2022 RESULTS

UPPER NORTH FARMING SYSTEMS

ANNUAL RESEARCH
& EXTENSION **COMPENDIUM**

UNFS

Upper North Farming Systems

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DISCLAIMER

A MESSAGE FROM THE CHAIR

James Heaslip

It is a great honour to present to you the 2021-2022 Upper North Farming Systems (UNFS) compendium. A tremendous amount of work has gone into producing these reports. Grain producers have generally seen above average seasons over the past two seasons and UNFS is well placed and funded to continue providing great value to members through relevant local RD&E and networking events.

During the year, we farewelled two long standing staff members. Ruth Sommerville, our Executive Officer, who had been a driving force for UNFS for 10 years. Kristina Mudge, our Finance officer also retired, we thank you both for your outstanding contribution to UNFS over the years and you will be missed.

These departures have led to a staffing restructure and succession. We welcomed back Jade Rose to the team as our Farming Systems project manager. Jade has hit the ground running and really making this position her own. We have also added Deb Marner to the team as our Business Manager and Rachel Trengove remains as our project officer. This small, dedicated team is working very well and I thank you all for your continued hard work.

UNFS has held some great events during the year with some highlights including the "Summer of Weeds" a joint initiative with the Laura Ag Bureau that had a great mix of presenters and paddock demonstrations. The Post harvest/Pre seeding Event held at Booleroo Centre was a great opportunity for members to come together and debrief after a big harvest and all the issues that arose from a wet and mild spring. My personal favourite event was the post-harvest catch up at the Jacka Brothers Brewery. The hub reps held some great events during the year as well, in particular the Ladies On The Land hub events continued to be exceptional and the best attended throughout the year.

I would like to take this opportunity to express appreciation to our funding bodies, project partners, sponsors and volunteers. Your contributions are vital to UNFS and very much appreciated.

I would personally like to thank the Strategic and Operations Board for your support over the past 12 months in my role as Chair of UNFS. Every board member's commitment and contributions have been invaluable. As my term as Chair draws to a close, I am confident with this Boards leadership that UNFS is in a great financial and strategic position to keep delivering fantastic outcomes to our members. I look forward to continuing to play a part in UNFS.

UPPER NORTH FARMING SYSTEMS
CONTACT DETAILS 2022/23

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THANK YOU TO OUR FUNDING BODIES & PROJECT PARTNERS

National Landcare Program: Smart Farming Partnerships; Department of Agriculture, Water and the Environment: Future Drought Fund; SAGIT; GRDC; Department of Water and Natural Resources; Landscape South Australia Northern and Yorke; MLA; SARDI; SPAA, Birchip Cropping Group, Mallee Sustainable Farming, Agrifutures; Ag Excellence Alliance; Rufous and Co., AIR EP, Ag Consulting Co., AgXtra; Greening Australia; Elders, University of Adelaide; Agbyte; Northern Ag; NR Ag; YP Ag; HART;

Pinion Advisory, Nutrien Ag Solutions, Seednet, Ag Communicators and Ag Tech Services.

Without the support and funding from these organisations and funding programs the Upper North Farming Systems Group would not remain viable.

UPPER NORTH FARMING SYSTEMS
85 989 501 980

INCOME STATEMENT
FOR THE YEAR ENDED 30 JUNE 2022

	Note	2022 $	2021 $
INCOME			
Group Income			
Interest		55	85
Membership		6,886	5,704
Merchandise		64	-
Project Administration		83,384	45,906
Field Days		23,743	19,053
Commercial Paddock		10,309	8,430
Sponsorship		3,809	9,409
Donations		-	500
Sundry Income		2,680	-
Hub Management		16,489	-
		147,419	89,087

	Note	2022 $	2021 $
OTHER INCOME			
Abnormal Income			
ATO Cash Flow Boost		-	10,000
Project Income			
Barley Grass Management Option		14,583	23,750
Vetch on Saline Soils		-	2,000
Ag Tech Hub		-	595
Regenerating Goyder's Line		14,000	10,000
SARDI Partnership Projects		-	19,381
Sheep Producer Tech Group		-	25,000
Soil Pathogen		14,550	1,000
Building Soil Knowledge in the UN		-	92,500
Septoria Epidemiology		13,700	-
Producer Technology Uptake		7,967	11,951
Pulse Check		-	15,229
Cover Crop		-	5,000
Dryland Legumes		30,000	20,000
Weather Station Network		1,500	20,000
Barley Time of Sowing		29,521	28,875
Fodder Crop Trials		-	6,000
Frost in UN		20,000	-
Native Plant Guide		9,050	-
Pulse Extension		6,000	-
IPMS		10,000	-
Lotsa Lambs		9,500	-
TTT Events		22,600	-
		202,971	281,281
		202,971	291,281
		350,390	380,368

UPPER NORTH FARMING SYSTEMS
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INCOME STATEMENT
FOR THE YEAR ENDED 30 JUNE 2022

	Note	2022 $	2021 $
EXPENDITURE			
Group Expenses			
Administration		32,427	58,250
Audit Fees		2,690	2,150
Insurance		2,441	1,972
Advertising		2,034	982
Publications		7,352	2,409
Field Days		26,621	20,609
Commercial Paddock		11,625	3,720
Bank Fees		43	-
Depreciation Weather Station		14,609	18,262
Other Project Expense		7,059	10,059
Travel		4,168	3,290
WorkCover RTWSA		-	377
Total Wage Expense		43,377	22,071
Merchandise		194	3,545
Depreciation - Plant & Equip		-	1,340
Hub Management		8,955	-
		163,595	149,036

UPPER NORTH FARMING SYSTEMS
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INCOME STATEMENT
FOR THE YEAR ENDED 30 JUNE 2022

	Note	2022 $	2021 $
Project Costs			
Barley Grass Management Options		49,469	9,076
Vetch of Saline/Sodic Soils		52	3,403
Ag Tech Hub		-	127
Regenerating Goyder's Line		18,330	7,432
SARDI Partnership Projects		19,084	128
Sheep Producer Tech Group		12,855	12,060
Soil Pathogen		4,926	1,902
Building Soil Knowledge in the UN		23,706	10,202
Septoria Epidemiology		19,989	87
Producer Technology Uptake		18,678	99
Drought Hub Partnership		5,541	350
Micronutrients in Upper North		43,414	38,110
Pulse Check		117	36,191
Cover Crop		19,398	10,251
Dryland Legumes		16,799	11,050
Weather Station Network		800	1,881
Barley Time of Sowing		35,339	15,368
Fodder Crop Trials		-	6,691
Frost in UN		17,357	-
Pulse Extension		3,368	-
IPMS		3,159	-
Lotsa Lambs		4,293	-
TTT Events		13,571	-
Canola in UN		321	-
Drought Resilience Mixed Farm		132	-
		330,698	164,408
		494,293	313,444
(Loss) Profit for the year		(143,903)	66,924
Retained earnings at the beginning of the financial year		581,180	514,256
GST Adjustment 2021 Year		(2,534)	
Retained earnings at the end of the financial year		434,743	581,180

The accompanying notes form part of these financial statements.

UPPER NORTH FARMING SYSTEMS
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BALANCE SHEET
AS AT 30 JUNE 2022

	Note	2022 $	2021 $
ASSETS			
CURRENT ASSETS			
Cash and cash equivalents	3	387,943	524,095
TOTAL CURRENT ASSETS		387,943	524,095
NON-CURRENT ASSETS			
Property, plant and equipment	4	58,436	73,045
TOTAL NON-CURRENT ASSETS		58,436	73,045
TOTAL ASSETS		446,379	597,140
LIABILITIES			
CURRENT LIABILITIES			
Trade and Other Payables	5	11,636	15,960
TOTAL CURRENT LIABILITIES		11,636	15,960
TOTAL LIABILITIES		11,636	15,960
NET ASSETS		434,743	581,180
MEMBERS' FUNDS			
Retained earnings	6	434,743	581,180
TOTAL MEMBERS' FUNDS		434,743	581,180

The accompanying notes form part of these financial statements.

UPPER NORTH FARMING SYSTEMS
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NOTES TO THE FINANCIAL STATEMENTS
FOR THE YEAR ENDED 30 JUNE 2022

		2022 $	2021 $
3	**Cash and Cash Equivalents**		
	Freedom Bank Account 92540	127,932	264,138
	Business Bank Account 93340	260,011	259,957
		387,943	524,095
4	**Property, Plant and Equipment**		
	Plant & Equipment - at Cost	1,340	1,340
	Less Prov'n for Depreciation	(1,340)	(1,340)
		-	-
	Other Plant & Equipment	100,750	100,750
	Less Prov'n for Depreciation	(42,314)	(27,705)
		58,436	73,045
	Total Plant and Equipment	58,436	73,045
	Total Property, Plant and Equipment	58,436	73,045
5	**Accounts Payable and Other Payables**		
	Current		
	PAYG Withheld	2,680	3,319
	Superannuation Liability	1,778	1,348
	GST Account	4,644	11,293
	GST Adjustment 2021	2,535	
		11,636	15,960
6	**Retained Earnings**		
	Retained earnings at the beginning of the financial year	581,180	514,256
	GST Adjustment 2021	(2,534)	
	(Net loss) Net profit attributable to the association	(143,903)	66,924
	Retained earnings at the end of the financial year	434,743	581,180

INDEPENDENT AUDITOR'S REPORT
TO THE MEMBERS OF UPPER NORTH FARMING SYSTEMS
85 989 501 980

Report on the Audit of the Financial Report

Opinion

I have audited the accompanying financial report, being a special purpose financial report, of Upper North Farming Systems (the association), which comprises the balance sheet as at 30 June 2022, and the income and expenditure statement for the year then ended, and notes to the financial statements including a summary of significant accounting policies and other explanatory information, the statement by members of the committee.

In my opinion, the accompanying financial report of the association for the year ended 30 June 2022 is prepared, in all material respects, in accordance with the Associations Incorporation Act 1985.

Basis for Opinion

I conducted my audit in accordance with Australian Auditing Standards. My responsibilities under those standards are further described in the Auditor's Responsibilities for the Audit of the Financial Report section of my report. I am independent of the association in accordance with the auditor independence requirements of the ethical requirements of the Accounting Professional and Ethical Standards Board's APES 110 Code of Ethics for Professional Accountants (the code) that are relevant to my audit of the financial report in Australia. I have also fulfilled my other ethical responsibilities in accordance with the code.

