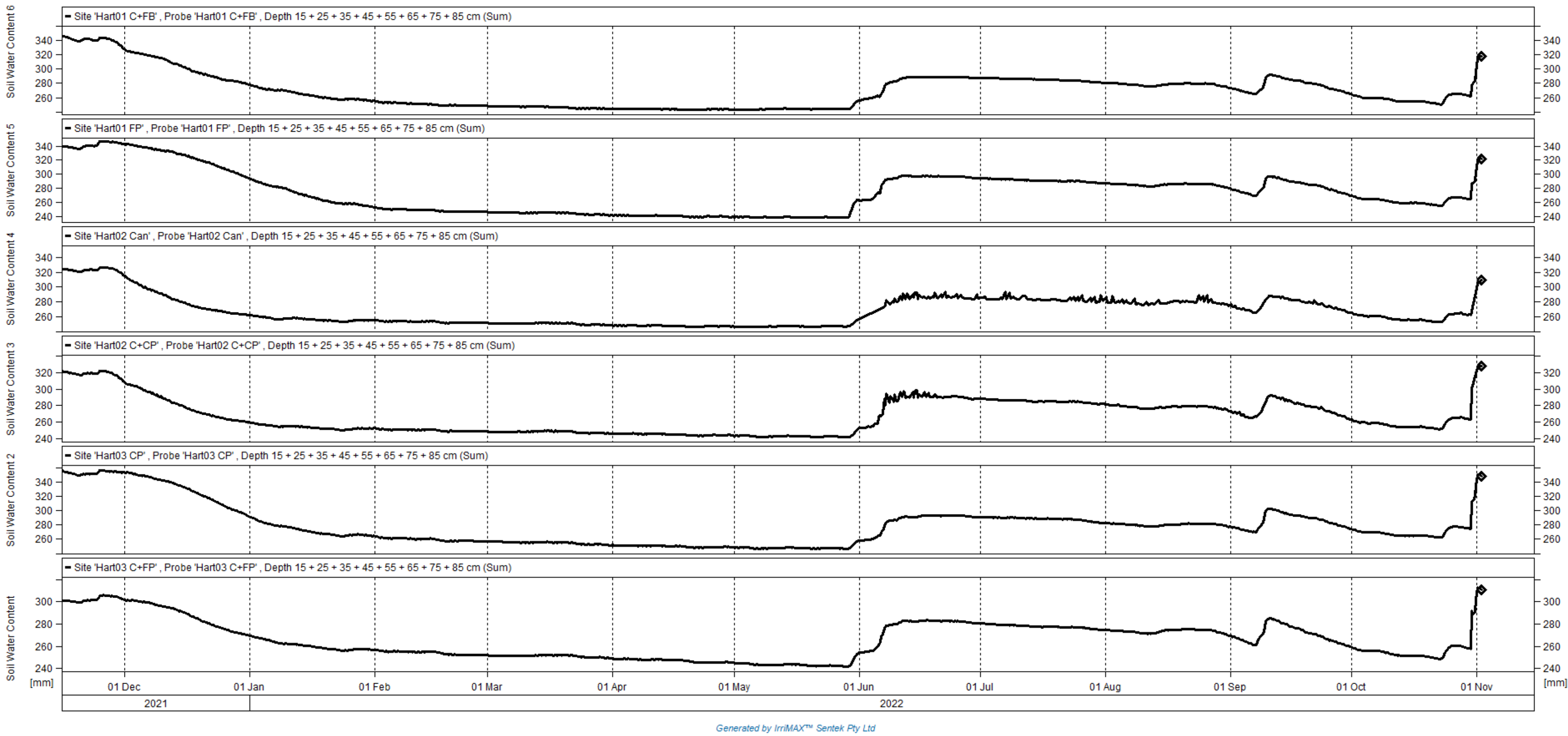


Figure 8. Soil water content measured by capacitance probes (EnviroPro 80 cm EP100GL-08) in canola + faba bean, field pea, canola, canola + chickpea, chickpea and peaola plots, over sown to Scepter wheat in 2022.



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WEED smart

Legume and oilseed herbicide tolerance

Rebekah Allen
Hart Field-Site Group

Key findings

- Most IBS treatments had no effect on legume and oilseed crops at Hart in 2022. A number of post-emergent treatments applied at 3-4 and 5-6 node either had moderate damage impacting crop safety of legume and oil seed crops, or a high level of control.
- The new generation of Group 14 spike herbicides Voraxor® and Terra'dor® provided an additional level of control (rating 5 and 6) across all crop types at Hart in 2021 when compared to carfentrazone, Sledge®, Terrain Flow and Butafenacil.
- Lontrel® Advanced had the highest control (rating 6) for chickpea, lentil and vetch. Talinor + Hasten was also the most effective combination to control medic and clover.

Introduction

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

Methodology

Plot size	2.2 m x 2.0 m	**Fertiliser**	MAP (10:22) + 1% Zn + Impact @ 80 kg/ha
Seeding date	June 22, 2021	**Soil type**	Clay loam
Location	Hart, SA		

This trial was set up as a demonstration and is a non-replicated matrix. Seventeen varieties were sown in strips across 11 different crop types including canola, faba bean, field pea, chickpea, lentil, vetch, sub clover and barrel medic. Wheat, barley and oats were also included in 2022 and 47 herbicide treatments were applied across all 17 crops at various timings. The trial was split into two components; crop safety (1A) and pulse control (1B). The trial was sown dry, with 23 mm rainfall received within the first two weeks of the applied IBS and PSPE treatments, providing good conditions for herbicide activity.

Application timings:

Incorporated by sowing (IBS)	June 22
Post seeding pre-emergent (PSPE)	June 22
Early post emergent (3-4 node)	August 8
Post emergent (5-6 node)	August 26
Post emergent (Group 14 spike at 3-4 node)	August 26

Treatments were visually assessed and scored for herbicide effects approximately six weeks after each application from June – August (Table 1). Crop damage ratings were:

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

Some of the herbicides used in this demonstration are not registered for crops that have been sprayed. It is important to check herbicide labels before following these strategies used. In 2022, a number of herbicide treatments displayed varying crop tolerances that were not expected. Care should be taken when interpreting these results, as herbicide effects can vary between seasons and is also dependent upon conditions at application, soil type and weather conditions.

Results and discussion

Crop safety

Most IBS treatments had no effect on legume and oilseed crops at Hart in 2022 (Table 1). This was similar to observations in 2020 – 2021. BoxerGold® and Luximax® provided moderate crop effects to Pioneer 44Y90 as they are not registered for use in canola, however no crop effects were observed for grain legumes and other oilseed varieties. Overall, good crop safety (rating 1) was observed for most post sowing, pre-emergent herbicides when applied at Hart on June 22. As expected, slight to increasing damage was observed for canola varieties, resulting from PSPE applications of Balance® + simazine or Terbazine. Crop effects were also observed from all PSPE herbicides for Zulu II clover. A number of post-emergent treatments applied at 3-4 node displayed moderate damage across many legume and oil seed crops (Table 1).

Pulse control

At Hart in 2022, Lontrel® Advanced had the highest level of control (rating 6) for chickpea, lentil and vetch (Table 2). In addition to Lontrel, Saracen® + Cando® and Paradigm + MCPA LVE + Uptake® and Talinor® + Hasten® provided excellent control of all oilseed and legume crops (rating 5 – 6) when applied at 5 – 6 node. Triathlon® and Flight® EC performed equally, providing slight to severe control across all legume and oilseed crops. Herbicide efficacy was observed to be lower for these two products when compared to 2021. Talinor + Hasten was the most effective combination when controlling Sultan SU medic and Zulu II clover (rating 6). This was expected as Talinor is on label at rates of 500 – 750 mL for the control of clover and medic when applied no later than 6 – 8 leaf.

As expected, most Group 14 (previously Group G) herbicides provided a high level of control across oilseed, legume and cereal crops. Similarly to 2021, the new generation of Group 14 spike herbicides Voraxor® and Terra'dor® provided an additional level of control (rating 5 and 6) across all crop types at Hart when compared to carfentrazone, Sledge®, Terrain Flow and butafenacil. Both herbicides offer a great option for controlling glyphosate tolerant canola. Crucial was applied standalone at 800 and 1200 mL /ha and provided a good level of control across cereals and some legumes. In most cases, pulse and oilseed control was improved when applied with a Group 14 herbicide.

Table 1. Crop damage ratings for the legume and oilseed herbicide tolerance trial at Hart in 2022.

CROP SAFETY – Part 1A

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

Table 2. Crop damage ratings for the legume and oilseed herbicide tolerance trial at Hart in 2022.

PULSE CONTROL – Part 1B

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

Management of annual ryegrass in genetically modified canola options

Rebekah Allen
Hart Field-Site Group

Key findings

- Seasonal conditions at Hill River in 2022 were wet with 506 mm growing season rainfall (GSR). This favoured conditions for multiple germinations of annual ryegrass (ARG) to occur throughout the growing season.
- Herbicide treatments for dual tolerance technologies LibertyLink® + TruFlex™ and LibertyLink + Triazine Tolerant (TT) performed well, providing ≥ 79% in-crop weed control. However, Liberty Link + TT spray regimes were not able to provide similar suppression of ARG heads when compared to glyphosate and other dual tolerant glyphosate options.
- Weed control benefits were observed for LibertyLink and glyphosate tolerant technologies when compared to TT and Clearfield® (CL), resulting from the extended application windows these technologies offer (> crop stage 6-leaf).
- Liberty herbicide applied in-crop at 2-leaf, followed by a second application 14 days later, performed similarly to glyphosate when applied twice in-crop at Hill River.
- Trials will be conducted in 2023 to further evaluate in-crop applications of glyphosate as a two and three-spray regime option.

Introduction

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

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

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

Methodology

A field trial was conducted in 2022 at Hill River in the Mid-North of South Australia. The trial was a randomised block design with 22 treatments, including various canola technologies, herbicide regimes and application timings (Table 1). The varieties trialed were Pioneer 44Y94 (CL), HyTTec Trophy (TT), Pioneer 44Y27 (RR), Nuseed Raptor TF (TruFlex) and Hyola Garrison XC (Clearfield and TruFlex dual tolerance). The trial was managed with the use of pesticides to ensure an insect and disease-free canopy. Treatments were analysed using a spatial model in Genstat 22nd edition.

The site had a high initial background population of ARG with 1287 plants/m^2 when assessed post seeding. It was lightly burnt in April prior to seeding to remove significant ground cover affecting herbicide efficacy and seeding operations.

The trial was sown on May 7, after IBS treatments were applied using a standard knife-point press wheel system on 22.5 cm (9") spacings. Follow up herbicide applications were applied, including a post sowing, pre-emergent for the LibertyLink + TT treatment. Various in-crop applications of glyphosate and glufosinate with mixing partners were applied when canola was at two-leaf (2L), four-leaf (4L) and 8-leaf (8L) (Table 2). These in-crop application timings were applied early due high ryegrass populations emerging post-seeding. Late applications of glyphosate were also applied to some treatments at first flower to evaluate a three-spray regime, however due to a spray error at final application, this data could not be analysed.

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

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

Hart			
Plot size	2.0 m x 10.0 m	**Water rate**	100 L/ha
Seeding date	May 7, 2022	**Nozzle application**	Coarse
Location	Hart, SA		
Harvest date	November 9, 2022		
Previous crop	Scepter wheat		

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

Results and discussion

Seasonal conditions

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

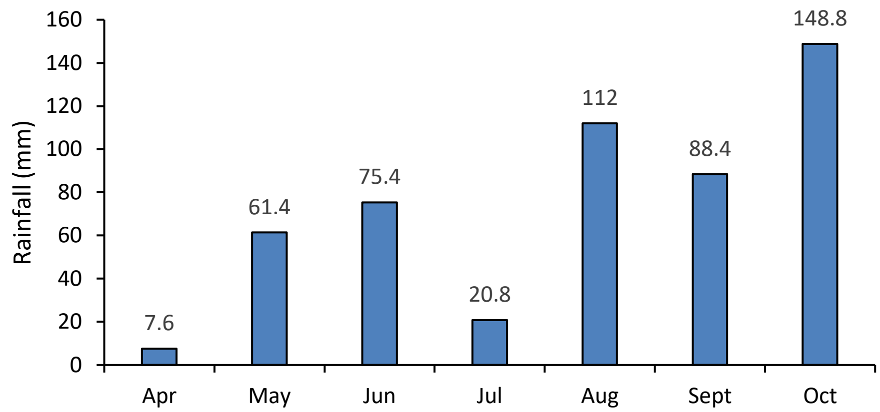

Figure 1. Monthly growing season rainfall near Hill River in 2022. Rainfall data sourced from the Clare Mesonet station (2022).

Pre-emergent herbicides

Background ARG populations at Hill River were high (1287 plants/m^2) with pre-emergent herbicides Overwatch® and propyzamide providing similar control. Pre-emergent herbicides alone did not provide any benefits over the nil (no herbicide applied) treatment This was a result of early ARG germination at seeding time in wet conditions, influencing herbicide efficacy.