I believe that the audit evidence I have obtained is sufficient and appropriate to provide a basis for our opinion.

Emphasis of Matter- Basis of Accounting

I draw attention to note 1 to the financial report, which describes the basis of accounting. The financial report is prepared to assist the association in . As a result, the financial report may not be suitable for another purpose. My report is intended solely for the association and should not be distributed to or used by parties other than the association. My opinion is not modified in respect to this matter.

Responsibilities of Management and those Charged with Governance

Management is responsible for the preparation and fair presentation of the financial report in accordance with the Associations Incorporation Act 1985 and for such internal control as management determines is necessary to enable the preparation of the financial report is free from material misstatement, whether due to fraud or error.

In preparing the financial report, management is responsible for assessing the association's ability to continue as a going concern, disclosing, as applicable, matters related to going concern and using the going concern basis of accounting unless management either intends to liquidate the association or to cease operations, or has no realistic alternative but to do so.

Those charged with governance are responsible for overseeing the association's financial reporting process.

INDEPENDENT AUDITOR'S REPORT
TO THE MEMBERS OF UPPER NORTH FARMING SYSTEMS
85 989 501 980

Auditor's Responsibility for the Audit of the Financial Report

My objectives are to obtain reasonable assurance about whether the financial report as a whole is free from material misstatement, whether due to fraud or error, and to issue an auditor's report that includes our opinion. Reasonable assurance is a high level of assurance, but is not a guarantee that an audit conducted in accordance with the Australian Auditing Standards will always detect a material misstatement when it exists. Misstatements can arise from fraud or error and are considered material if, individually or in the aggregate, they could reasonably be expected to influence the economic decisions of users taken on the basis of this financial report.

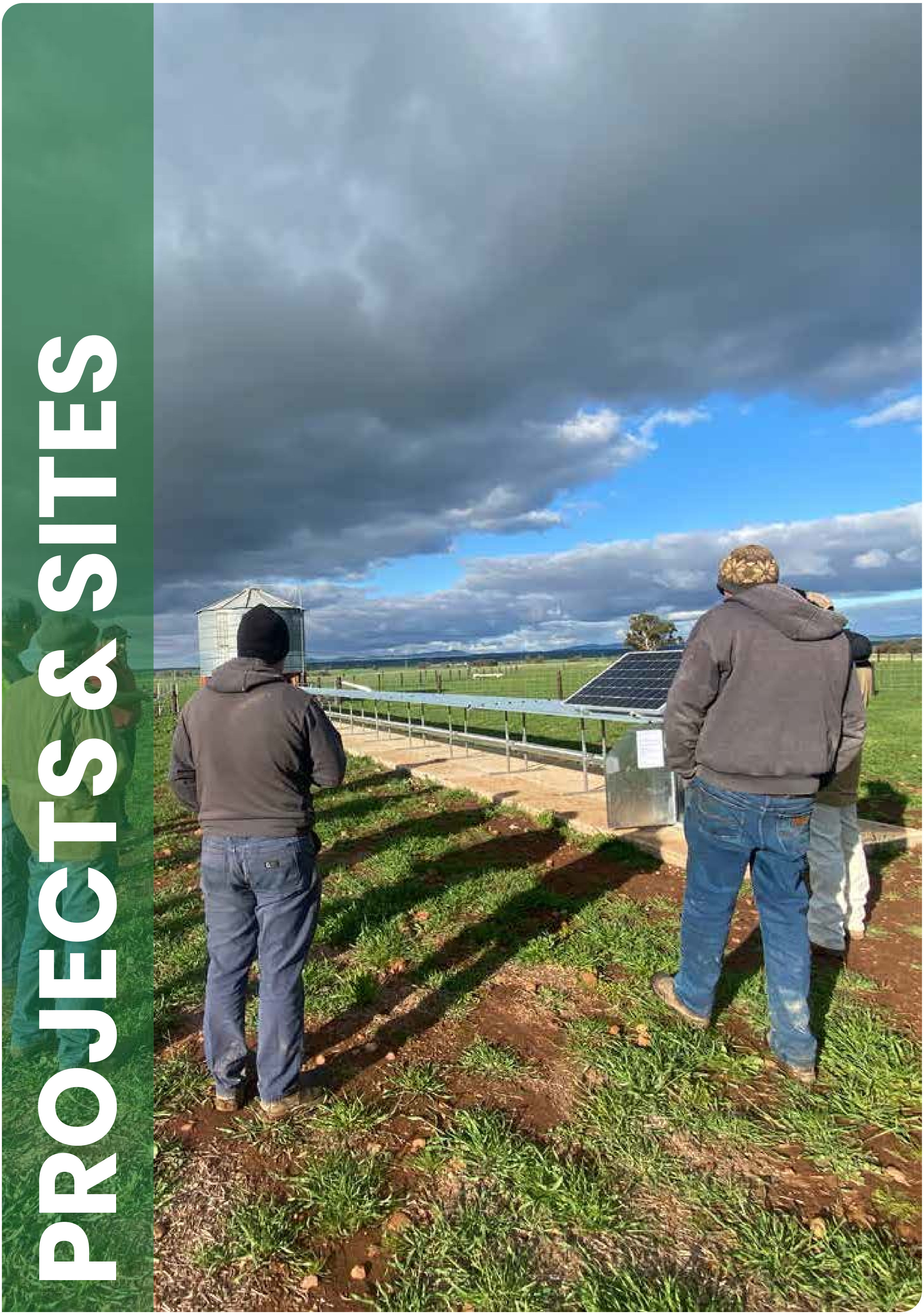
Name of Firm: Mid North Accounting
Certified Practising Accountant

Name of Principal: ____________________
Vonnie Lea CPA

Address: 40 Irvine Street Jamestown SA

Dated this 9th day of May 2023

PROJECTS & SITES

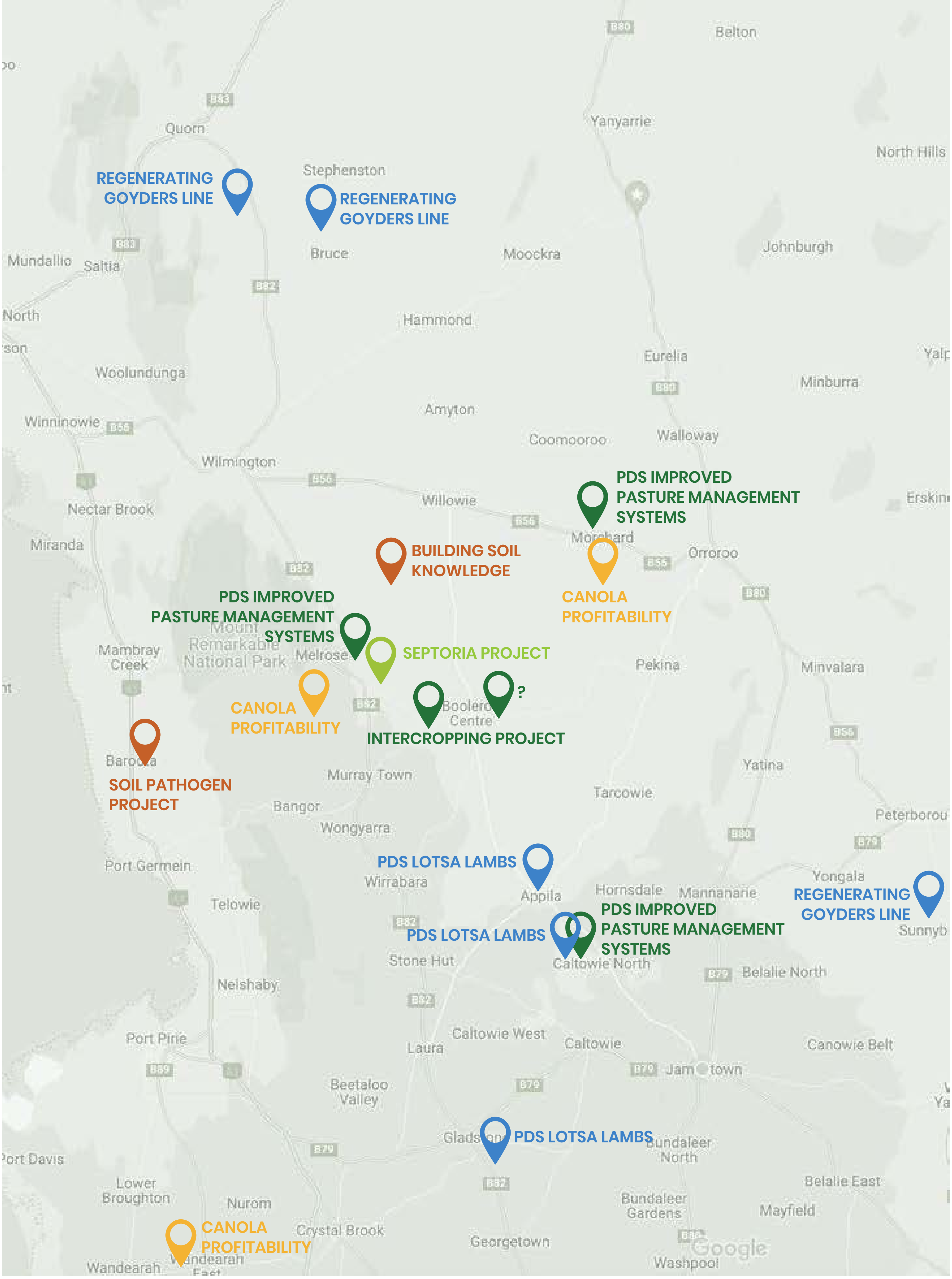


UNFS PROJECTS AND FUNDING

UNFS Project #	Other Names/ References	Full Name	Funding Source/ Contact	UNFS Project Manager	Project Delivery	Project Delivery Contact	Project Total (GSTEXCL)	2020/ 2021	2021/ 2022	2022/ 2023	2023/ 2024	2024/ 2025	In Kind Cont. PA	Start Date	End Date
101	Administration	Group Administration	Internal Transfers, Sponsorship	Ruth Sommerville											
102	Hub Activities	AgTech, LOTL, Jamestown, Booleroo, Nelshaby, Laura/Glastone, Wilmington, Quorn, New Farmers, Morchard/Orroroo/ Pekina/Black Rock,	GrainGrowers, AGT, Davis Grain Sponsorship	Morgan McCallum			TBC		7000						
103	Events		ADM Sponsorship + Other Sponsorship?	Morgan McCallum					5000					1/1/2019	7/3/2022
104	Commercial Paddock	Fundraising for delivery of RD&E in UNFS Region	Northern Ag	Joe Koch				5000	5000	5000				1/9/2019	30/12/2021
227	Cover Crop	Warm and coolseason mixed cover cropping for sustainable farming systems in south eastern Australia.	National Landcare Program; Smart Farming Partnerships initiative Rd 1 VIA AG Ex Alliance	Jade Rose	Elders Jamestown - Darren Pech		47000	5000						2019	
228	Barley Grass	Barley Grass Management Options	GRDC/University of Adelaide - Gurjeet Gill/Amanda	Jade Rose	2019 Matt McCallum 2020 Beth Sleep		72500	23750	38333					1/5/2019	30/6/2020
229	Dryland Legumes	Dryland legume pasture systems project	Rural R&DfP/MSF/ Naomi Scholz	Jade Rose	Morchard, Andrew Catford, Canowie, Beth Sleep		80000	20000	20000					1/4/2019	30/8/2022
231	Weather Station Network	Upper North Fire Danger Index Alerting Weather Station Network Project	Safecom/NSS	Morgan McCallum	Leeton Wilksch		95000								
232	Barley Time of Sowing	Upper North Barley Time of Sowing; Frost / Heat Stress Effects	SAGIT	Jade Rose	Steph Lunn - Agxtra		88825	28875	31075						
235	Regenerating Goyders Line	Regenerating Goyders Line - re-establishing productive pasture in once cropped land	National landcare Program; Smart farming Partnerships iniative round	Ruth Sommerville	Partners - Anne Brown - Native veg Council, Jack desbioselles		50000	50000							
			NYLandscape Board				20000	10000	10000						
236	SARDI Partnership Projects	Site Management Support to SARDI Research Sites in the UN	SARDI/Penny Roberts, Sarah Day	Jade Rose	SARDI		-20000	0							
237	Sheep Tech Group	Red Meat and Wool Growth Program - Producer Technology Group, Upper North Farming Systems Incorporated	PIRSA/Jodie Reseigh Obrien	Rachel Trengove	UNFS/Nutrien Ag/ AC Ag Consulting		25000	25000							30/5/2022
238	Soil Pathogen Project	Soilborne cereal pathogens national extension project - Workshops	GRDC via FarmLink/ Allan Umbers. Also SAGIT via SARDI	Denni Agnew (2020)	SARDI/ Ag Communicators	Katherine Lindsell and Belinda Cay	500	500						1/7/2020	30/6/2023
		Soilborne cereal pathogens national extension project - Trial Sites	Allan Umbers	Jade Rose (2021)	UNFS	Barry Mudge/ Jonno Mudge	21550	5550	9000	7000				1/6/2021	30/6/2023

UNFS Project #	Other Names/ References	Full Name	Funding Source/ Contact	UNFS Project Manager	Project Delivery	Project Delivery Contact	Project Total (GSTEXCL)	2020/ 2021	2021/ 2022	2022/ 2023	2023/ 2024	2024/ 2025	In Kind Cont. PA	Start Date	End Date
239	Building Soil Knowledge	Building soil knowledge & capacity to implement change in the farmers of the Upper North Agricultural zone of SA. Improving soil structure & function to improve plant health, landscape function & farming system resilience.	National landcare Program; Smart farming Partnerships iniative round/ ID K2LZKXT	Beth Sleep (Elders)	Field Systems		92500	25700	50400	16400			2500	1/5/2021	30/6/2023
240	Septoria Epidemiology	Epidemiology of Septoria Tritici Blotch in the low and medium rainfall zones of the Southern region to inform IDM strategies.	GRDC/ Tara Garrard at SARDI	Morgan McCallum	AgXtra	Steph Lunn	29150		13700	13700	1750				
241	Producer Technology Uptake	Incorporating digital farming for improved productivity in the Upper North of SA	Agrifutures	Jess Koch	Breezy Hill PA	Jess Koch	19918	11951	7967					31/5/2021	31/5/2022
242	Drought Hub Partnership	SA Drought Resilience and Innovation Hub	Uni Adelaide	Morgan McCallum											
		Intercropping					35500			35500					
		Pasture Management Systems					30000			30000					
		Tech Toolbox					20000			20000					
243	Frost in UN	Frost Extension in the Upper North	GRDC/MSF Tanja Morgan	Morgan McCallum	Breezy Hill PA	Jess Koch	20000		20000						
244	Native Plant Guide	Guide to Native Grazing Plants	SAAL Landscape Board	Morgan McCallum	Anne Brown		9050		9050					1/7/2021	30/6/2022
245	Pulse Extension	D & E to close the economic yield gap & maximise farming systems benefits from grain legume production in SA	GRDC via SARDI	Jade Rose		Penny Roberts	17600	6600	4400	4400	4400	2200		28/5/2021	6/6/2025
246	IPMS	Improved Pasture Management Systems	MLA	Morgan McCallum			75000		25000	25000	25000			Jan - 22	Mar - 25
247	Lotsa Lambs	Lotsa Lambs - Improving Reproduction Success	MLA	Rachel Trengove			75000		25000	25000	25000			1/12/2021	1/1/2025
248	TTT Events	Tools Tech & Transformation: UNFS and its HUBS 2022	FRRR	Morgan McCallum			20000		20000				4500	1/11/2021	29/8/2022
249	Canola Profitability	Canola Profitability in the UN	SAGIT	Steph Lunn	AgXtra		101180			33760	33710	33710		TBC	8/2025
250	Mixed Farming Hub	Mixed Farming Cross Hub Project	Chris Preston				TBC								
251	Industry Partnership Projects	Grass Weed Management	Ben Fleet, UoA		UoA		Nil								
		Medic Varietys	David Peck, SARDI		SARDI										
		lucerne varieties	Alan Humphris, SARDI		SARDI										
252	Farmer Comedian	ifarmwell - The farmer, comedian and psychologist workshops	Kate Gunn. Drought Fund				TBC								
TOTAL											**56150**	**2200**	**2500**		

UNFS 2022 RESEARCH SITES



UNDERSTANDING TRIAL RESULTS AND STATISTICS

Interpreting and understanding replicated trial results is not always easy. We have tried to report trial results in this book in a standard format, to make interpretation easier. Trials are generally replicated (treatments repeated two or more times) so there can be confidence that the results are from the treatments applied, rather than due to some other cause such as underlying soil variation or simply chance.

The average (or mean)

The results of replicated trials are often presented as the average (or mean) for each of the replicated treatments. Using statistics, means are compared to see whether any differences are larger than is likely to be caused by natural variability across the trial area (such as changing soil type).

The LSD test

To judge whether two or more treatments are different or not, a statistical test called the Least Significant Difference (LSD) test is used. If there is no appreciable difference found between treatments then the result shows "ns" (not significant). If the statistical test finds a significant difference, it is written as "P<0.05". This means there is a 5% probability or less that the observed difference between treatment means occurred by chance, or we are at least 95% certain that the observed differences are due to the treatment effects.

The size of the LSD can then be used to compare the means. For example, in a trial with four treatments, only one treatment may be significantly different from the other three – the size of the LSD is used to see which treatments are different.

Results from replicated trial

An example of a replicated trial of three fertiliser treatments and a control (no fertiliser), with a statistical interpretation, is shown in Table 1.

Table 1 Mean grain yields of fertiliser treatments (4 replicates per treatment)

Treatment	Grain Yield (t/ha)
Control	1.32 a
Fertiliser 1	1.51 a,b
Fertiliser 2	1.47 a,b
Fertiliser 3	1.70 b
Significant treatment difference P<0.05 LSD	(P≥0.05) 0.33

Statistical analysis indicates that there is a fertiliser treatment effect on yields. P<0.05 indicates that the probability of such differences in grain yield occurring by chance is 5% (1 in 20) or less. In other words, it is highly likely (more than 95% probability) that the observed differences are due to the fertiliser treatments imposed.

The LSD shows that mean grain yields for individual treatments must differ by 0.33 t/ha or more, for us to accept that the treatments do have a real effect on yields. These pairwise treatment comparisons are often shown using the letter as in the last column of Table 1. Treatment means with the same letter are not significantly different from each other. The treatments that do differ significantly are those followed by different letters.

In our example, the control and fertiliser treatments 1 and 2 are the same (all followed by "a"). Despite fertilisers 1 and 2 giving apparently higher yields than control, we can't dismiss the possibility that these small differences are just due to chance variation between plots. All three fertiliser treatments also have to be accepted as giving the same yields (all followed by "b"). But fertiliser treatment 3 can be accepted as producing a yield response over the control, indicated in the table by the means not sharing the same letter.

On-farm testing – Prove it on your place!

Doing an on-farm trial is more than just planting a test strip in the back paddock, or picking a few treatments and sowing some plots. Problems such as paddock variability, seasonal variability and changes across a district all serve to confound interpretation of anything but a well-designed trial.

Scientists generally prefer replicated small plots for conclusive results. But for farmers such trials can be time-consuming and unsuited to use with farm machinery. Small errors in planning can give results that are difficult to interpret. Research work in the 1930's showed that errors due to soil variability increased as plots got larger, but at the same time, sampling errors increased with smaller plots.

The carefully planned and laid out farmer un-replicated trial or demonstration does have a role in agriculture as it enables a farmer to verify research findings on his particular soil type, rainfall and farming system, and we all know that "if I see it on my place, then I'm more likely to adopt it". On-farm trials and demonstrations often serve as a catalyst for new ideas, which then lead to replicated trials to validate these observations.

The bottom line with un-replicated trial work is to have confidence that any differences (positive or negative) are real and repeatable, and due to the treatment rather than some other factor.