This was in contrast to trials conducted in 2021, with propyzamide at 1 L/ha providing increased weed control when compared to Overwatch at 1.25 L/ha. This increased control was due to the persistence of propyzamide in the soil after a significant opening rain event in May (23 mm) following dry conditions, controlling ARG for a longer period of time. After in-crop applications were applied at crop stage 6 – 8 leaf, no differences in weed control were observed between treatments with either propyzamide or Overwatch applied (Allen R 2021).

In-crop weed control

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

Two in-crop applications of glyphosate as Roundup Ready PL at 1.67 L/ha, performed similarly when compared to two in-crop applications at lower rates, of either Roundup Ready PL at 1.15 L or Crucial at 1.5 L/ha. This was a result of the Hill River ARG population having 100% susceptibility to glyphosate. When glyphosate was applied as a single application early in-crop, weed control was reduced. It was also noted that single applications of Roundup Ready PL at low rates of 1.15 L/ha further reduced control when compared to the highest on-label rate of 1.67 L/ha.

This suggests that when high populations of ARG are present, higher rates of glyphosate may be required for sufficient control. A trial at Spalding in 2021 showed that Roundup Ready PL at 1.15 L/ha performed similarly to rates of 1.67 L/ha under low ARG populations (Allen 2021). This gives growers confidence that lower rates may be applied to susceptible ARG populations, still achieving effective weed control while reducing input costs. However, however when ARG is present in high numbers, higher rates may be required in-crop, but only when a maximum of two glyphosate applications will be applied.

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

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

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

Liberty herbicide applied in-crop at 2-leaf, followed by a second application within 14 days (as per label recommendations), performed similarly to glyphosate options applied as a two-spray regime at Hill River in 2022. This was observed in 2021 trials at Hart, with in-crop applications of glufosinate providing equal control to glyphosate options (Figure 2).

Similar trends were observed for weed control (%) and ARG head suppression (Table 1 and Figure 2). In addition to the LibertyLink + TruFlex treatment, all glyphosate treatments with two in-crop applications (+/- mixing partners) significantly reduced ARG head numbers by 79 – 100% (Table 1).

Table 1. Annual ryegrass head counts (plants/m2) for treatments at Hill River. Treatments with the same letter are not significantly different. Shading indicates highest level of ARG head suppression.

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

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

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

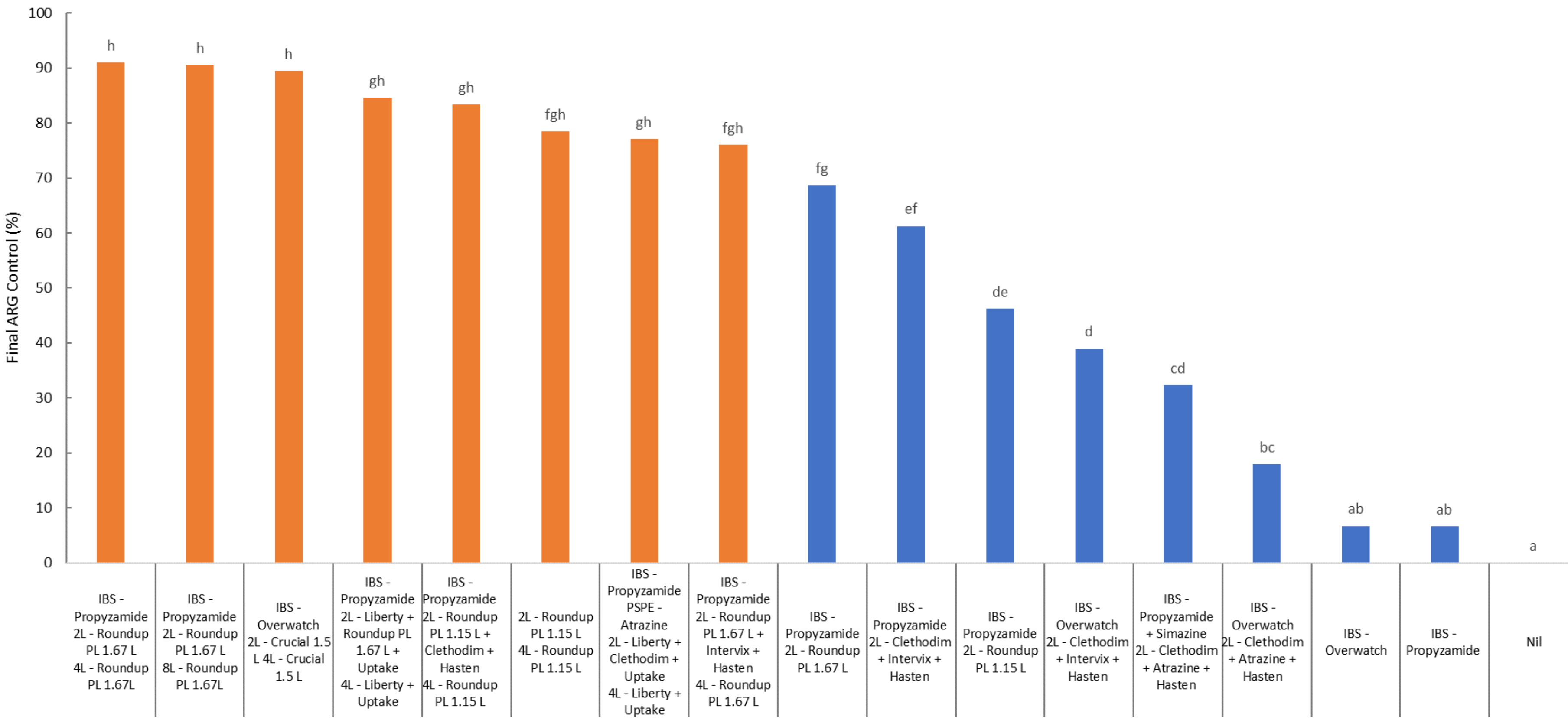

Figure 2. Final assessment for weed control (%) on herbicide treatments at Hill River in 2022. Treatments with same letter are not significantly different. Orange columns represent herbicide regimes which provided the highest level of annual ryegrass control. Columns with an asterix (*) show treatments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

Table 3. Herbicide costs ($/ha) for various spray regimes trialed at Hill River in 2022. Costs include IBS, PSPE and in-crop applications and should be used as a guide only.

Technology	Spray regime	Rates/ hectare	Herbicide costs ($/ha)
Clearfield	IBS: Propyzamide Post-emergent: Clethodim 360 + Intervix + Hasten	1 L 330 mL + 600 mL + 1%	$78.55
TT	IBS: Propyzamide + Simazine Post emergent: Clethodim 360 + Atrazine + Hasten	1 L + 1 kg 330 mL + 1 kg + 1%	$82.68
Roundup Ready / TruFlex	IBS: Propyzamide Post-emergent: Roundup Ready PL (1 application)	1 L 1.67 L	$70.05
Roundup Ready / TruFlex	IBS: Propyzamide Post-emergent: Roundup Ready PL (2 applications)	1 L 1.67 L	$95.10
Roundup Ready / TruFlex	IBS: Propyzamide Post-emergent: Roundup Ready PL (2 applications)	1 L 1.15 L	$79.50
LibertyLink + TT	IBS: Propyzamide PSPE: Atrazine Post-emergent 1: Liberty + Clethodim 360 + Uptake Post-emergent 2: Liberty + Uptake	1 L 1 kg 2 L + 330 mL + 0.5% 2 L + 0.5%	$130.45
LibertyLink + TruFlex	IBS: Propyzamide Post-emergent 1: Liberty + Roundup Ready PL + Uptake Post-emergent 2: Liberty + Uptake	1 L 2 L + 1.67 L + 0.5% 2 L + 0.5%	$136.25
TruFlex	IBS: Propyzamide Post-emergent: Roundup Ready PL (3 applications)	1 L 1.15 L	$96.75
	IBS: Propyzamide Post-emergent: Crucial (2 applications)	1 L 1.5 L + 1.5 L	$90.00
	IBS: Propyzamide Post-emergent 1: Roundup Ready PL + Clethodim 360 Post-emergent 2: Roundup Ready PL	1 L 1.15 L + 330 mL 1.15 L	$89.75
TruFlex + CL	IBS: Propyzamide Post-emergent 1: Roundup Ready PL + Intervix + Hasten Post-emergent 2: Roundup Ready PL	1 L 1.67 L + 600 mL + 1% 1.67 L	$118.40

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

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Pre-emergent herbicides and mixtures for annual ryegrass control in wheat and barley

Declan Anderson[1], Rebekah Allen[1] and Christopher Preston[2]

Hart Field-Site Group[1], School of Agriculture, Food & Wine, University of Adelaide[2]

Key findings

- Sakura, Mateno Complete and EPE treatments provided the most effective control in wheat (89-98% control) and barley (76-91%).
- Minimal damage was observed in 2022. Luximax caused a reduction in grain yield (17%) in wheat, although weed control was excellent.
- Using any pre-emergent herbicide in 2022 increased grain yield in wheat (24-52%). Mateno Complete, Overwatch and EPE treatments resulted in grain yield increases (17-40%) in barley when compared to no pre-emergent herbicide.
- Mateno Complete and IBS treatments with EPE applications performed well in wheat and barley. Good winter rainfall suited the solubility and soil binding attributes of pyroxasulfone, resulting in good weed control.

Introduction

Pre-emergent herbicides have become a vital tactic for controlling weed populations in broadacre crops. There are many different pre-emergent herbicide options available to growers, providing varying levels of weed control when applied IBS (incorporated by sowing). Pre-emergent herbicides also act differently in response to soil properties and soil moisture, which can have an impact on herbicide performance. The availability of early post emergent (EPE) herbicides targeting in-crop weeds at early growth stages has increased flexibility for growers.

Annual ryegrass (ARG) is the most challenging grass weed in the Mid-North region, across all broadacre crops including wheat and barley. The recent introduction of new herbicides, such as Overwatch® (bixlozone), Luximax® (cinmethylin) and Mateno® Complete (pyroxasulfone, diflufenican and aclonifen) offer new options for paddocks with resistance to older chemistries across South Australian and Victorian cropping regions (Preston 2021) including Group 15 (formerly Group J, K) and Group 3 (formerly Group D).

This trial assessed the performance of new pre-emergent herbicides applied IBS and EPE, standalone or in mixtures, for the control of annual ryegrass in wheat and barley.

Methodology

Plot size	1.75 m x 10.0 m	**Fertiliser**	DAP (18:20) + 1% Zn + Impact @ 80 kg/ha
Seeding date	May 13, 2022		Easy N (42.5:0) 70 L/ha on July 22, 2022
Crop history	Mulgara Oaten Hay		Easy N (42.5:0) 60 L/ha on August 17, 2022
Harvest date	November 25, 2022		
Location	Hart, SA		

Two trials were set up as a randomised complete block design with three replicates, 14 herbicide treatments for wheat and 13 herbicide treatments for barley. Both trials were managed with the application of other pesticides to ensure an insect and disease-free canopy.

All plots were assessed for crop establishment (%), ARG weed counts (plants/m^2), ARG head counts (heads/m^2) and grain yield (t/ha). Data was analysed using a one-way ANOVA model in Genstat 22nd edition.

Annual ryegrass seed with known susceptibility to all herbicide groups was broadcast to trial plots and lightly incorporated on May 13, prior to the application of herbicide treatments. Scepter wheat and Spartacus CL barley was sown after IBS treatments were applied using a standard knife-point press wheel system on 22.5 cm (9") spacings. Early post emergent treatments were applied on June 29 when ryegrass was at GS 12 (two leaves emerged). Ryegrass populations at EPE application were very low, however, due to good winter rainfall, grass weed populations were high during the late winter months.

Herbicides and rates trialed on wheat and barley are listed in Table 1 and Table 2, respectively.

Table 1. IBS and EPE herbicide treatments applied to wheat at Hart in 2022.

	Herbicide treatment	**IBS Product rate** (/ha)	**EPE Product rate** (/ha)
1	Nil		
2	Sakura®	118 g	
3	Sakura + Avadex® Xtra	118 g + 2 L	
4	Mateno Complete	1 L	
5	Luximax	500 mL	
6	Luximax + Avadex Xtra	500 mL + 2 L	
7	Villain	1.5 L	
8	Overwatch	1.25 L	
9	Overwatch + Avadex Xtra	1.25 L + 2 L	
10	Overwatch + Sakura	1.25 L + 118 g	
11	Trifluralin + Avadex Xtra	1.5 L + 2 L	
12	Boxer Gold® + Avadex Xtra	2.5 L + 2 L	
13	Trifluralin + Mateno Complete (EPE)	1.5 L	1 L
14	Trifluralin + Avadex Xtra + Boxer Gold (EPE)	1.5 L + 2 L	2.5 L

Table 2. IBS and EPE herbicide treatments applied to Barley at Hart in 2022.