To get the best out of your on-farm trials, note the following points:

- Choose your test site carefully so that it is uniform and representative - yield maps will help, if available.
- Identify the treatments you wish to investigate and their possible effects. Don't attempt too many treatments.
- Make treatment areas to be compared as large as possible, at least wider than your header. • Treat and manage these areas similarly in all respects, except for the treatments being compared.
- If possible, place a control strip on both sides and in the middle of your treatment strips, so that if there is a change in conditions you are likely to spot it by comparing the performance of control strips.
- If you can't find an even area, align your treatment strips so that all treatments are equally exposed
- to the changes. For example, if there is a slope, run the strips up the slope. This means that all treatments will be partly on the flat, part on the mid slope and part at the top of the rise. This is much better than running strips across the slope, which may put your control on the sandy soil at the top of the rise and your treatment on the heavy flat, for example. This would make a direct comparison very tricky.
- Record treatment details accurately and monitor the test strips, otherwise the whole exercise will be a waste of time.
- If possible, organise a weigh trailer come harvest time, as header yield monitors have their limitations.
- Don't forget to evaluate the economics of treatments when interpreting the results. • Yield mapping provides a new and very useful tool for comparing large-scale treatment areas in a paddock.

The "Crop Monitoring Guide" published by Rural Solutions SA and available through PIRSA offices has additional information on conducting on-farm trials. Thanks to Jim Egan for the original article.

SOME USEFUL CONVERSIONS

Area
1 ha (hectare) = 10,000 m² (square 100 m by 100m) 1 acre = 0.4047 ha (1 chain (22 yards) by 10 chain) 1 ha = 2.471 acres

Mass
1 t (metric tonne) = 1,000 kg
1 imperial tonne = 1,016 kg
1 kg = 2.205 lb
1 lb = 0.454 kg

A bushel (bu) is traditionally a unit of volumetric measure defined as 8 gallons.
For grains, one bushel represents a dry mass equiv alent of 8 gallons.
Wheat = 60 lb, Barley = 48 lb, Oats = 40 lb 1 bu (wheat) = 60 lb = 27.2 kg
1 bag = 3 bu = 81.6 kg (wheat)

YIELD APPROXIMATIONS

Volume
1 L (litre) = 0.22 gallons
1 gallon = 4.55 L
1 L = 1,000 mL (millilitres)

Speed
1 km/hr = 0.62 miles/hr
10 km/hr = 6.2 miles/hr
15 km/hr = 9.3 miles/hr
10 km/hr = 167 metres/minute = 2.78 metres/second

Pressure
10 psi(pounds per sq inch) = 0.69 bar = 69 kPa (kiloPascals)
25 psi = 1.7 bar = 172 kPa

Yield
1 t/ha = 1000 kg/ha
Wheat 1 t = 12 bags 1 t/ha = 5 bags/acre 1 bag/acre = 0.2 t/ha
Barley 1 t = 15 bags 1 t/ha = 6.1 bags/acre 1 bag/acre = 0.16 t/ha Oats 1 t = 18 bags 1 t/ha = 7.3 bags/acre 1 bag/ acre = 0.135 t/ha

"Reprinted with permission from the Eyre Peninsula Agricultural Research Partnership Foundation from the Eyre Peninsula Farming Systems Summary 2019"
30 Eyre Peninsula Farming Systems 2019 Summary

EVENTS

UNFS 2022 EVENT SUMMARY

Date	Event	Location	Participants	Details
February				
1	Producer Tech Update	Zoom webinar	8	Producer Technology Update through Agrifutures, designed to help growers understand and interpret their precision ag data and plan for the cropping season ahead.
March				
7	TTT in the Hubs - Young Farmers Hub	Jamestown	7	Mary from "Are you bogged mate?" talked about "Are you bogged mate?" and how it aims to boost awareness and start a conversation with the broader community about the rising issue of depression and suicide rates in men in rural areas.
17	TTT in the Hubs - Appila/Booleroo	Appila	6	Phoenix Livestock presented on the cost of production information and turn it into useable information that you can act on.
31	TTT in the Hubs - Quorn/Wilmington	Wilmington	12	Miles Cockington from Podium Livestock
April				
6	Soil Pits for CTF	Bundaleer North	10	Two soil pits were investigated to assess the impact of CTF of the soil types of the Upper North. The pits highlighted the impact of wheel track compaction and the structure changes from wheel tracks to between tracks.
4	TTT in the Morchard/ Orroroo/Pekina/ Black Rock Hub	Orroroo	13	Agriwebb software company presented on helping record data. Looking at the all-in-one, always-connected, farm mapping, insight uncovering, profit driving, sustainability enhancing solution to help businesses moving forward.
12	LOTL Bubbles and Chats	Orroroo	59	Nibbles and Bubbles while listening to local, inspiring rural women.
29	Deep Ripping Demonstration	Melrose	10	Part of the Soils Knowledge Project, looking at lime and gypsum from Penrice quarries
June				
22	Soil Pit Workshop	Melrose	12	Andrew Harding (PIRSA) presented on two soil pits in Melrose and Booleroo looking at soil fertility, sodicity, water holding capacity, soil carbon and productivity.
28	Lotsa Lambs: Improving Reproductive Success	Appila	21	Michelle Cousins, Cousins Merino Services and Andrew Michael, Leachim Stud presented breeding objectives, merino flock profiling, ASBVs and more.
30	Farm Tech Planning Workshop	Melrose	10	Brooke Sauer from intellect Ag
30	Regen Goyders Line "Burra to Birdlake" Bus Tour	Burra	35	A bus tour looking at productive pastures and functional ecosystems across the compacted soils and degraded landscapes along Goyders Line. Part of the "Regenerating Goyders Line" Project.

UNFS 2022 EVENT SUMMARY

Date	Event	Location	Participants	Details
July				
14	Tools, Technology and Transformation	Melrose	70	There were a wide range of technology and transformation based presenters across both livestock, cropping enterprises data communication systems.
August				
15/16	Nelshaby Ag Bureau Bus Trip To Eyre Peninsula	Eyre Peninsula	30	The Nelshaby Agricultural Bureau undertook a two day investigative trip to Eyre Peninsula sponsored in part by the TTT funding from UNFS.
24	Ag Tech Hub Event	Melrose	12	Site visit to see a fully automated feeding system for sheep.
September				
2	Western UNFS & Nelshaby Ag Bureau Crop Walk	Warnertown	20	A visit to the GRDC Soil Pathogen trial on crown rot, with Marg Evans, Spiny Emex Management site with Stefan Schmitt, the lower Broughton Salinity Trial at Wandearah, the SAGIT Canola profitability site at Wandearah and the SARDI Pulse Extension Site at Warnertown with Penny Roberts and Dylan Bruce.
8	UNFS Annual Members Expo	Booleroo	70	Annual Members Expo with speakers talking about confinement feeding, pasture satellite imagery,cover crops, disease in the UN,changing soil properties and rotation options and novel systems.
15	Eastern Sticky Beak Day	Jamestown	50 +	Visit to the Syngenta Learning Centre, Self Regenerating Legume Pastures and MLA Producer Demonstration Site
20	UNFS Sticky Beak Day	Blackrock, Morchard, Booleroo	13	Visited the Northern Trial Sites including Medic Varieties Trial, Canola Profitability Trial and MLA Producer Demonstration Site
30	LOTL Transitioning People Through The Farming Business	Melrose	31	Transitioning people into and out of the farming business, how do we do this well? Building a successful farming team, Playing to individual's skills, How to attract and retain people in your business and Defining your business's 'purpose, plan and people.
October				
18	Using Satellite Imagery for late season crop management decisions	Melrose	11	Understanding crop dry down using satellite imagery, harvest management, yield predictors, soil testing techniques, mixed pastures species site visit.
21	Orroroo Hub Event - Breedelite Smartdrafter Demo	Orroroo	18	Jonathon Byerlee, Windhurst Merino Stud brought along his sheep and BreedELITE smartdrafter to demonstrate and present his merino breeding

BUBBLES AND CHATS

Ladies on the Land's first event of the year was 'Bubbles and Chats' at the Orroroo Town Hall. Following-on from our successful Bubbles & Chats night at Bundaleer in November, this popular event once again drew a great attendance with over 59 ladies joining us for the event. The evening included some inspirational local women sharing their personal stories, followed by a tour and access to browse the then newly opened 54 31 Collective.

Our first speaker was Emily Riggs, founder and owner of the Iris & Wool fashion label based at Burra and uses high quality merino wool. Next was Alice Nottle (aka Dr Bennett), a Booleroo Centre farmer and gastroenterologist, as well as the founder of 'Good Gracious Gut.' The third presenter was Hannah Pech, a mother of 5 who transformed her style to improve her health and inspire mothers to do the same. The final presenter was Bec Rasheed from Orroroo. This hard-working woman not only helps run the station but is a high level football player.

This free event was made possible thanks to the generous support of the Northern and Yorke Landscape Board who helped fund the night. Also, to the 54 31 Collective for catering and Flinders Gin for sneaky cocktail on arrival!

UNFS TOOLS, TECHNOLOGY AND TRANSFORMATION EVENT REPORT

The UNFS Tools, Technology and Transformation field day event was held on Thursday the 14th of July 2022 at the Melrose Showgrounds, SA. There were a wide range of technology and transformation based presenters across both livestock, cropping enterprises data communication systems. There was a total attendance of 70 people which included attendees, stall holders, presenters and UNFS staff. With a total of 17 presenters and 20 stall holders, there was a lot to see and do on the day.

The day kicked off with three presentations in the main hall on the day. The first being Rick Llewellyn from CSIRO presenting on his work with virtual fencing, what has been done and what is left to test before being commercially available. Secondly, Ed Scott from Field Systems Australia presented on Soil Carbon work on behalf of Perennial. Going through what the trial was showing and the future steps towards this important topic. Thirdly, Dominic Coscia from SARDI presented on the tech that has been implemented on the farm scale throughout each of the SARDI and PRISA demonstration farms.

Following on from those presentations all the attendees had an opportunity to mix and mingle with each other over some lunch and liaise with each of the stall holders. Throughout lunch, each of the stall holders got to have a session on the microphone to present on their business.

After lunch and the stall speed dating session, 9 concurrent workshops were held. 3 workshops on cropping, 2 on livestock and 3 on data systems that all ran at the same time.

The three cropping sessions were Seeding prescriptions and variable rates mapping presented by Jess Koch, Breezy Hill Precision Ag Services and Beth Humprhris, Elders. A presentation from Barry Mudge and Darren Pech from elders on resilient rotation followed this. Lastly for the cropping session Jess Koch and Beth Humprhris came back up and ran another workshop talk on Satellite Imagery to Improve in-season Decision Making. In the livestock session, there was a late minute change of plans due to Michelle Cousins from Cousins Merino Services testing positive to Covid. Michelle joined us virtually and Jodie Reseigh from SA Sheep connect joined this session in person to facilitate the zoom call. They both touched on using EID's and ways they can be introduced and used into your sheep program on farm. Following on from this Dan Roe from Neogen presented on sheep genomics and how to use and gain this data on farm. Lastly, in the data systems workshops, we had Stephanie Dickson from Mallee Climate services present on The Climate Services for Agriculture (CSA) prototype

helps Australian farmers to adapt to climate variability and related trends and thereby improving the viability of their businesses. Then Tim Stockman presented on data communication systems and telecommunication in rural areas. Lastly, Leighton Wilksch presented on the weather station network that is located in the Upper North Region.

The afternoon session of the day kicked off with a drone demonstration from both Xtreme drones and the WSB Ag tech team. They went through the technical side of both drones used on the day and finished up with a demonstration on how they work. Once attendees were back inside Shane Oster from Alapha Group consulting and Scott Michael presented on Water telemetry and water management through technology. Scott has a property in the far North and spoke about the technology they had implemented on their property. Lastly, Royce Pitchford from Pinon presented on how to plan for tech changes on farm and the steps that need to be taken from a farm and management perspective.

An evaluation was done after the event through survey monkey and showed that there was an abundance of positive feedback provided. The survey showed that majority of attendees selected that the information was relevant to them, well presented and met their expectations for the event. 53% of the attendees that completed the evaluation survey stated that the level of information was suitable for them and another 73% indicated that the information was well presented and 86% indicated that the event met their expectations. Some of the feedback comments are as follows:

- Great learning and networking opportunity
- Great work organising - hope more people can attend in future events
- It was a good event due to wide range of presentations, catering to both livestock and cropping enterprises.

This event is supported by FRRR, through funding from the Australian Government's Future Drought Fund, the National Landcare Program the Northern and Yorke Landscape Board. Upper North Farming Systems would also like to thank the Booleroo Centre Lions club, Melrose Show society and BMW football club for catering and venue hire on the day.

Australian Government
Department of Agriculture, Water and the Environment
Future Drought Fund
FRRR
Australian Government
National Landcare Program
LANDSCAPE SOUTH AUSTRALIA NORTHERN AND YORKE
UNFS Upper North Farming Systems

20th SEPTEMBER

TRANSITIONING PEOPLE THROUGH THE FARMING BUSINESS

Our second event wasn't just for the ladies! A thought-provoking workshop followed by drinks and nibbles, 'Transitioning people through the farming businesses was held in Melrose at Over the Edge Bike Shop. We were extremely fortunate to have Jeanette Long from Ag Consulting Co. available to facilitate the evening. Jeanette is a Director and Facilitator, Trainer and Coach who is passionate about developing people skills in agriculture and working with rural women and farming families. She assists organisations and farm families with succession, strategic and business planning.

The main topics of the evening included:

- Transitioning people into and out of the farming business, how do we do this well?
- Building a successful farming team
- Playing to individual's skills
- How to attract and retain people in your business
- Defining your business's 'purpose, plan and people'

With 31 people in attendance, there was a lot of valuable information and resources shared to assist farming business'.

Once again, this event was made possible due to the generous support by FRRR, through funding from the Australian Government's the Northern and Yorke Landscape Board.

21st NOVEMBER

RELAX AND REST **POSTPONED**

Our third event that was scheduled for November included an Active Farmers express workout followed by a yoga session with Alison King. This was unfortunately postponed until we find a more suitable time in 2023.

In 2022 we were still feeling the impacts of Covid, however it was great to provide opportunities for ladies (and men) to connect in person. Aside from our events, the LOTL social page continues to provide an online platform to share relevant information and opportunities to regional women.

HUB ACTIVITIES

BLACK ROCK - ORROROO - MORCHARD HUB REPORT

To summarise 2022 from a farming perspective in the Black Rock - Orroroo - Morchard district, it was challenging from start to finish. It began quite dry, and those with confidence powered in and conducted a large amount of their cropping program before any significant rainfall. Livestock feed was very slow to get going, with many producers supplementary feeding well into late winter. We experienced a pretty wet period through the spring, which got the crops and the feed going at last. But it also brought problems with chemicals that just didn't seem to work like they should, and issues with rust which we rarely see, and also worm problems in the sheep. Harvest yields ranged from some crops being fantastic, down to below average, and the very frustrating white grain disorder issue and lack of organisation from the grain receivers affected most wheat growers to some degree. Hopefully 2023 is a bit smoother sailing, but I'm sure we'll find a way to deal with whatever conditions come our way.

Led by David Peck, PIRSA have begun a low rainfall zone pasture trial at Black Rock. The trial has focused on various varieties of medics, clovers, and dryland lucerne. Although the dry start to the season wasn't the ideal conditions, the germination was still quite pleasing, and the resilience during the dry spell through winter was pretty impressive. When we had the wet period in the spring, it responded quickly, and showed some interesting results. Hopefully the information gained will help develop some new varieties to benefit the low rainfall grazing zones into the future.

We also had a demonstration day in October focusing on Breed Elite auto drafters, and the associated systems of electronic eartags, fleece weighing, and individual animal management. Tim Johnsson from Breed Elite attended to explain all the technical aspects, and Jonathan Byerlee of Wyndhurst Poll Merinos gave us a demonstration of his auto drafter and gave an explanation of the practical side of the system and how he uses it to record the data used for his stud ram operation. It was great to see a selection of the Wyndhurst rams up close, and if anyone is looking for some great plain bodied low micron rams, I would encourage you to look them up as there is great value for money on offer there.

by Tom Kuerschner - *UNFS representative*

GLADSTONE / LAURA AG BUREAU HUB REPORT

JAN – DEC 2022

The season started out very dry with well below average rainfall with many dry seeding again. Only about 55mm rain was recorded for the year until the break of the season at the end of May. It then turned around with 5 months above average rainfall. The last three years 2020, 2021 and 2022 have been above average rainfall years.

We invited Tim Gurney and Andrew Polkinghorne from T- Ports to speak about Lucky Bay and Wallaroo sites on Monday 21st February at the Caltowie pub for tea. About 35 farmers from northern areas turned up.

For our next gathering we invited Nelshaby Ag Bureau to join us at Laura to hear from Leigh Creek Energy's Tony Lawry about the Urea plant they are hoping to build at Leigh Creek. David Evans and David Long also spoke about the Farmers Business Network buying group. About 30 attended for a tea meeting at the hotel.

PIRSA Grain Biosecurity Officer conducted insect surveillance at several local farmers grain storage facilities during June followed by a hands on workshop held at Laura on 29th June.

Our AGM was held 15th August at Marty Gilberts Laura Bee Shed. A very informative talk and demonstration of honey extracting was given. We then had tea at the hotel and chewed the fat on issues in our area.

Several of the Laura Ag Bureau members attended the UNFS Tools, Technology and Transformation day at Melrose in July and were very impressed with the day.

A planned 4WD family day tour in late September organized in conjunction with CFS through the Beetaloo Valley and Wirrabara Forrest restricted tracks was cancelled due to the tracks being too wet.

Our annual sticky bus tour was held on 14th October with about 43 farmers and company reps attending. A great day was had by all. During the BBQ lunch at Page's shed, grain company reps were given time to tell us about their businesses.

by Andrew Kitto

YOUNG FARMERS HUB

Positives this year:

Held our first hub event in a long time in March

Challenges this year:

Hub activities/events held: Season wrap up and had 'Are you bogged mate' Mary Obrien come and speak. Unfortunately there were only a few attendees but the content presented by Mary was extremely helpful

General comments:

This year we have received some funding to get our group up and going. We will be brainstorming some options in the coming month and look to have more regular hub events for Young Farmers over the course of the next year

by Alison Henderson

JAMESTOWN HUB REPORT

Positives this year:

Yields, especially canola and wheat, Strong commodity prices. Reinforcing of the importance of good agronomic practice, time of sowing not as critical but still important, good rotation critical to weed control. Dry Harvest little grain damage. I established some perennial pasture with amazing success. Harvest was long but quite smooth.

Challenges this year:

Dry seeding and resulting poor weed control. Shaky confidence in June July. My shearing was delayed and very difficult. White Grain disorder. Sheep price crash

Hub activities/events held:

Jamestown

General comments:

Another good income year gives confidence to the sector. Hoping to see more interesting UNFS events and increase participation, its an exciting time and an enjoyable group.

by David Moore

NELSHABY AG BUREAU - HUB REPORT

Mixed results were produced in 2022 throughout the mid north, as rainfall was not consistent in all areas. With it being very dry until the first week of August, for some in a small area the rain was too late, for others it was just in time to have a very productive year with a combination of great prices and good yields. For some it was their best year ever, but unfortunately, others had their worst ever year with the rain coming too late. As the early areas started harvesting the rain didn't want to stop as well as strong wind and hail. For these areas this meant crop damage, loss of grain, some downgraded grain (mainly being lentils) as well as paddocks being very hard to access with machinery. From this there has been damage to paddocks with lots of wheel ruts to tidy up.