	Herbicide treatment	**IBS Product rate** (/ha)	**EPE Product rate** (/ha)
1	Nil		
2	Sakura	88 g	
3	Mateno Complete	750 mL	
4	Mateno Complete + Avadex Xtra	0.75 L + 2 L	
5	Voraxor®	200 mL	
6	Overwatch	1.25 L	
7	Overwatch + Avadex Xtra	1.25 L + 2 L	
8	Trifluralin + Avadex Xtra	1.5 L + 2 L	
9	Boxer Gold + Avadex Xtra	2.5 L + 2 L	
10	Trifluralin + Avadex Xtra + Mateno Complete (EPE)	1.5 L + 2 L	750 mL
11	Trifluralin + Avadex Xtra + Boxer Gold (EPE)	1.5 L + 2 L	2.5 L
12	Trifluralin + Avadex Xtra + Intervix® (EPE)	1.5 L + 2 L	750 mL
13	Voraxor + Boxer Gold (EPE)	200 mL	2.5 L

Sakura, although not registered, was applied to barley, as it shares an active ingredient (pyroxasulfone) with the new Mateno Complete, registered for use in barley (IBS and EPE), to compare efficacy. Sakura was applied at 88 g/ha to match the rate of pyroxasulfone in Mateno Complete applied at 0.75 L/ha.

Results and discussion

Seasonal conditions

Early growing season conditions at Hart were dry. The season's first significant rainfall event came on May 30 (26 mm), two weeks after seeding, with crop emergence occurring on June 8. After a dry start, the trial received average rainfall for June (47 mm) and below average rainfall of 15 mm for July (Figure 1).

Wet conditions in early June allowed ARG to germinate and the pre-emergent herbicides to move into the soil. Limited rainfall from late June onwards reduced the potential for crop damage from pre-emergent herbicides (Preston et al 2022). There were no visual symptoms of phytotoxicity or other herbicide damage in 2022 for barley or wheat.

A wet August and September encouraged further ARG and other grass weeds to emerge in the two trials.

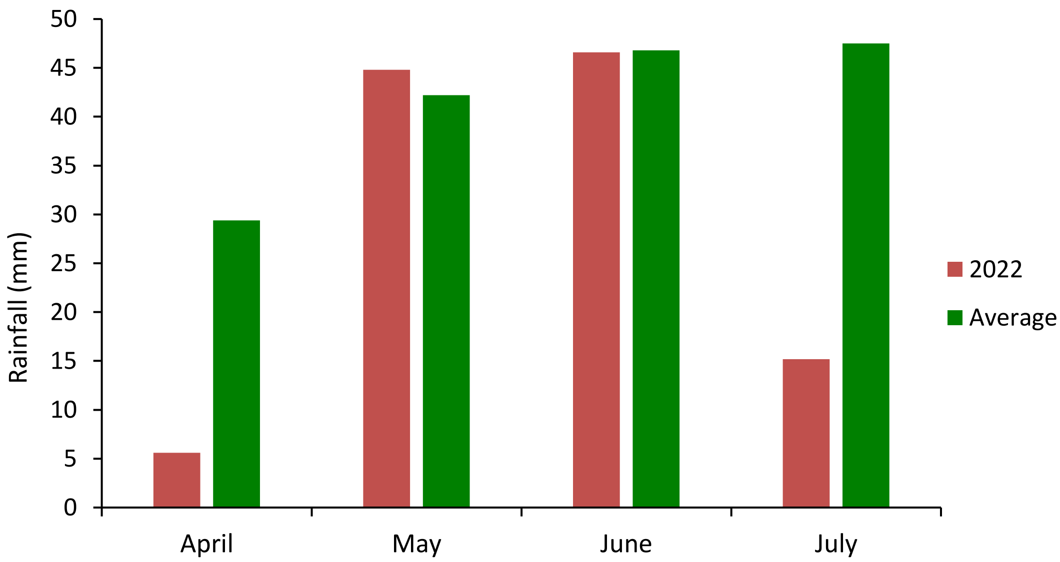

Figure 1. Total monthly rainfall and the 100-year average rainfall for April – July for Hart in 2022.

Pre-emergent herbicide performance in wheat

Varying levels of ARG control were observed for pre-emergent and EPE treatments at Hart in 2022. Sakura, Mateno Complete, Luximax, and the two IBS treatments followed by an EPE application showed excellent control, providing > 85% control for ARG populations (< 11 weeds/m^2) and an 80% reduction in seed production (< 80 heads/m^2) when compared to the nil treatment (Table 3). Villain, a new product undergoing commercialisation by Sipcam, containing terbuthylazine and pyroxasulfone (active ingredients currently in Terbyne® Xtreme and Sakura), performed similarly. This product is likely to be registered on wheat (not durum) as an IBS herbicide, targeting grass and broadleaf weeds.

Pyroxasulfone is an active ingredient in Sakura, Mateno Complete and Villain. Good rainfall in May and June (91 mm) provided ideal conditions for pyroxasulfone to move into the soil profile, resulting in good ARG control.

Crop establishment (%) was not affected by any herbicide treatment.

The good growing conditions through spring allowed surviving annual ryegrass to set more seed. Some of the herbicides with shorter persistence, such as Boxer Gold + Avadex Xtra, resulted in more seed heads than other treatments. However, all treatments containing pyroxasulfone (Sakura, Mateno Complete and Villain) had less than 70 seed heads/m^2. This demonstrates the ability of this herbicide to provide more control through the season.

Table 3. The effect of pre-emergent herbicides on ARG weed counts (8 weeks after sowing) and ARG head counts in wheat. Shaded values show the highest performing treatments.

Herbicide Treatment	**Annual Ryegrass** (plants/m^2)	% control	**Annual Ryegrass** (heads/m^2)	% control
Nil	70	0	436	0
Sakura	4	94	28	94
Sakura + Avadex Xtra	2	98	25	94
Mateno Complete	3	96	36	92
Luximax	11	84	80	82
Luximax + Avadex Xtra	4	95	58	87
Villain	6	91	70	84
Overwatch	24	66	172	61
Overwatch + Avadex Xtra	17	76	106	76
Overwatch + Sakura	7	90	58	87
Trifluralin + Avadex Xtra	18	74	75	83
Boxer Gold + Avadex Xtra	17	75	150	66
Trifluralin + Mateno Complete (EPE)	5	92	32	93
Trifluralin + Avadex Xtra + Boxer Gold (EPE)	8	89	22	95
LSD (P≤0.05)	**13.3**		**70.4**	

Yields were high in 2022 following the good winter and spring rainfall. The nil treatment was the lowest yielding (3.4 t/ha) due to high weed pressure providing crop competition. Treatments that included pyroxasulfone (Sakura, Mateno Complete and Villain) resulted in the highest yields alongside the two IBS treatments with an EPE application, ranging from 4.79 – 5.18 t/ha (Table 4). Some older chemistries applied IBS, including trifluralin and Boxer Gold, did not perform as well and had significantly higher weed pressure reducing crop yield potential. This shows that pyroxasulfone was highly effective under 2022 conditions due to the wet seasonal conditions suiting pyroxasulfone better than some other products.

Although Luximax treatments provided good weed control, a yield penalty was observed. Luximax is more soluble than pyroxasulfone, meaning it moved further into the soil with the good winter rainfall in 2022, producing crop damage. Across the Mid-North region in recent years, Luximax has been observed to provide good ARG control, but at the expense of crop damage when there is high rainfall after sowing, particularly where soil is dry at application.

Applying a pre-emergent herbicide or mixture resulted in a yield increase by 24 – 53% in 2022, highlighting the importance of pre-emergent herbicides for annual ryegrass control.

Table 4. Grain yield (t/ha) of all herbicide treatments applied to wheat at Hart in 2022. Shaded values show the highest performing treatments.

Herbicide Treatment	**Grain yield** (t/ha)
Nil	3.40
Sakura	5.08
Sakura + Avadex Xtra	4.95
Mateno Complete	5.01
Luximax	4.28
Luximax + Avadex Xtra	4.42
Villain	4.79
Overwatch	4.55
Overwatch + Avadex Xtra	4.69
Overwatch + Sakura	5.18
Trifluralin + Avadex Xtra	4.21
Boxer Gold + Avadex Xtra	4.56
Trifluralin + Mateno Complete (EPE)	5.00
Trifluralin + Avadex Xtra + Boxer Gold (EPE)	4.83
LSD (P≤0.05)	**0.45**

Pre-emergent herbicide performance in barley

All treatments applied in 2022 reduced ARG populations and ARG seed set (heads/m^2). Many treatments provided high levels of control, including Sakura, Mateno Complete (IBS), Overwatch, Trifluralin + Avadex Xtra, Boxer Gold + Avadex Xtra, and the EPE treatments including Boxer Gold or Intervix ranging from 76 – 91% control (9 – 24 plants/m^2) (Table 5).

While treatments containing Voraxor provided better control when compared to the nil treatment, there were higher ARG weed counts (52 – 70%) and head counts (heads/m^2) compared to most other treatments. When measuring seed set potential, treatments containing Voraxor had the highest number of ARG heads when compared to other treatments. This was expected as Voraxor is only registered for suppression of ARG in lighter soils.

When applied EPE, the residual properties of Mateno Complete were able to suppress ryegrass seed set later in the season. With the exception of Voraxor, all herbicide treatments performed well at reducing ARG seed set with reductions between 82-96% (Table 5).

Table 5. The effect of pre-emergent herbicides on ARG plant counts (8 weeks after sowing) and ARG head counts in barley at Hart in 2022. Shaded values show the highest performing treatments.

Herbicide Treatment	**Annual Ryegrass** (plants/m^2)	% control	**Annual Ryegrass** (heads/m^2)	% control
Nil	101[e]	0	692[d]	0
Sakura	16[ab]	84	64[ab]	91
Mateno Complete	9[a]	91	24[a]	96
Mateno Complete + Avadex Xtra	24[ab]	76	84[ab]	88
Voraxor	70[d]	31	268[c]	61
Overwatch	21[ab]	79	105[ab]	85
Overwatch + Avadex Xtra	19[ab]	81	80[ab]	88
Trifluralin + Avadex Xtra	21[ab]	79	126[abc]	82
Boxer Gold + Avadex Xtra	19[ab]	81	79[ab]	89
Trifluralin + Avadex Xtra + Mateno Complete (EPE)	39[bc]	62	104[ab]	85
Trifluralin + Avadex Xtra + Boxer Gold (EPE)	17[ab]	83	96[ab]	86
Trifluralin + Avadex Xtra + Intervix (EPE)	12[ab]	88	45[a]	94
Voraxor + Boxer Gold (EPE)	52[cd]	49	196[bc]	72
LSD (P≤0.05)	**27.6**		**20.7**	

Values with the same letter are not significantly different.

Barley yields were high at Hart in 2022 following good winter and spring rainfall, ranging from 4.01 – 5.68 t/ha (Table 6). Treatments containing Mateno Complete and Intervix had the best yields with an average of 5.35 t/ha.

Clearfield technology is still useful in farming systems with populations of ARG susceptible to Group 2 herbicides (formerly Group B), as shown through the good control of ARG with Intervix applied EPE.

Table 6. Grain yield (t/ha) of all herbicide treatments applied to barley at Hart in 2022. Shaded values show the highest performing treatments.

Herbicide Treatment	**Grain yield** (t/ha)
Nil	4.01
Sakura	4.86
Mateno Complete	5.68
Mateno Complete + Avadex Xtra	5.17
Voraxor	4.64
Overwatch	4.49
Overwatch + Avadex Xtra	4.98
Trifluralin + Avadex Xtra	4.43
Boxer Gold + Avadex Xtra	4.37
Trifluralin + Avadex Xtra + Mateno Complete (EPE)	5.24
Trifluralin + Avadex Xtra + Boxer Gold (EPE)	4.83
Trifluralin + Avadex Xtra + Intervix (EPE)	5.30
Voraxor + Boxer Gold (EPE)	4.70
LSD (P≤0.05)	**0.63**

Acknowledgements

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

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

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Useful resource

Pre-emergent herbicides Fact Sheet, GRDC *https://grdc.com.au/resources-and-publications/all-publications/factsheets/2022/pre-ermergent-herbicides-fact-sheet*

New seed treatment for the management of crown rot in cereals

Declan Anderson and Rebekah Allen

Hart Field-Site Group

Key findings

- Victrato reduced disease severity and white head expression at Hart.
- Disease severity was low, resulting in a minimal yield loss.
- White head expression averaged 1.2% across the trial and crown rot infected 71% of plants. Variety resistance did not influence disease levels in 2022.
- Crown rot levels in 2022 were low and there was no impact on yield. Grain yield averaged 5.10 t/ha across the trial. Variety resistance to crown rot did not affect grain yield due to the low disease levels.

Introduction

Crown rot (*Fusarium pseudograminearum and/or Fusarium culmorum)* is a fungal disease that can infect cereals and grasses. It is a disease that is common across all cropping areas in South Australia and can cause yield losses between 5-20% in wheat and more than 50% in Durum (GRDC 2019).

Strategies that can be used to reduce the impact of crown rot are to include non-cereal crops in the paddock rotation, selecting varieties with improved genetic resistance or the use of seed treatments. A combination of these treatments is the best way to reduce the impact of crown rot.

Victrato® (active ingredient cyclobutrifluram) is a seed treatment that is undergoing registration by Syngenta for the control of crown rot and suppression of root lesion nematodes. Victrato also provides control of fusarium head blight and fusarium seedling blight. Victrato is recommended to be applied with other seed treatments as the product does not have any control or suppression of smut, bunt and other soil diseases typically controlled by seed treatments.

This trial aims to evaluate the performance of Victrato on barley, wheat and durum for the control of crown rot.

Methodology

Plot size	1.75 m x 10.0 m	**Fertiliser**	Seeding: DAP (18:20) Zn 1% + Impact @ 80 kg/ha
Seeding date	May 13, 2022		July 22: Easy N (42.5:0) @ 70 L/ha
Location	Hart, SA		August 17: Easy N (42.5:0) @ 60 L/ha
Harvest date	December 1, 2022		
Crop history	Mulgara Oaten Hay		

The trial was a split plot design with three replicates, five varieties and two seed treatments (Tables 1 and 2). It was managed with the application pesticides to ensure a weed and insect free canopy. All plots were assessed for grain yield (t/ha), protein (%), test weight (kg/hL), screenings (%) and disease severity (%). Data was analysed using a split-plot ANOVA model in Genstat 22nd edition.

Plant samples were collected at early grain fill for assessment of whitehead expression and browning on main stem bases. Crown rot incidence (% of main stems with basal stem browning) and severity (extent of browning on main stems) was scored visually on a 0-5 scale:

0 = 0%	No yield loss
1 = 1-10%	Possibility of minor yield loss
2 = 10-25%	Possibility of some yield loss
3 = 25-50%	Probably some yield loss
4 = 50-75%	Significant yield loss likely
5 > 75%	High yield loss likely

Table 1. Summary of varieties and their crown rot resistance sown at Hart in 2022 (GRDC 2022).

Crop type	Variety	Crown rot resistance
Durum	DBA-Aurora	VS
Durum	Bitalli	SVS
Durum	Patron (AGTD109)	SVS
Wheat	Scepter	MSS
Barley	Spartacus CL	S

Table 2. Summary of seed treatments trialed at Hart in 2022.

Treatment name	Products
Nil	Cruiser® 350FS + Vibrance®
Tymirium	Cruiser 350FS + Vibrance + Victrato

Predicta®B sampling was completed at the trial location before seeding. It was determined there was a medium risk for crown rot infection. To ensure a high background level of crown rot infection was present, sterile Millet seed was infected with *F. pseudograminearum* and was placed in furrow with the trial seed.

Results and discussion

Disease severity and incidence

The application of Victrato reduced the severity and incidence of crown rot at Hart in 2022 (Table 3). Crown rot severity was higher in the nil treatment than the Tymirium treatment, although the trial average was low. A basal stem browning (crown rot severity) score of around 2.00 is often associated with some yield loss (Evans et al 2020). The 2022 trial averaged a disease severity score of 1.00, meaning yield loss would be unlikely. The percentage of infected plants (incidence) was reduced when Victrato was applied.

Table 3. Summary of crown rot severity, incidence and white head expression at Hart in 2022. Values shaded blue are best performing treatments.

Seed treatment	Disease severity	Incidence (%)	White head expression (%)
Nil	1.20^{b}	77^{b}	1.5^{b}
Tymirium	0.81^{a}	65^{a}	0.8^{a}
LSD (P≤0.05)	**0.16**	**7.4**	**0.47**

White head expression was also reduced by Victrato application in 2022. White head expression is more common when crops experience warm, dry springs (GRDC 2019). When white head expression is low, yield loss is likely to be minimal. If the 2022 trial experienced a water stressed spring, it would be likely for increased white head expression to occur due to high crown rot incidence.

Crown rot incidence was affected by variety selection, with Bitalli, DBA-Aurora and Scepter recording the lowest incidence, averaging 61%. Patron and Spartacus recorded high incidence levels of 79% and 93%, respectively (data not shown). An incidence of 20% or greater can present a risk of yield loss due to crown rot (Evans et al 2020). This suggests all varieties trialed in 2022 had a higher risk of yield loss, although a wet spring reduced this risk.

A trial conducted at Hart in 2020, also assessed the impact of Victrato on crown rot severity and grain production. The Victrato seed treatment reduced disease severity and white head expression at Hart in 2020 (Evans et al 2020). This reduction in disease was reflected in grain yield increases of 4-26% at Hart with very susceptible durum wheat benefitting most.

Figure 2. Patron (AGTD109) durum wheat untreated (left) and Victrato (right) applied at Hart in 2022.

Crop quality and yield

Crown rot severity was low and did not result in yield loss at Hart in 2022. Yields were similar for all varieties, ranging from 4.79 – 5.35 t/ha (Table 4). Spartacus CL was the best performing variety for grain protein, measuring 11.9 %. This would be expected as the nitrogen requirement of barley is lower than wheat. Scepter and DBA-Aurora also produced higher levels of protein with 10.6% and 10.2%, respectively. Test weights for durum and wheat were high with Scepter performing well.

Screenings were low across all varieties.

Table 4. Summary of grain yield and grain quality of varieties trialed at Hart in 2022. Shaded values show the best performing treatments.

Variety	Grain Yield (t/ha)	Protein (%)	Test Weight (kg/hL)	Screenings (%)
DBA-Aurora	5.13	10.2^{bc}	82.8^{b}	0.63^{b}
Bitalli	5.35	10.0^{b}	83.6^{c}	0.38^{a}
Patron	5.25	8.6^{a}	82.4^{b}	0.57^{ab}
Scepter	4.79	10.6^{c}	85.2^{d}	0.57^{ab}
Spartacus CL	5.00	11.9^{d}	67.6^{a}	0.96^{c}
LSD (P≤0.05)	**NS**	**0.58**	**0.78**	**0.2**

Values with the same letters are not significantly different.

Application of Victrato did not affect grain protein or test weight in 2022. As this was observed in a wet spring, the grain quality could be different if there was a dry spring and high levels of disease in the crop. Screenings were reduced when Victrato was applied as seed treatment, although screenings were still low across the trial, averaging 0.61%. In years where screenings are higher due to crown rot, Victrato could potentially reduce screenings.

Crown rot severity and white head expression was greater in 2020 than 2022, resulting in yield loss due to crown rot infection. Victrato improved grain yield in trials at Hart and Pinery, with increases of 4-26% and 13-32% respectively due to reductions in disease severity and white head expression (Evans et al 2020).

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 Marg Evans for her training and input to allow Hart to conduct this trial.

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Managing lentil diseases in high pressure seasons - otherwise known as 2022!

Sarah Day[1,3], Sara Blake[2,3], Penny Roberts[1,3]
[1]SARDI Agronomy Clare, [2]SARDI Waite, [3]University of Adelaide

Key findings

- Botrytis grey mould (BGM) in lentil was frequently reported and widespread throughout spring in South Australia in 2022.
- The first step to good disease management is choosing a resistant variety.
- BGM is best controlled initially by using a prophylactic foliar fungicide targeting BGM, applied immediately prior to canopy closure.
- Newer fungicides with dual actives can provide superior disease control of BGM of lentil and may preserve yields in a high disease situation.

Methodology

A disease management field experiment combining five fungicide strategies (Table 1) and three lentil varieties (Table 2) was conducted at Hart in 2022 to assess the grain yield loss from foliar disease infection in lentil. Fungicide treatments were allocated to control both botrytis grey mould (BGM) and ascochyta blight infection.

The field experiment was set up as a randomised block design with three replicates. Each fungicide treatment consisted of two key fungicide application stages: prior to canopy closure, and post-canopy closure but prior to podding applied ahead of rain.

All fungicides were applied ahead of a rain event where > 5 mm is forecast.

BGM disease plot severity was assessed on November 16 by looking at the level of infection showing on the top of the canopy and visually assessing the area affected within the plot.

A score was allocated for area of infection, where 1 = 0-10%, 2 = 10-20%, 3 = 20-30%, 4 = 30-40%, 5 = 40-50%, 6 = 50-60%, 7 = 60-70%, 8 = 70-80%, 9 = 80-100%.

Plots were harvested at crop maturity and grain yield was converted from kg/plot to t/ha.

Data was analysed using an ANOVA model in Genstat 22nd Edition.

Plot size	1.75 m x 10.0 m	**Location**	Hart field site
Sowing date	April 22, 2022	**Fertiliser**	80 kg/ha MAP

Table 1. Details for each of the five fungicide treatments, applied to lentil to manage foliar disease at Hart, 2022.

No.	Fungicide product	Active Ingredient (concentration)	Rate (mL or g/ha)
T1	Untreated control	N/A	N/A
T2	Carbendazim (pre-cc) f/b carbendazim (post-cc)	Carbendazim (500 g/L)	500
T3	Veritas® (pre-cc) f/b Veritas® (post-cc)	Tebuconazole (200 g/L) + azoxystrobin (120 g/L)	1000
T4	Aviator® Xpro® (pre-cc) f/b carbendazim (post-cc)	Prothioconazole (150 g/L) + bixafen (75 g/L) Carbendazim (500 g/L)	600 500
T5	Miravis® Star (pre-cc) f/b carbendazim (post-cc)	Fludioxonil (150 g/L) + pydiflumetofen (100 g/L) Carbendazim (500 g/L)	750 500

Note: f/b = followed by, pre-cc = pre-canopy closure, post-cc = post-canopy closure

Table 2. Lentil varieties and associated disease resistance ratings. Source: GRDC NVT Disease Ratings (https://nvt.grdc.com.au/nvt-disease-ratings).

Variety	Botrytis Grey Mould	Ascochyta Blight (Foliar) Pathotype 1 (Nipper virulent)	Ascochyta Blight (Foliar) Pathotype 2 (PBA Hurricane XT virulent)
PBA Bolt	S	MR	MRMS
PBA Highland XT	MS	MR	MR
PBA Jumbo2	RMR	R	R

Key: S = susceptible, MS = moderately susceptible, MRMS = moderately resistant/moderately susceptible, MR = moderately resistant, R = resistant.

Results and Discussion

Ascochyta blight was not visibly present at Hart in 2022. BGM infection occurred relatively late, with infection only becoming visible on the top of the canopy in November. BGM is favoured by mild temperatures and high humidity, and in spring 2022 the disease was frequently reported and observed as aggressive across South Australia. Due to the nature of the season and the high disease pressure, all fungicide strategies controlled BGM at a similar level at Hart (P=0.808). Variety selection for disease resistance was critical in reducing disease infection (P<0.001) and grain yield loss (P<0.001). PBA Jumbo2, rated RMR for BGM, was the highest yielding variety at 4.2 t/ha. PBA Bolt, which is susceptible to BGM infection, had a reduced grain yield of 2.76 t/ha. Disease score and grain yield of lentil were highly correlated, where greater disease infection resulted in lower grain yields (Figure 1).

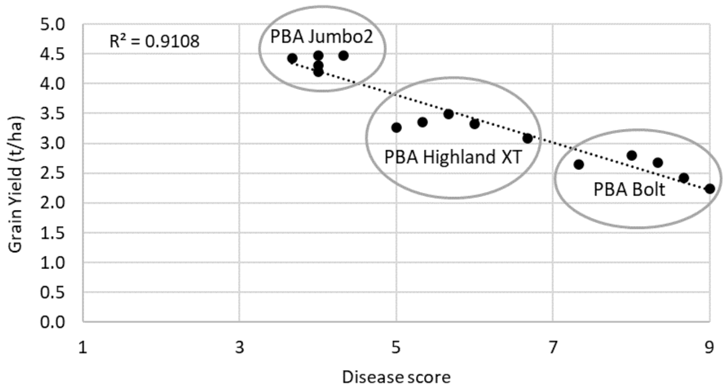

Figure 1. Lentil grain yield was highly correlated with disease severity at Hart, 2022.

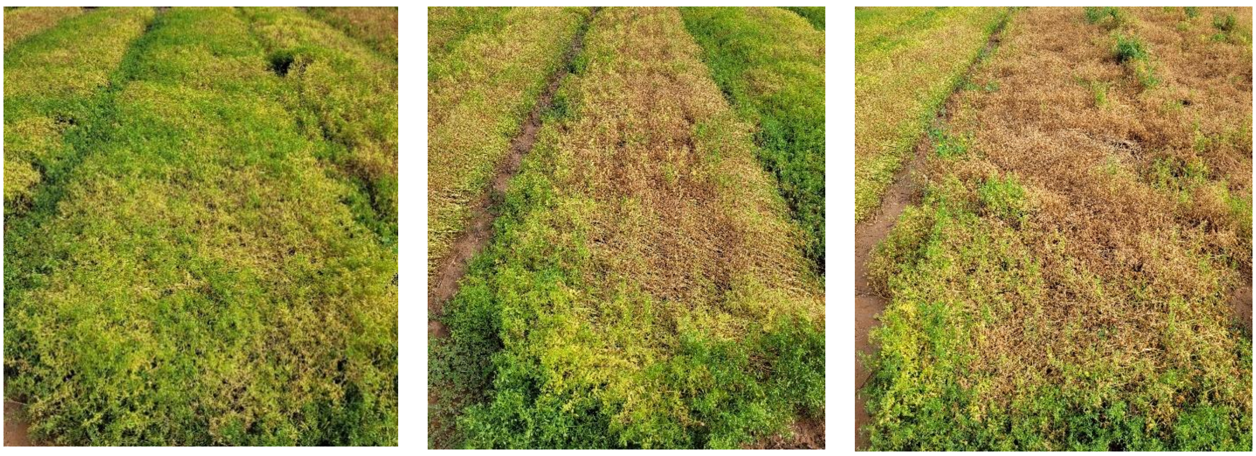

Figure 2. Lentil varieties PBA Jumbo2 (left), PBA Highland XT (middle) and PBA Bolt (right) in November, at Hart 2022.