Hub activities/events held:

The Nelshaby Agricultural Bureau undertook a two-day investigative trip to Eyre Peninsula sponsored in part by SA Drought Hub. After an early start on Monday, August 15 from Port Pirie, we travelled to Buckleboo to look at a SA Drought Hub strip and disc trial on Vandeleur's farm. This trial was set up in 2022 but is intended to run for several years to analyse the benefits and disadvantages of this type of farming system compared with conventional knife points. This year, the main issue being investigated is the impact and effectiveness of different herbicide packages on crop safety under the different systems. Good discussions were had with the Vandeleur's about their farming system and why they have moved to disc seeding. We then travelled to the Minnipa Agricultural Centre and inspected trials with the Acting Farm Manager and also the Local Drought Hub coordinator Fiona Tomney. Crops and pastures on the Ag centre were in very good condition with the ideal season. We inspected and discussed a local pasture trial which was studying the benefits of mixed pasture species on productivity. We completed Day 1 by visiting Bruce Heddle, a farmer near Minnipa. Bruce provided us with an excellent overview of his mixed farming system, including the inspection of some very nice crops. Next morning, we went to Polda Rock, near Wudinna to inspect a water harvesting scheme which was important in supplying water to the local area during early closer settlement. We then travelled to Elbow Hill, near Cowell, to discuss a low rainfall rotational grazing system being established by local farmer Greg Williams. Greg is using mixed pasture species along with innovative grazing techniques to improve productivity of very marginal cropping land. A learning highlight here was the flexibility Greg was building into his farming system to allow him to respond to the high level of climate variability inherent in this region. We then moved to Lucky Bay to inspect the T-Ports development with Tim Gurney, Business Development and Client Relations Manager. The final stop for the trip was to an SA Drought Hub early sowing trial at Mitchellville. This trial is using innovative methods to try to improve crop establishment under marginal soil moisture conditions which often occur early in the season. Unfortunately for the trial (but fortunate for the local farmers!), the area had experienced an excellent seasonal opening and the crops were all very good. Repeating this trial in future years may be beneficial. Overall, the trip was highly regarded by participants. It provided excellent learning opportunities along with the strong social benefits of travelling with like-minded people investigating issues of common interest. We are very appreciative of the sponsorship support from both the TTT initiative from UNFS and the SA Drought Hub. (Credit: Barry Mudge)

Members in control room of 3000 tonne barge at Lucky Bay

In September the Nelshaby Ag Bureau celebrated 100 years of the bureau. This was held at the Port Pirie golf club which was very well attended with some good speakers from past and present members of the bureau telling many stories. Was great to see both young and old there with the bureau in great hands with many young members.

Inspecting Polda reservoir and early water harvesting scheme near Wudinna

Nelshaby Ag Bureau members inspecting the SA Drought Hub early seeding trial near Mitchelville

The bureau had its yearly crop walk/sticky beak day also in September, starting at looking at some Crown rot sites on Barry Mudge's farm at Baroota with key speaker Marg Evans talking to us about what the promising results she has found in her research trials. We then went and looked at Dennis's weedit camera sprayer which resulted in some good discussion with a number of members investing in this new technology. Following that we went and looked at some trials that Stefan Schmitt conducting on three corner jacks in lentils as well as a trial plot looking at crop establishment in saline soils. We finished the day looking at SARDI pulse extension site with Penny Roberts and Dylan Bruce talking us through what they have found from the trials with early sown lentils being a standout.

The Nelshaby Ag Bureau is looking forward to a wet growing season and hope that everyone has a safe and successful year.

by Nathan Crouch

MELROSE HUB REPORT

Growing Season Rainfall:

Hugely variable, likely 250-400 across the hub area

Positives this year:

After a nerve wracking start, final yields were some of the best ever seen in the district with cereals typically yielding 4-6 t/ha and up to 10 t/ha barley reported, Canola up around 3-4 t/ha, Beans around 4-5 t/ha, lentils 2-4 t/ha, all well above our 10 year average. Grain prices also were well above average, resulting in some fantastic gross margins.

Challenges this year:

Excessively high input costs had us at some of the highest risk we have seen. Very dry conditions from May to August, crops established then no significant rain until mid August. Disease pressure on crops resulting in multiple fungicide applications. A lot of paddocks too wet to spray, had to use the plane to cut them. Also was not possible to windrow all canola as planned as paddocks too wet. Lots of wheel tracks left in paddocks to deal with. Smashed by hail in 2 separate events in November, resulting in claims of up to 50% in a lot of crops. A lot of crops further out recovered from the dry start but not to the extent that closer in crops did. Harvest sure did drag out due to the amount of grain to come off, leaving a lot of very weary people by the end of it. A lot of hay was damaged due to rain in October and hay season pushed well into the start of grain harvest.

Hub activities/events held:

Unfortunately the Expo trip to the SARDI test site and deep ripping/soil amendments trial was cancelled due to rain, not a bad reason to cancel it! Some very interesting results came from the SARDI trial though and looking forward to this seasons follow up trial work.

General comments:

Was a very up and down (or more down then up) season for our district. Post seeding things looked great, but then the dry spell caused a lot of stress, both to crops and farmers. Once it started raining though, it didn't stop and was amazing to see so much water in the area. Stress was again high about a potential wet harvest, but once harvest started there was very little rain in the area leading to a smooth run over harvest. Really great to see such a good year for our region after a pretty hard 5 years prior.

by Andrew Walter

UNFS 2022 COMMERCIAL PADDOCK REPORT

The Commercial Paddock is the result of very generous donations of land, time and resources from the community that support Upper North Farming Systems and its impact to the group is nothing short of amazing. The Paddock is located on the outskirts of Booleroo Centre and is owned by Northern Ag, the local NRI business in Booleroo Centre.

Northern Ag has been supporting the group since its beginning and when the use of the paddock was brought up they were very generous to offer its use as sponsorship to the group. UNFS members now sow, spray, spread, harvest, cart and sell the grain produced from the paddock in order to generate income for the group that is not tied to funding bodies or grants.

This means that the group has the capacity to undertake events and research activities in a timely manner when weather events or economic impacts occur, it also enables us to undertake research that is a significant priority for the Upper North but is not for the State or National funding bodies at this time. We would like to take this opportunity to thank Dustin Berryman and the team at Northern Ag for making it possible for us to fundraise in this way and giving back to your local community so generously.

Thank you to all those involved in making the 2022 Commercial Paddock Oats Crop (Export Hay) a success.

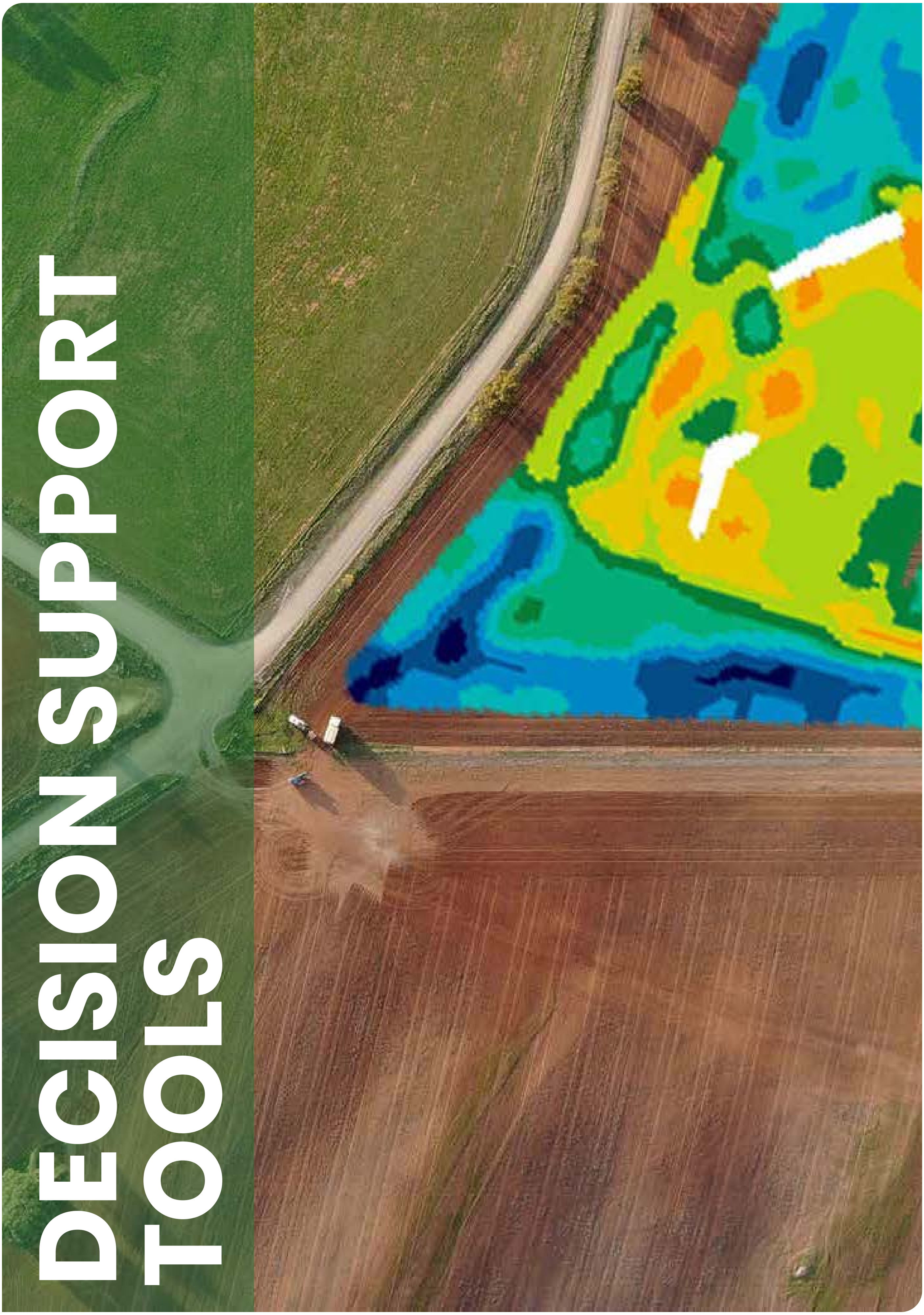
- Sowing – Wayne Chapman and Phil Waters
- Summer Spraying – Orrock Farming
- Cut, Raked, Baled, Carting: Gum View Pastoral (Jesse, Joel, David McCallum)
- Seed donated by Gum View Pastoral - Jesse and Joel McCallum

In 2022/2023 the funds from the 2022 Commercial Paddock were used to support the following projects

- Weather Station Maintenance and Upgrade Proposal Development: $1500
- Regenerating Goyder's Line – Site assessments post project completion $5000
- Development & Implementation of a Calcareous Soils East of the Range Pilot Project $10000.
- It will still retain approx. $10000 in the Commercial Paddock to allow for future season inputs and to be responsive to seasonal issues as they arise.