Conclusion

Wet and humid conditions throughout spring and early summer aided the rapid spread of botrytis grey mould (BGM) in lentil crops across South Australia in 2022. In these exceptional conditions, disease may not be successfully controlled with fungicides alone. Dense canopies remained wet and humid at the base, promoting the disease. BGM is best controlled initially by using a prophylactic foliar fungicide targeting BGM applied immediately prior to canopy closure. This is recommended in all regions for all varieties to protect the base of the crop, regardless of resistance rating. Follow up sprays may be required in medium to high rainfall regions or seasons conductive to infection. Some newer fungicide products with dual actives can provide superior disease control of BGM in lentil and may preserve yields in a high disease situation. In these types of high-pressure seasons, the first step to good disease management is choosing a resistant variety.

Acknowledgements

The authors would like to thank growers and funding partners for their continued support. The work 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 (UOA2105-013RTX – SA Grain Legume Validation). The continued assistance in trial management from SARDI Agronomy Clare is gratefully acknowledged and appreciated.

Epidemiology of septoria tritici blotch in medium rainfall zones

Declan Anderson[1] and Tara Garrard[2]

[1]Hart Field-Site Group, [2]SARDI

Key findings

- Conditions at Hart in 2022 were conducive for moderate infection levels of septoria tritici blotch (STB) due to high volumes of regular spring rainfall.
- Wheat varieties rated MSS or above performed best at reducing disease severity at Hart in 2022. Variety resistance did not affect grain yield with a trial average of 3.51 t/ha.
- Septoria tritici blotch infection decreased test weight (kg/hL) and increased screenings (%) in the variety resistance trial. Test weight was also reduced in the fungicide timing trial where a GS 39 foliar fungicide was not applied.
- In the fungicide timing trial, treatments with foliar fungicides at both GS 31 and GS 39 increased grain yield by 0.57 t/ha when compared to no fungicide or seed treatment only.
- Fungicide treatments applied as foliar spray at GS 31, foliar spray at GS 31 + GS 39 and seed treatment + Foliar spray at GS 31 + GS 39, reduced disease infection levels to 2-8% in the fungicide timing trial. Foliar spray at GS 39 did not reduce disease (20%) when compared to the nil (23%).

Introduction

Septoria tritici blotch (STB) is a foliar fungal disease (*Zymoseptoria tritici*) in wheat that is a common occurrence for growers in high rainfall areas. In recent seasons, septoria tritici blotch has become more prevalent in medium and low rainfall zones across the southern region.

Septoria tritici blotch survives on wheat stubble over summer, causing infection in following crops through windborne spores. The spread of STB in-season is assisted by rainfall and infection can be more severe when regular rainfall events occur. In seasons suitable for STB development, yield losses of around 40% have been experienced in susceptible varieties (GRDC 2022b).

Growing varieties with increased genetic resistance to STB is a major tool for minimising the impact of the disease on grain production. Avoiding highly susceptible varieties allows fungicides to control STB more effectively (GRDC 2022b). Fungicide timing can be critical in maximising STB control and reducing yield loss by protecting emerging leaves. Rotating fungicide groups is also crucial to limit development of resistance in STB populations. Fungicide resistance is already developing in southern Australia, with reduced sensitivity to Group 3 DMI fungicides.

Another strategy for reducing the impact of STB is avoiding wheat on wheat to decrease inoculum levels. This strategy decreases the risk of severe infections in surrounding wheat crops. A combination of these strategies is required to minimise the impact of STB in Australian farming systems (GRDC 2022b).

The trial aims to create an integrated disease management strategy for STB in the medium rainfall zone. Two trials were hosted at Hart in 2022, assessing the (1) impact of variety selection, and (2) fungicide timing and management strategies (Tables 1 and 2).

Methodology

Plot size	1.75 m x 10.0 m	**Fertiliser**	Seeding: DAP (18:20) Zn 1% @ 80 kg/ha
Seeding date	May 5, 2022		July 22: Easy N (42.5:0) @ 70 L/ha
Location	Hart, SA		August 17: Easy N (42.5:0) @ 60 L/ha
Harvest date	November 25, 2022		
2021 crop	Mulgara Oaten Hay		

Trials were managed with the application of pesticides to ensure a weed and insect free canopy. All plots were assessed for grain yield (t/ha), protein (%), test weight (kg/hL), screenings (%) and disease severity (%).

The trials were inoculated with STB on July 5 using infected stubble from 2021 trial sites at Hart and Waite. The stubble was spread evenly to all + disease plots in the variety resistance trial and all plots in the fungicide timing trial.

The variety resistance trial was a randomised split plot design with six replicates, six wheat varieties and two treatment blocks of +/- disease. To reduce the spread of disease across treatments, barley buffer plots were sown between the treatment blocks. The – disease plot was sprayed with fungicides at GS 31 and GS 39 to control disease. Data was analysed using a split-plot ANOVA model in Genstat 22nd edition.

Table 1. Varieties sown at Hart in 2022 in the STB variety resistance trial with maturity and septoria tritici blotch resistance rating (GRDC 2022a).

Variety	Maturity	Resistance rating to STB
LRPB Impala	Mid	SVS
Razor CL Plus	Quick-mid	SVS
Scepter	Quick-mid	S
Calibre	Quick-mid	S
Hammer CL Plus	Quick-mid	MSS
LRPB Lancer	Mid-slow	MS

VS = Very susceptible, SVS = Susceptible – very susceptible, S = Susceptible, MSS = Moderately susceptible – susceptible, MS = Moderately susceptible, MRMS= Moderately resistant – moderately susceptible

The fungicide timing and yield loss trial was a randomised block design with six replicates and six fungicide treatments that were applied on Scepter wheat, a susceptible variety to STB. Barley buffer plots were sown between each plot to reduce the potential drift of fungicide at application. Data was analysed using a randomised complete block ANOVA model in Genstat 22nd edition.

Table 2. Fungicide treatments trialed at Hart in 2022 in the fungicide timing and yield loss trial.

Treatment timing	Fungicide actives	Fungicide groups
Nil	-	-
Seed treatment	Fluquinconazole	3
Foliar spray @ GS 31	Benzovindiflupyr + propiconazole	7 + 3
Foliar spray @ GS 39	Epoxiconazole	3
Foliar spray @ GS 31 + GS 39	Benzovindiflupyr + propiconazole @ GS 31 + Epoxiconazole @ GS 39	7 + 3 3
Seed treatment + foliar spray @ GS 31 + GS 39	Fluquinconazole + Benzovindiflupyr + propiconazole @ GS 31 + Epoxiconazole @ GS 39	3 7+3 3

Results and discussion

2022 season at Hart

Trial emergence was delayed due to late opening rains with 26 mm recorded on May 30. This caused crops to establish late into cool conditions, resulting in low crop vigour and slow crop growth.

Hart received above average growing season rainfall, characterised by a dry start followed by a wet spring. Disease pressure and crop potential were greatly influenced by the 2022 growing season conditions.

The late emergence of crops caused a delay in STB infection. There was average rainfall for May and June, followed by a dry July (Figure 1). This period was also colder than normal, resulting in very slow crop growth.

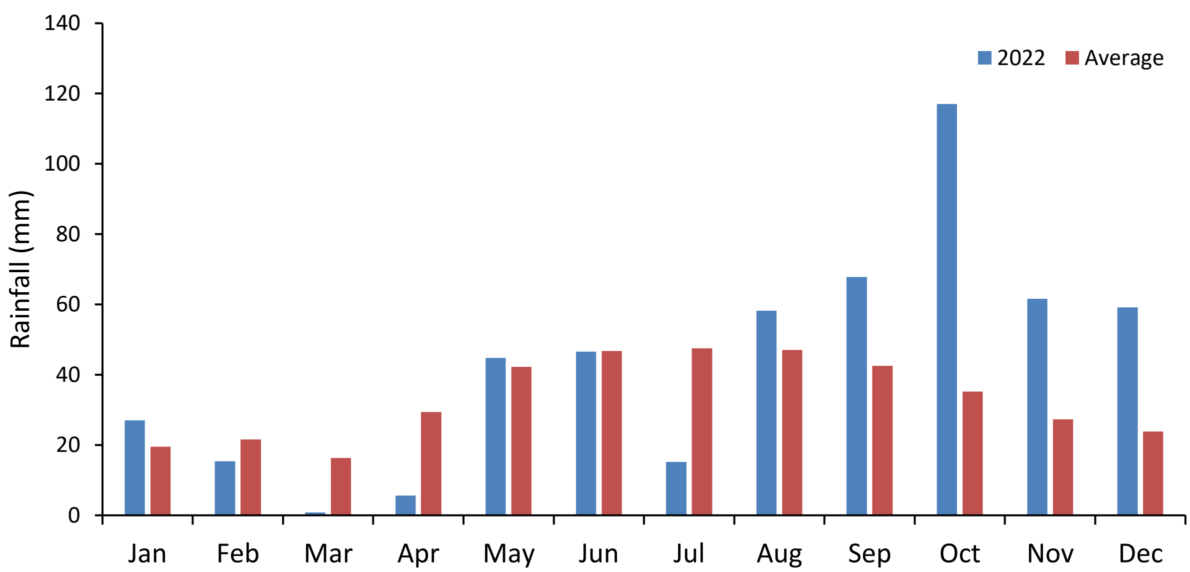

Figure 1. Monthly rainfall for Hart in 2022 as recorded on the Hart Mesonet station. Annual rainfall in 2022 was 520 mm, growing season rainfall was 355 mm. Hart's average annual rainfall is 400 mm and average GSR is 290 mm.

Trials were inoculated with STB infected stubble on July 5. Conditions were not ideal for disease spread and development as dry July conditions persisted. A conducive environment for STB development presented in early August and remained until harvest. This resulted in increased development and spread of STB in all trials.

Variety resistance

Disease levels were moderately high in 2022 with susceptible varieties Scepter and Razor CL Plus recording 30% and 26 % disease severity (% total leaf area infected) respectively (Figure 2). Calibre (S) and Impala (SVS) also had moderately high levels of disease, with 20.3% and 19.5% of the total leaf area affected by STB. Increased volume and regularity of September and October rainfall contributed to the increased disease development when compared to 2021 where Impala recorded the highest disease level of 11% (Anderson et al 2021). A combined 36 mm was recorded in September and October in 2021, compared to 185 mm in 2022 across the same time period, reflecting the amount of disease. A minimum variety resistance rating of MSS was required to maximise disease control at Hart in 2022.

The Mid-North pathotypes for STB caused higher infection in Scepter than in the SVS variety Impala. As Scepter is widely grown, the local strains of STB have become better suited to infecting that variety. A similar trend was observed at Booleroo Centre in 2022, although Impala still experienced significant yield loss (Figure 6). Impala still poses a high risk of yield loss in regions with STB present.