Thank you to Northern Ag and our amazing group of volunteers that make this partnership an integral part of our delivery of high quality engagement and trial activities to the region

DECISION SUPPORT TOOLS

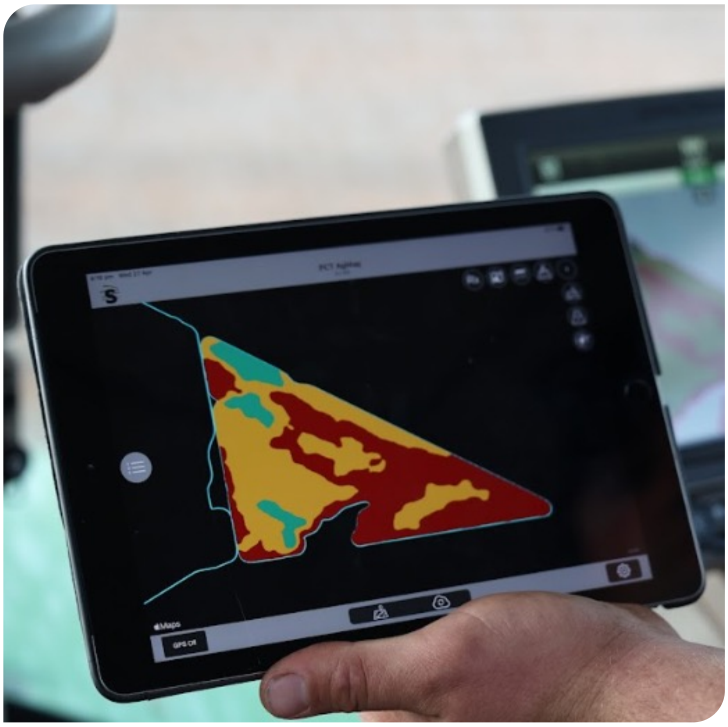


Using SATELLITE IMAGERY *to* INFORM ADAPTIVE MANAGEMENT

Author: Jessica Koch, *Breezy Hill Precision Ag Services*

INTRODUCTION

Satellite technology in agriculture has become a widely adopted method of viewing and analysing broadacre crops, giving new insights into variability across and between fields. As time has gone on, accessibility to satellite imagery has become higher in resolution, faster and more affordable for growers. Agronomists have satellite imagery available in their software programs, and the maps can even be viewed in machinery data services such as John Deere Operations Centre. Despite this fact, the practical uses for the maps are still not widely known or adopted. In low rainfall environments, the opportunities for changed management using the maps and information from the imagery are huge. Data can offer increased confidence when making tough decisions in harder drought years. We will explore four very different case studies throughout the Upper North, and how the growers made profitable management decisions through understanding variability.



SATELLITE IMAGERY USES:

- Crop Scouting – gain insights into the crop variability before visiting the field. Often variability shows up that isn't visible from the ute cab
- Change Detection – Comparing images over time to view the changes in crops within a season or between seasons. Very important for management of both abiotic (eg - heat stress, drought, chilling stress, salinity) and biotic (eg - disease, pest) crop stressors
- Harvest Order Management - As a crop grows its amount of green leaf area increases. As it senesces the green leaf area begins to decrease. This effect shows clearly on the imagery and can be very helpful in targeting desiccation timings and harvest operations
- Crop Effect - Hail/Storm/Herbicide Damage/ Overspray assessment
- Fallow Selective Spot Spraying – In a summer spray scenario, spraying outcrops of weeds in stubble
- In Crop Selective Spot Spraying – Fungicide application for example – spraying product based on the density of the crop canopy
- Frost Management – finding and defining frost affected zones to make harvest decisions – cutting for hay or selective harvesting
- Targeted Insect Inspections – Pests tend to congregate in thicker biomass zones, nutrient or moisture deficient/excess areas. Crop inspections can be targeted accordingly
- Soil Performance Zoning - soil types and soil condition delineation (soil capability and capacity)

ABOUT SATELLITE IMAGERY

Most agricultural satellite imagery is derived from two satellites – LANDSAT 8 and Sentinel-2. Landsat 8 provides data with a spatial resolution of 30 m, while Sentinel-2 of 10, 20 or 60 m (depending on the band), Planetscope of 3 m and SkySat of 1 m. The temporal resolution (time between availability of images) is in most cases regular. For example, Landsat 8 is available every 16 days, while Sentinel-2 is available every 3 to 5 days Planetscope and Skysat have a daily resolution. The regular passage of the satellites determines the availability of the data in several phases of the growing season, but it is also important to understand that during the satellite transit, where the area under examination is covered by clouds, the data is not usable.

WHAT ARE VEGETATION INDICES?

A vegetation index (also called a vegetative index) is a single number that quantifies vegetation biomass and/or plant vigor for each pixel in a remote sensing image. The index is computed using several spectral bands that are sensitive to plant biomass and vigor. The index we are most familiar with in agriculture is NDVI (Normalised Difference Vegetation Index). Similar to NDVI, the Satamap Vegetation Index (SVI) exposes variability in vegetation by exploiting the difference in reflectance in the red and near infrared bands. SVI also uses the green band to help mitigate the effects of soil colour.

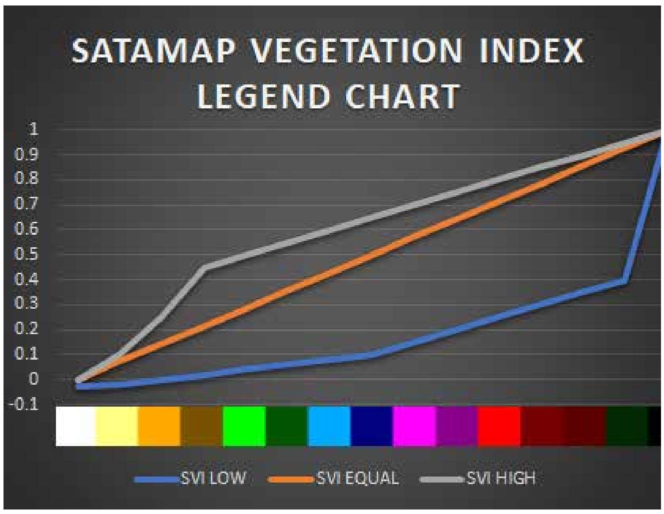
The Satamap Vegetation Index (SVI) offers three colour scales to represent the information: Equal, Low and High. SVI Equal distributes SVI values evenly across the colour scale, whereas SVI Low gives bias to low biomass crops and SVI High bias to high biomass crops. This allows maximum information to be extracted from the imagery. Many would be familiar with this colour scale in programs like Agworld.

VEGETATION INDICES:

- **NDVI** - Normalised Difference Vegetation Index
- **SVI** - Satamap Vegetation Index
- **PCD** - Plant Cell Density
- **CCC** - Canopy Chlorophyll Content

OTHER INDICES:

- **RGBI** – Red Green Blue Index
- **MSI** - Moisture Stress Index
- **NDRE** - Normalised Difference Red Edge



USING THE 'MOISTURE STRESS INDEX' TO MAKE STRATEGIC GRAZING DECISIONS

THE GROWERS:
David, Chloe, Ian & Sue Clarke

FARMING ZONE:
Booleroo Centre, SA

PADDOCK LOCATION:
Amyton 'Shed Paddock'

ANNUAL RAINFALL:
290mm

With farms spread up to 80km apart, and cropping country well north of Goyders Line, David Clarke has turned to satellite imagery to assist in proactively making grazing and harvest management decisions differently.

THE PROBLEM

- Below average rainfall in July/August 2021 meant a strategic decision had to be made on a moisture stressed barley crop.

THE QUESTIONS

- How can we make an informed decision on whether to graze this paddock? If the answer is yes, when?
- Should the paddock be harvested after being grazed?

Amyton is traditionally a marginal cropping zone, and after an extended dry period throughout July and August in 2021, David chose to be proactive in his crop scouting methods using satellite imagery to guide him. This case study focuses on the 'Shed' paddock at their 'Brindinna' property.

THE SOLUTION

David used a map called MSI (Moisture Stress Index) to help him crop scout his barley. The crop had a solid start with good opening rains but follow up rains were sparse. The crop was beginning to struggle from moisture stress but it was clear that the affect of the moisture stress was variable throughout the paddock. The decision to graze the paddock needed to be made swiftly and logically, to maximise the use of the crop as feed, and still allow the option to harvest it.

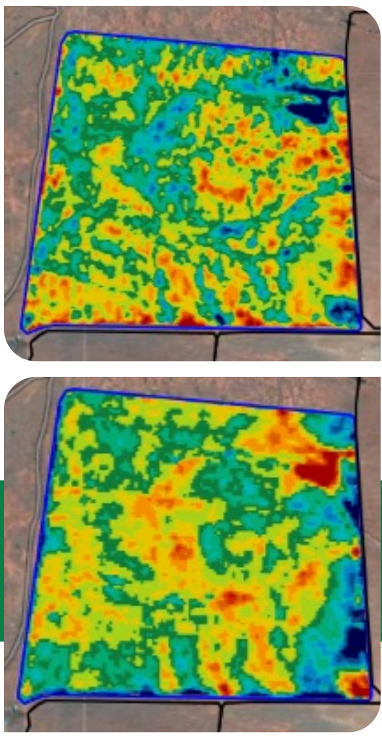


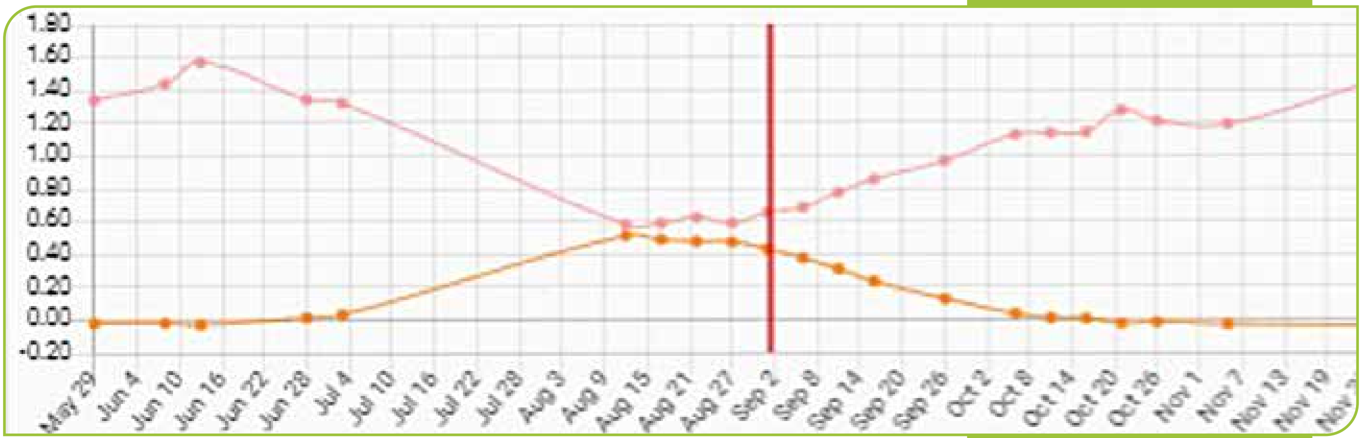
***Fig 1** – An SVI biomass satellite image from the 1st of September 2021 on the top and a MSI (Moisture Stress Index) map on the bottom. The maps are generally the inverse of one another, explained more below.*

WHAT IS A MOISTURE STRESS INDEX (MSI) MAP?