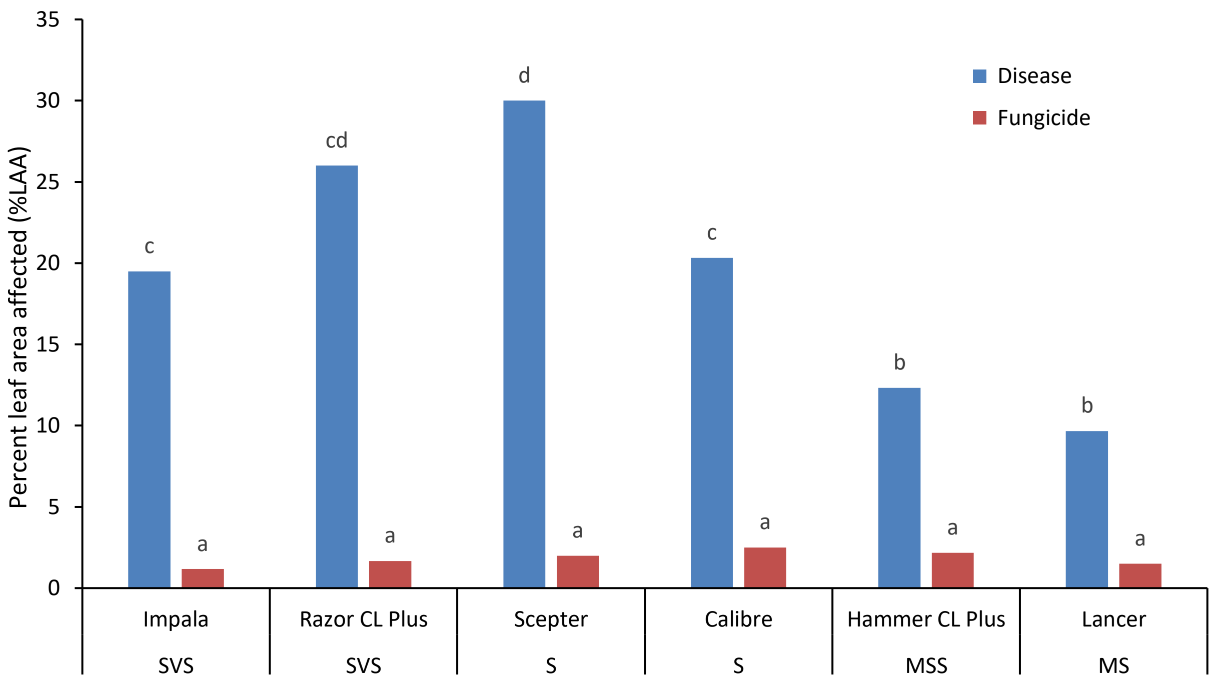

Figure 2. Average disease severity (%) of wheat varieties trialed at Hart in 2022. Varieties are ordered in increasing resistance to STB. Varieties with the same letter are not significantly different.

Despite the moderately high infection severity recorded in disease plots there was no yield loss between diseased and treated in any variety (Figure 3). Yield loss due to foliar disease can be attributed to the infection levels on the top 3 leaves. Whilst the disease severity of the whole plant was as high as 30% in this trial much of the infection was on the lower leaves and could contribute to the lack of yield losses. In addition, variety resistance to STB did not influence yield loss at Hart in 2022 (Figure 3). The variety resistance trial recorded an average grain yield of 3.51 t/ha.

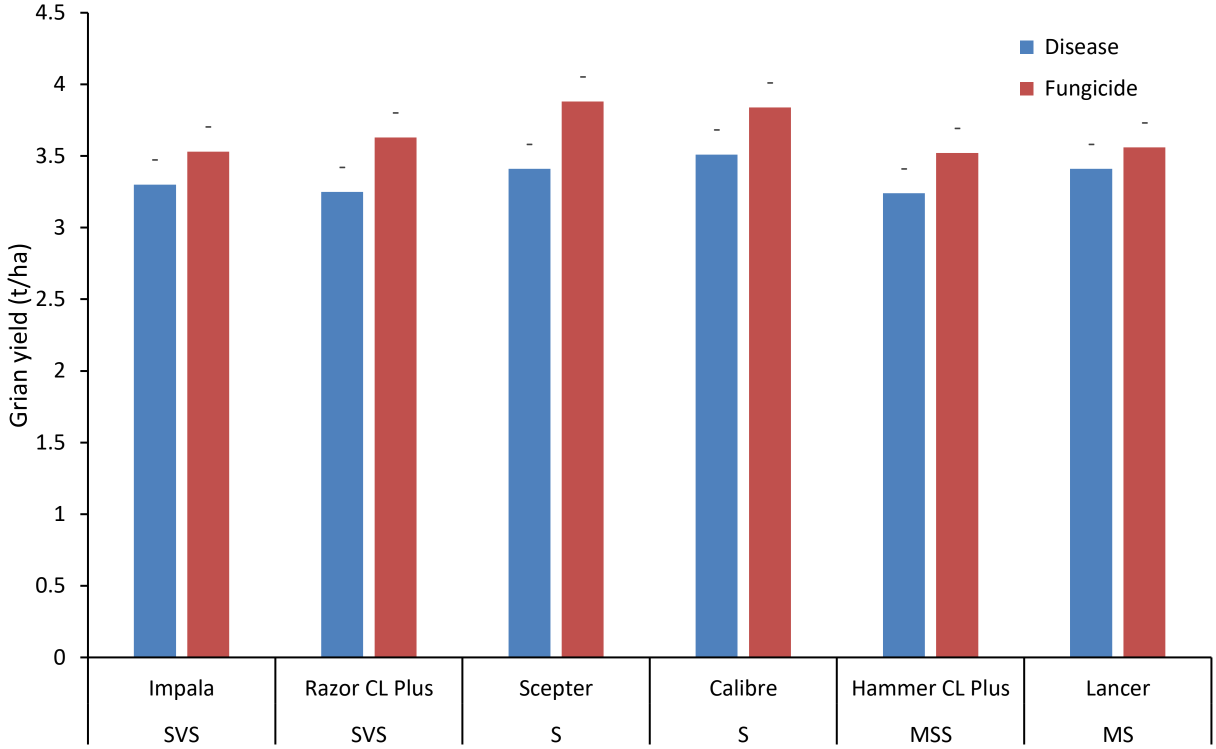

Figure 3. Grain yield of wheat varieties trialed at Hart in 2022. Varieties are ordered in increasing resistance to STB. Data is not significant.

The fungicide control block recorded higher yields than the disease block, with a 0.31 t/ha increase in grain yields. This highlights the impact fungicides can possess in moderate infection situations. Application of fungicides improved grain quality with increased test weight (82.5 kg/hL) and decreased screenings (2.6%) (Table 3). Protein was unaffected by the disease or fungicide treatment.

Table 3. Summary of grain yield and quality of disease and fungicide treatments at Hart in 2022. Values shaded blue indicate best performing treatments.

Treatment	**Grain Yield** (t/ha)	**Protein** (%)	**Test weight** (kg/hL)	**Screenings** (%)
Disease	3.35[a]	9.2	81.9[a]	2.9[b]
Fungicide	3.66[b]	9.1	82.5[b]	2.6[a]
LSD (P≤0.05)	**0.16**	**NS**	**0.36**	**0.2**

Fungicide timing

Septoria tritici blotch disease severity in Scepter was highest in the untreated control (23%), seed treatment (18%) and the foliar spray at GS 39 (20%) treatments. These treatments were significantly different from the disease severity in the foliar spray at GS 31, foliar spray at GS 31 + GS 39 and Seed + Foliar spray at GS 31 + GS 39 which ranged from 2-8% leaf area infected (Table 4).

Application of two foliar fungicides increased grain yield at Hart in 2022 (Figure 4). Foliar sprays at both GS 31 and GS 39 resulted in a 0.57 t/ha increase in grain yield. Use of a seed treatment or foliar sprays at a single timing did not improve grain yield when compared to the untreated plots. Higher disease pressure would explain the reduced effectiveness of single foliar sprays.

Table 4. Disease severity expressed as % total leaf area infected and % leaf infection on the top 3 leaves for each treatment in the fungicide timing trial. Varieties with the same letter are not significantly different. Values shaded blue indicate best performing treatments.

Treatment	STB Disease severity (% total leaf area infected)
Untreated control	23[C]
Seed treatment	18[bc]
Foliar spray at GS 31	8[ab]
Foliar spray at GS 39	20[c]
Foliar spray at GS 31 + GS 39	4[a]
Seed treatment + Foliar at GS 31 + GS 39	2[a]

Grain quality was largely unaffected by fungicide applications with protein (%) and screenings (%) averaging 9.7 % and 3.1 %, respectively, across all treatments. Test weight (kg/hL) was higher where a GS 39 spray was included in the fungicide treatment, averaging 83.4 kg/hL (data not shown). The remaining treatments recorded an average test weight of 81.1 kg/hL which would not result in a downgrade in receival standards.

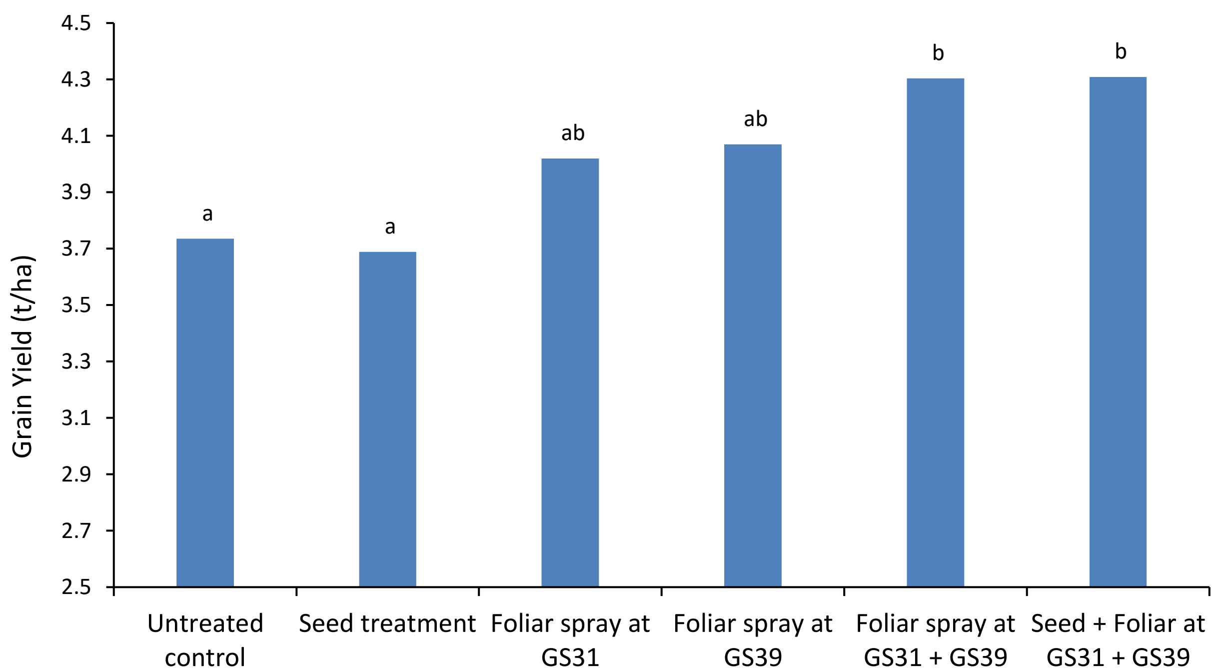

Figure 4. Summary of grain yields for the fungicide timing trial at Hart in 2022. Values with the same letter are not significantly different.

Model development and climate modelling

Disease development was tracked over the course of the 2022 growing season at Hart (MRZ) and Waite (HRZ) by assessing STB disease severity every 2 weeks. Figure 5 shows the percentage of leaf area infected was low (less than 10%) at both sites until GS 55. Both sites had reached this stage by mid-late August and disease development began to increase as they moved into flowering (GS 61-69). Disease severity levels differed in the grain development stage with Hart reaching 43% total leaf area infected and Waite reaching 94% leaf area infected by the end of the season. This provides an example of maximum infection levels with no disease management strategies across the two rainfall zones. At Hart, the disease development data can also be compared with the variety resistance trial's disease severity and yield values, where the same variety Razor CL Plus had no significant yield loss and had reached 26% disease severity by GS 71. This disease level was comparable to both Waite and Hart sites at GS 71 and spring rainfall and humidity is likely to drive late season STB development.

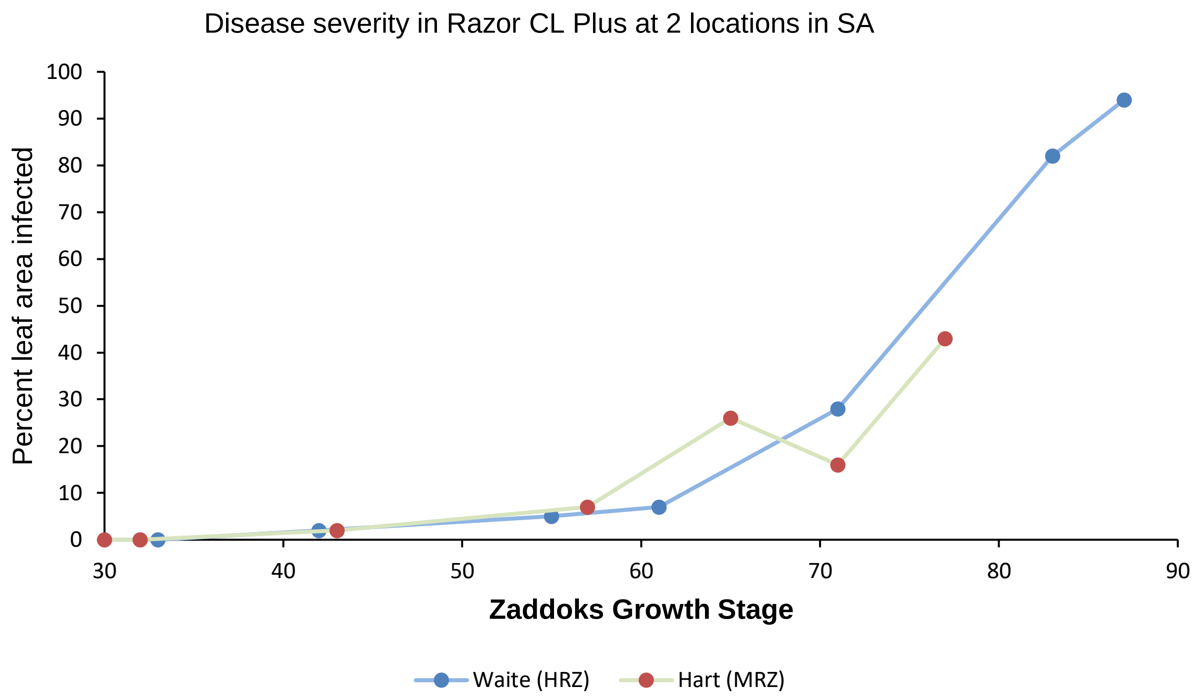

Figure 5. Disease development over the course of the 2022 growing season in an SVS variety in the MRZ and HRZ in SA.

Low rainfall zone – Booleroo Centre

A variety resistance trial was also conducted at Booleroo Centre, to represent STB under low rainfall conditions. The trial site contained high levels of disease in susceptible varieties with Scepter, Calibre and Razor CL Plus recording 72%, 74% and 83% disease severity, respectively (Figure 6) (Garrard 2023).

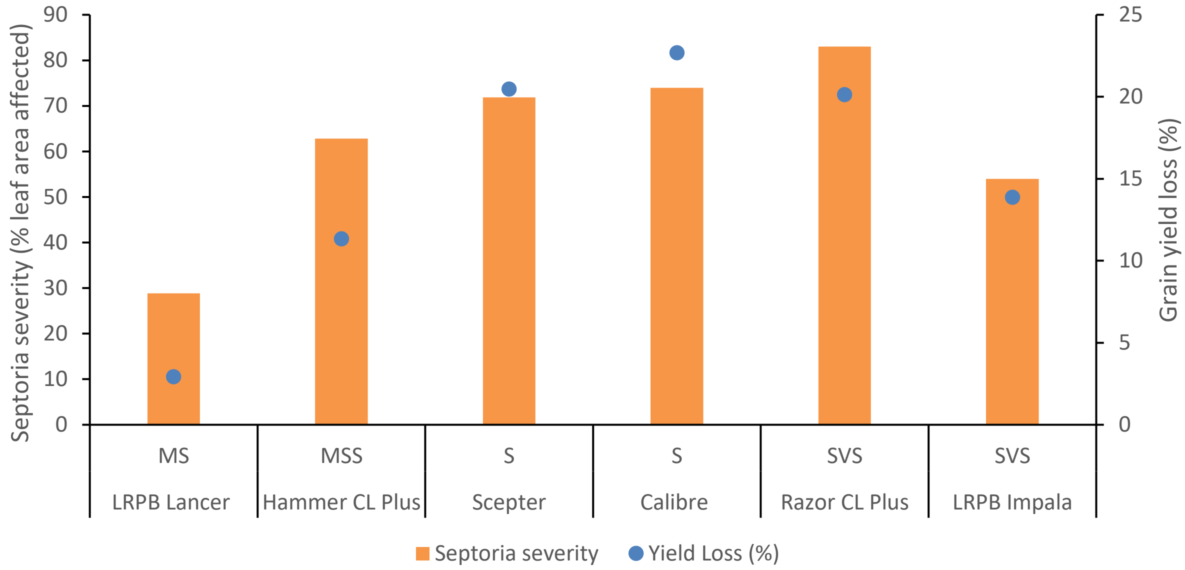

Figure 6. Grain yield losses and STB disease severity at Booleroo Centre STB Variety trial in 2022. All varieties, excluding LRPB Lancer, recorded significant yield loss (Garrard 2023).

The average grain yield of the trial was 5.7 t/ha with yield losses of 13.9 - 22.77% for all varieties present, excluding LRPB Lancer (Garrard 2023). High disease levels and yield loss can be contributed to large and consistent volumes of rainfall in late winter and spring creating optimal conditions for STB.

Acknowledgements

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Management options for dry saline soils on Upper Yorke Peninsula

Sam Trengove, Stuart Sherriff, Jordan Bruce & Sarah Noack
Trengove Consulting

Key Findings

- Application of sand and straw improved lentil growth and grain yield in the first year. Sand rates above 650 t/ha and straw rates above 6.6 t/ha resulted in lentil grain yields of 0.45 t/ha – 0.57 t/ha compared to the control 0.12 t/ha.
- Oats were the highest yielding species at 0.9 t/ha, followed by safflower, barley and peas. Canola also performed well but was not harvested due to bird damage. Wheat, triticale, lentil and vetch were the lowest yielding species trialed.

Introduction

Dry saline soils are a type of land salinity that occurs in soils with high levels of naturally occurring salt (but is not associated with a shallow water table). In mild situations, dry saline land can also be referred to as transient salinity, where salts are trapped within the soil profile (e.g., due to low permeability clay subsoil) and salts move up and down depending on seasonal conditions. Situations which lead to higher evaporation of moisture include long hot summers, periods of drought and the loss of surface plant / stubble cover increase the presence and severity of saline soils patches. Poor plant growth and yields are commonly observed on impacted areas due to the difficulties for crops to up take water in saline soils and the toxic effects of high salt in the plant.

This research aims to trial and demonstrate different management practices which could be used by growers to ameliorate saline soil patches:

1) Amending soil with sand, straw or gypsum - application of amendments to the soil surface can improve crop emergence by reducing evaporation leading to more soil moisture, or by reducing the moisture required to germinate a seed by increasing the sand content of the soil surface. Gypsum was also included to increase the amount of calcium relative to the level of sodium (salt) and address sodicity in the longer-term.
2) Selecting crop types / varieties – to investigate the differences in crop performance on saline soils between crop species and varieties with improved salt tolerance.

Methodology

Site selection and rainfall

Two trials were established at Tickera, SA (-33.8466, 137.6844) – a soil amelioration trial and a crop species/variety trial. The saline area was selected based on historical crop performance and soil test results (Table 1). The amelioration trial was a randomised complete block design, and the crop species/variety trial was a split plot design where crop type (monocot/dicot) was the whole plot and crop species/variety was the sub plot. Both trials had four replicates and the individual treatments are described below. All plots were scored prior to seeding for stubble cover (barley) to assess the variation in salinity level across the site. Stubble cover was measured visually by scoring each plot from 1 (low stubble cover = more saline) to 5 (high stubble cover = less saline).

Growing season (April – October) rainfall at Tickera was 250 mm in 2022. Long-term (1969-2022) average growing season rainfall for Tickera is 252 mm.

Soil properties

Soil samples were collected on April 29, 2022 by sampling the surface 0-10 cm in all five stubble cover scores (Table 1). Deeper cores were sampled in areas with scores 1 and 4 and segmented as follows, 0-10 cm, 10-20 cm, 20-40 cm and 40-60 cm with no replicates per depth.

The Tickera site is a moderate to strongly alkaline (pH > 8.0) clay loam with salinity issues (Table 1). Salinity was measured using chloride and an electrical conductivity estimated (ECe) which uses a texture conversion factor (9.5 for sandy loam) from the EC1:5. Chloride levels in the surface and subsurface ranged from 520 – 4800 mg/kg. The critical level for chloride in clay soils is 300 mg/kg (Hughes 2020). Above this critical value salinity damage is likely to occur depending on crop tolerance. The ECe across the site was 5.4 – 37. In general, it is expected at ECe 4-8 yields of many crops will be affected and 8-16 only crops with tolerance will yield well (Hughes 2020). Beyond 32 is generally considered too salty for most broadacre crops to grow.

Boron levels across the site and soil depths ranged from 8 – 38 mg/kg. Boron toxicity for sensitive crop generally occurs at levels > 5 mg/kg and at levels > 15 mg/kg it is considered toxic for dryland cereals (Hughes 2020).

Table 1. Soil properties for samples collected at salinity management trial Tickera, SA 2022.

Stubble cover score	**Sample depth** (cm)	**pH 1:5** (water)	**Chloride** (mg/kg)	**Salinity EC1:5** (soil:water) (dS/m)	**ECe** (estimated) (dS/m)	**Boron** (mg/kg)
1 (Low stubble / more saline)	0-10	8.1	4800	3.9	37	-
	10-20	8.6	1500	1.5	14	18
	20-40	8.9	1400	1.4	13	29
	40-60	9.1	1400	1.5	14	32
2	0-10	8.2	1800	1.6	15	-
3	0-10	8.2	1300	1.2	11	-
4 (High stubble / less saline)	0-10	8.0	1600	1.4	13	-
	10-20	8.8	520	0.62	5.9	8
	20-40	9.1	770	0.97	9.2	25
	40-60	9.1	1400	1.5	14	38
5	0-10	8.2	720	0.71	6.7	-

Sand, gypsum and straw amelioration trial

Sand and gypsum treatments were spread on the soil surface May 3, 2022. Straw treatments (from baled wheat) were applied post seeding on May 27, 2022. Treatments included control, gypsum 10 t/ha, straw 3.3 t/ha, straw 6.6 t/ha, straw 10 t/ha, sand 130 t/ha, sand 650 t/ha and sand 1300 t/ha. Sand rates were calculated on applying a sand layer of 1 cm (130 t/ha), 5 cm (650 t/ha) and 10 cm (1300 t/ha) covering surface. The sand was sourced from a sand pit 15 km northeast of the trial site at Alford and applied using a front-end loader and shovel. The gypsum used in the trial had a purity of 69% making it a grade 3 product.

The trial was sown with Hurricane XT lentils on May 26, 2022, at a rate of 50 kg/ha. Fertiliser at seeding was applied as MAP 1% Zn at 60 kg/ha. The trial was managed with the application of pesticides to ensure a weed, insect and disease-free canopy.

Crop type and variety trial

A range of crop types and varieties were selected for the trial based on their expected relative tolerance to soil salinity (Table 2). The trial was sown on the May 26, 2022. Boxer Gold® @ 2.5 L/ha was applied to all wheat, barley and triticale plots for ryegrass control, making oats the only cereal with no pre-emergent grass control. The site was treated with bifenthrin after Mandalotus weevil were observed damaging the canola.

Table 2. Crop types and varieties selected for salinity management trial Tickera, SA 2022.

Crop type	Variety	Target plant density (plants/m^2)	Expected tolerance to soil salinity level (ECe)
Barley	Compass	150	10
Oats	Mulgara	240	5.4
Triticale	Yowie	200	8
Wheat	Glad_V13*	180#	-
Wheat	Glad_V26*	180#	-
Wheat	Glad_V3*	180#	-
Wheat	Gladius	180	7.5
Wheat	Scepter	180	7.5
Lentil	Bolt	120	-
Lentil	Highland	120	-
Field Pea	Butler	50	3
Vetch	Timok	50	4
Canola	44Y94	50	8
Safflower	Conventional	40	6

**Near isogenic lines of Gladius wheat (able to accumulate 10x more sodium than current wheat varieties) was sourced from The University of Adelaide. Only two replicates of these varieties were included due to seed availability. #Seeding rates of near isogenic lines ranged from 50 - 80 kg/ha due to limited seed source.*

Crop assessments

The same crop assessments were conducted in both trials. Plant establishment was scored for each plot on June 21, 2022, ranging from 0 (no plant emergence) – 10 (full plant emergence). A Greenseeker was used to measure NDVI on July 12, 2022. Prior to harvest a score of crop cover was made on all plots where 100 = 100% crop cover and 0 = no crop cover. Grain harvest for all species, excluding Safflower and Canola, was completed on November 17, 2022 using a plot header. Safflower was harvested on Jan 6, 2023 due to delayed maturity compared to other crops using a plot harvester. Canola was not harvested due to severe bird damage at the end of the season.

Results

Sand, gypsum and straw amelioration trial

Lentil crop cover assessments at harvest show sand applied at 650 t/ha and 1300 t/ha had the highest level of crop cover (70-90%). This also translated to improved grain yields of 0.45 t/ha and 0.57 t/ha compared with the control 0.12 t/ha (Table 2). These results indicate the higher sand rate treatments provided a non-saline layer for crops to establish well and yield more in year one.

Crop cover for the two highest rates of straw were not as high (38% and 40%) compared to the sand treatments, however, had similarly high grain yields at 0.52 t/ha and 0.46 t/ha (Table 2). These results suggest the higher rates of straw may have been able to retain more soil moisture for the crop by reducing evaporation.

The lower rates of straw 3.3 t/ha and sand 130 t/ha produced plant cover and grain yields similar to the high rates, but they were also no different to the control (Table 2). In future years the longevity of the various sand and straw rates will continue to be measured.

Gypsum applied at 10 t/ha did not improve plant cover or grain yield compared to the control. A lack of crop response is not uncommon from many soil amendments in year one. For example, surface-applied gypsum will gradually move through the soil profile with rainfall, but this can take many years. Long-term monitoring of this site will be required to understand the full soil, crop and economic returns from these treatments.

Table 2. Crop cover (% plot) and grain yield (t/ha) for sand, straw and gypsum treatments at Tickera, SA.

Treatment	**Crop cover at harvest 2022** (%)	**Grain yield** (t/ha)
Control	18[a]	0.12[b]
Gypsum at 10 t/ha	30[a]	0.19[b]
Sand at 130 t/ha	45[ab]	0.34[ab]
Sand at 650 t/ha	70[bc]	0.45[a]
Sand at 1300 t/ha	90[c]	0.57[a]
Straw at 3.3 t/ha	45[ab]	0.35[ab]
Straw at 6.6 t/ha	40[a]	0.52[a]
Straw at 10 t/ha	38[a]	0.46[a]
Pr(>F)	**<0.001**	**0.01**
LSD (P≤0.05)	**28**	**0.24**

Grain yield response to the various sand rates applied (Figure 1) shows grain yield stabilises after approximately 200 t/ha. That is, application of sand rates beyond this point did not result in large yield gains in lentils in 2022. For straw application rates the response appears to plateau after 5 t/ha.

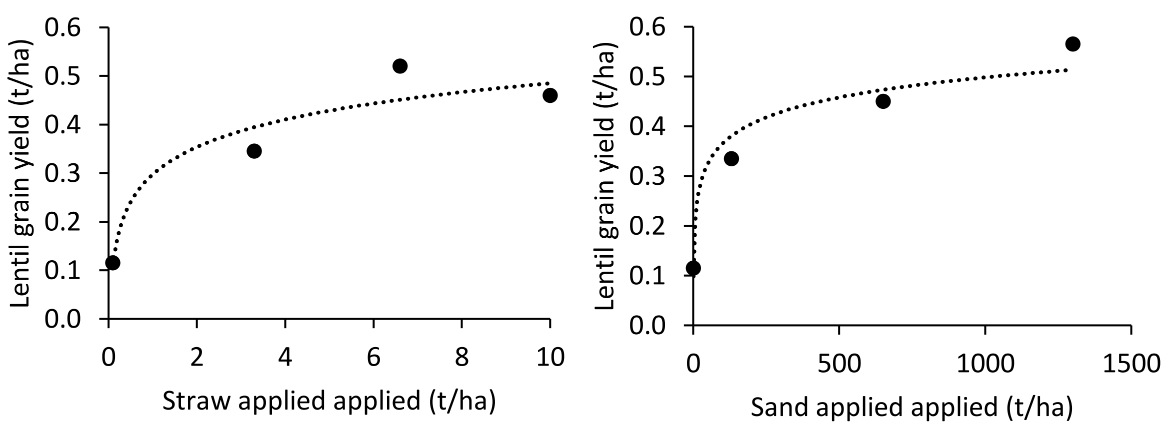

Figure 1. Lentil grain yield response in relation to straw (left, y = 0.0816ln(x) + 2.972, R^2 = 0.918) and sand (right, y = 0.0579ln(x) + 0.0983, R^2 = 0.9501) rates applied in salinity management trial Tickera, SA.

Crop type and variety trial

There were differences between crop species but there was no significant difference between varieties, within crop species (wheat and lentil), for any of the crop assessments. The Pr(>F) values for variety for the measurements were; emergence = 0.958, NDVI = 0.625, plant cover at harvest = 0.314 and grain yield = 0.614 (data not shown). The near isogenic wheat lines derived from Gladius (V3, V13, V36) had previously shown they can accumulate more salt however, in this trial they were not able to perform better than the parent variety Gladius.

Emergence scores for all crop types ranged from 4.9 for safflower up and average of 8.5 for all wheat varieties. The results show that all cereal crops (barley, oats, triticale and wheat) established better than the pulses (lentils, vetch and peas) and canola and safflower had the poorest establishment.

Across the trial NDVI values were low at the end of July (< 0.22). In general, the cereals and canola had the best plant cover (measured by NDVI) where lentils, field pea and safflower measured values similar to bare soil (0.11-0.14). The low NDVI values recorded in July across the trial were not reflective of the large differences in crop biomass observed in the field later in the season (Photo 1). The low NDVI for safflower in late July was not surprising given it was sown at the same time as all the other treatments. Safflower is slower developing and requires warmer conditions compared with the cereal, pulse and canola crops.

Despite low emergence early in the season, canola and safflower measured high crop cover (75% and 83%, respectively) at harvest (Table 3). Other treatments with high crop cover at harvest were oats (82%), lentil (57%) and vetch (57%). The lower crop cover in the cereals can be attributed to low rainfall from mid-June through July which caused crop damage / death in the more saline patches.

Grain yield was variable across the site, however there were significant differences between crop type with oats (0.9 t/ha) being the highest yielding (Table 3). Previous research (Lyons 2016) similarly reported oats tested under salinity stress yielded more than wheat, triticale and barley. Mulgara and Wintaroo were also identified as oat varieties with promising tolerance (Lyons 2016). Barley, peas, and safflower had intermediate performance averaging 0.53 t/ha. Wheat, triticale, lentil and vetch were the lowest yielding. Grain yield of canola was not recorded due to severe bird damage prior to harvest. No measurement was made to assess yield, however notes recorded at harvest, indicate that the canola yield was expected to be similar to the best treatments.

Crop types with more crop cover at harvest may be expected to have more residue cover over Summer, with implications for soil evaporation, salt accumulation, and the establishment and growth of the following crop. These legacy effects will be monitored and the whole site will be sown to wheat in 2023.

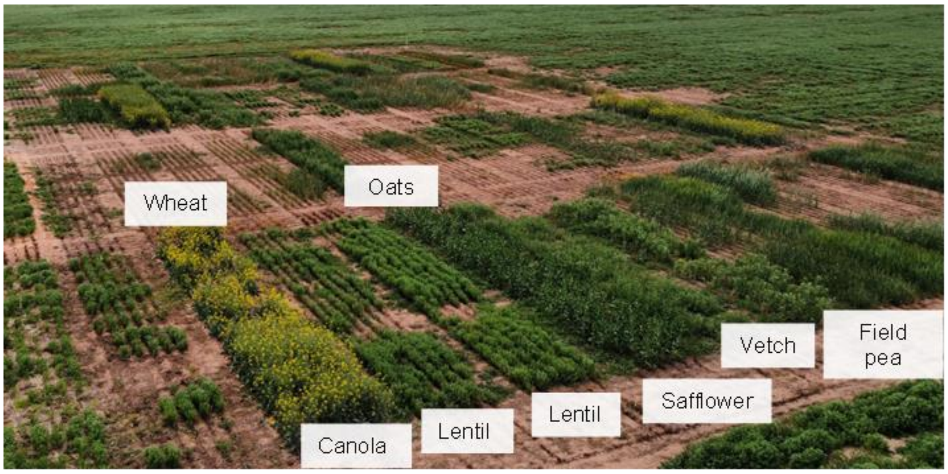

Photo 1. Crop type and variety treatments in the salinity management trial at Tickera, SA. Photo taken September 23, 2022.

Table 3. Plant emergence, Greenseeker NDVI, plant cover (%) and grain yield (t/ha) in crop type and variety salinity management trial Tickera, SA 2022.

Crop type	**Emergence score** (0-9)	**NDVI 22nd July**	**Crop cover at harvest 2022** (%)	**Grain yield** (t/ha)
Oats	8.9[a]	0.219[a]	82[d]	0.90[a]
Barley	8.1[ab]	0.200[ab]	38[ab]	0.53[ab]
Triticale	8.7[a]	0.211[a]	43[ab]	0.40[b]
Wheat	8.5[a]	0.193[abc]	34[a]	0.30[b]
Lentil	7.1[bc]	0.163[cde]	57[bc]	0.43[b]
Vetch	6.7[cd]	0.176[bcd]	57[bc]	0.45[b]
Peas	5.8[cde]	0.160[de]	48[ab]	0.49[ab]
Safflower	4.9[e]	0.143[e]	75[cd]	0.56[ab]
Canola	5.6[de]	0.215[a]	83[d]	-
Pr(>F)	**<0.001**	**<0.001**	**<0.001**	**0.011**
LSD (P≤0.05)	**1.36**	**0.032**	**22**	**0.42**

Conclusion

Application of at least 650 t/ha of sand or 6.6 t/ha of straw produced higher crop cover at harvest and grain yields compared to the untreated. The application of sand at that rate is logistically difficult unless a source is located nearby. However, if there is a source close by, it is achievable for this level of application, such as in the scenario of spreading clay on sands to alleviate non wetting properties. Where sand is not readily available it is likely to be unviable and application of straw at 6.6 t/ha would be more achievable. The longevity of response is important for these amelioration treatments due to high cost and needs further investigation.

Crop type had a bigger impact on crop performance compared to variety selection within this trial. It was expected that the near isogenic wheat lines would perform better than the standard varieties, Gladius and Scepter, as they have a greater capacity to accumulate salt. However, no crop or yield benefit was measured in this trial and more investigation is required to determine why this occurred.

Crop species performance did not rank in the order that was expected. Table 2 shows the expected ranking of crop tolerance to salinity with Barley > Canola > Triticale > Wheat > Safflower > Oats > Vetch > Field Peas. In this trial Mulgara oats produced the greatest grain yield of 0.9 t/ha closely followed by safflower, barley and field pea.

This trial will continue to be monitored in the 2023 season to observe any residual effects of applied sand and stubble and the effect of the different crop types.

Acknowledgements

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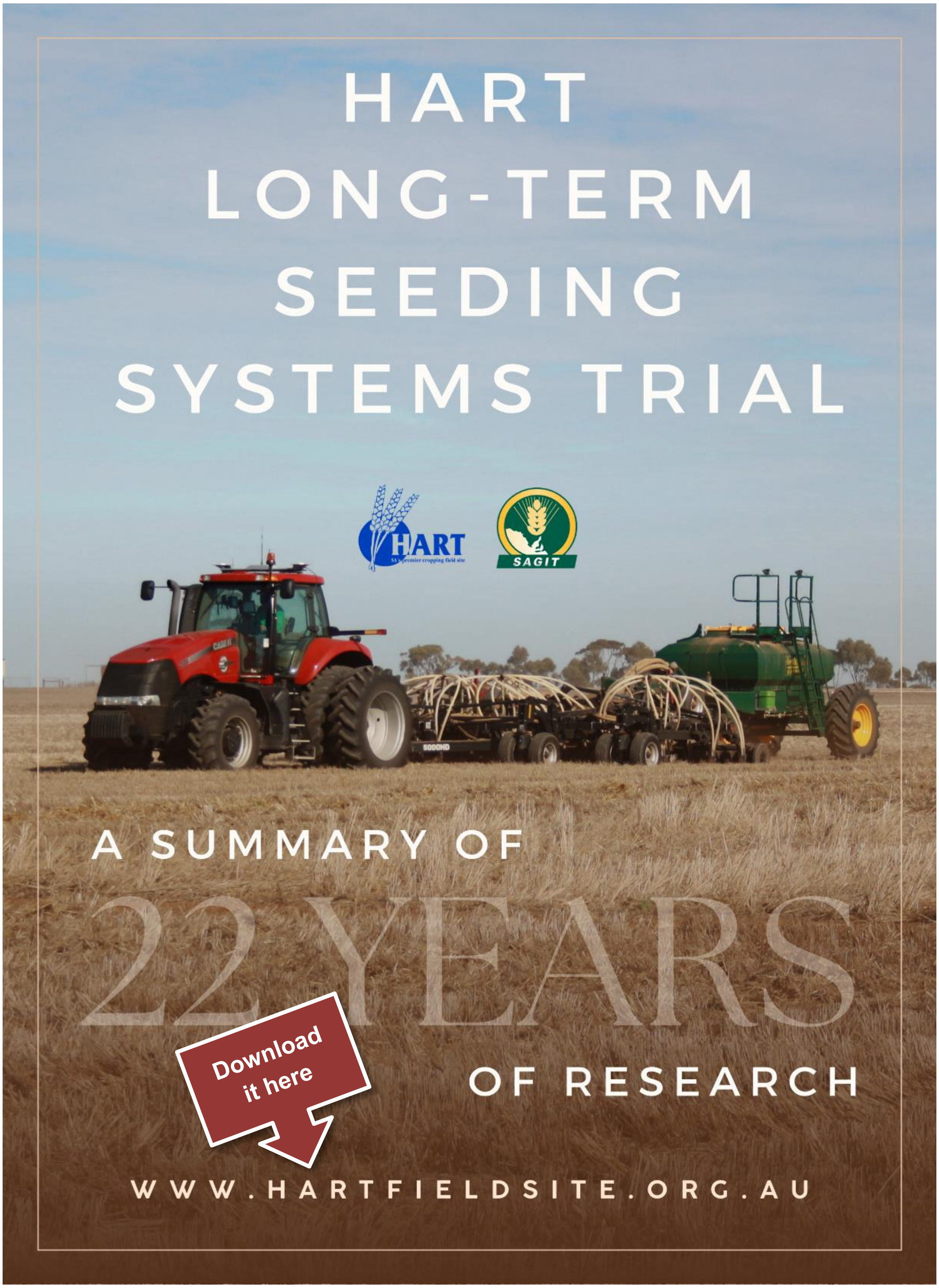
Long-term comparison of seeding systems



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