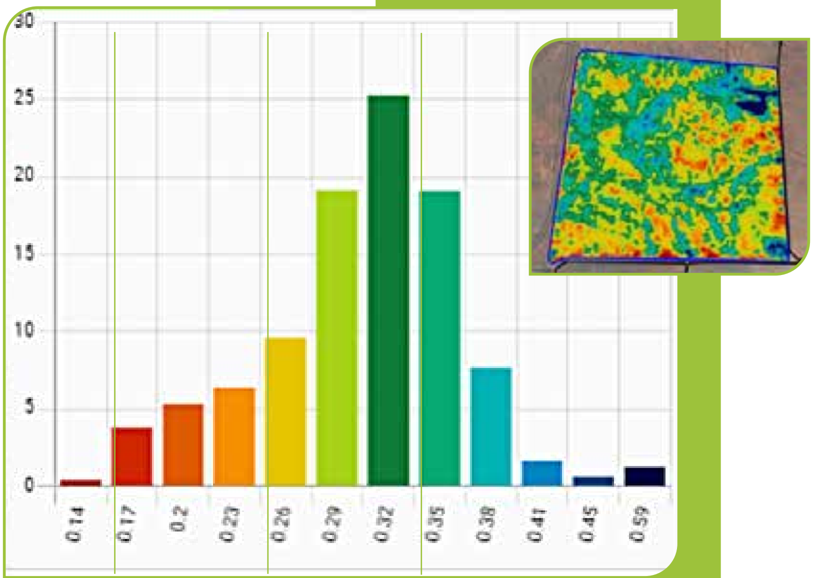
The MSI is an estimation of leaf water content. Near Infrared (NIR) is derived by shortwave infrared (SWIR). SWIR will reflect more as leaf water content decreases. NIR reflectance is not directly impacted by water content and is therefore used as a reference. Like Plant Cell Density (PCD), MSI is not normalised so we cannot know exactly what the range will be, but generally we see values from 0.4 to 2.

It is important to note that the values are inverted to a normal vegetation index. A high value indicates low water content/high plant stress.

Fig 2 – The correlation between moisture stress and biomass imagery was evident on the 1st of September. The MSI (pink) vs SVI (Orange). As the crop greenness diminishes, the moisture stress increases – a typical relationship.



The SVI image from the the 1st of September was divided up into four zones (right) based on SVI value. David also noted the area of each of the four zones. This map was downloaded as a KMZ file, so that it could be used as a layer with cellular GPS on his tablet. He then drove to each of the zones and made a correlation assessment. The decision was made to graze the paddock immediately.

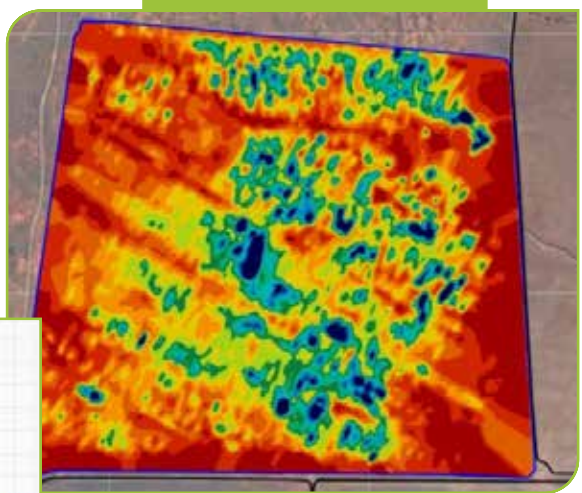


THE RESULTS

David was excited to have successfully used his imagery to make an informed, evidence based decision. He is keen to use the methodology in this case study in other areas of his crop management.

The main outcomes to note were:

- The satellite imagery indicated a moisture stress problem well in advance of physical assessment from a ute inspection
- The sheep grazed the poorer zones of the paddock, saving the higher biomass areas to be taken through to harvest, which added to the grazing benefit
- The sheep cleaned any volunteer wheat out of the barley as they grazed
- An extra 8 weeks of feed gained; other feed sources that would otherwise have been used were saved
- The barley crop was still worth harvesting and due to late spring rain David does not believe there was a yield penalty to this field despite the fact it was grazed



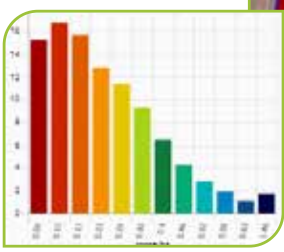


Fig 3 - The 2021 barley yield map

USING SATELLITE IMAGERY TO **SELECTIVELY SUMMER SPRAY** WITH **SECTION CONTROL**

THE GROWERS:
Scott and Luke Clark, Clark Forest View

FARMING ZONE:
Jamestown, SA

PADDOCK LOCATION:
Belalie

ANNUAL RAINFALL:
450mm

Satellite imagery helped the Clark Brothers cut their chemical bill by up to 87%, by selectively spraying weeds.

THE PROBLEM

In March 2021 the Clarks discovered volunteer canola had germinated where they had renovated shallow limestone patches in two of their paddocks – 'Bears West' and 'Back Paddock', the rest of the paddocks were relatively clean upon inspection. Scott and Luke turned to Satamap Vegetation Index (SVI) imagery in AgWorld to compare the map with what they were seeing in inspections. It was evident that the areas of the paddock that had germinated with canola were clearly defined in the satellite imagery.

THE SOLUTION

Scott and Luke could see potential in selectively spraying the weed areas given they were only affecting a small percentage of the paddock. They reached out to a precision ag consultant to create the prescription file. The boundary for the paddock was imported from John Deere Operations Centre to PCT AgCloud. PCT AgCloud uses the same Satamap enabled SVI imagery as Agworld, however there is the option to select a cloud free satellite map capture from your date of choice and download it for other applications. An SVI image from the 4th of April had the best correlation with what was seen in Agworld and in the paddock, so this was downloaded. At this point, a prescription could be created.

A spray prescription design was created for both Bears West and Back Paddocks, spraying 1.5 L/ha of Glyphosate on the canola patches. The self propelled boom spray had standard section control (11 sections), which was more than adequate for this operation.

THE RESULTS

'The concept worked well as the imagery picked up the weed affected areas very accurately, meaning we only sprayed 13% of one of our paddocks and 30% of the other. This spray run hit the big weeds we were targeting which means we could do our pre sowing spray at a lower rate, chemical saving for both passes, a win win.' - Luke Clark

Fig 4 (left to right) *– The Agworld SVI Image, the PCT AgCloud SVI Image, and the prescription made in PCT AgCloud. The green areas were sprayed and the red was left unsprayed.*

USING **SOIL COLOUR INDICES** AND **STRATEGIC SOIL TESTING** TO HELP DETERMINE **MANAGEMENT ZONES**

THE GROWERS:
Joe and Jessica Koch, Breezy Hill Ag

FARMING ZONE:
Booleroo Centre, SA

PADDOCK LOCATION:
Wepowie/Morchard

ANNUAL RAINFALL:
300mm

With the input prices soaring, farming in a low rainfall environment meant that nitrogen decisions had to be made strategically and precisely. RGB Soil Colour Maps made available through satellite imagery helped identify soil types in this zone.

THE PROBLEM

The 'Ruin' paddock at Breezy Hill is in a low rainfall zone, north of Goyders Line. Urea applications are made strategically, and usually in one singular pass. In 2021, the field was in a wheat rotation on the back of a 'vetchola' (vetch/canola) mix in 2020, which had been spray topped and grazed. It was hard to calculate the nitrogen fixation from the vetchola crop given that one of the crops is nitrogen (N) fixing and the other has a large nitrogen requirement.

The questions to answer for the 2021 wheat crop were:

- How much N (in the form of urea) is required to meet the yield potential of the wheat crop?
- Is a variable rate map an appropriate option given the paddock has significant historical yield variability?

THE SOLUTION

Step 1 – Determine representative zones to test

The soil types in this field are largely driven by topography. There are three distinct ridges that are heavily eroded, this is confirmed by a landscape change map layer (created from the elevation map). A simple 'Google Earth' image also gives clarity to the two distinct soil zones. It was decided that two Deep N tests should provide enough information to answer the question.

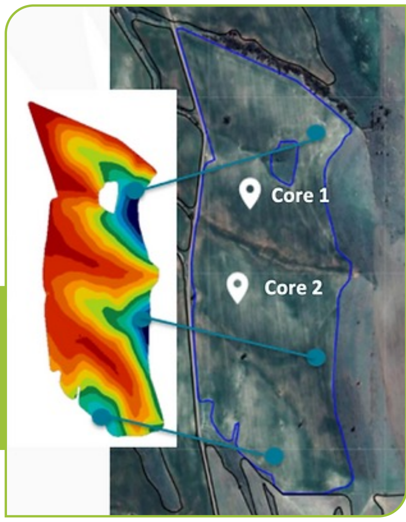


Fig 5 – The landscape change map on the left. The calcareous outcrops are evident on Google Earth as they are in the landscape change map as indicated by the blue markers. The two chosen soil core sites were placed in two representative zones.

Step 2 – Identify the yield potential for each zone

The yield potential in the paddock for 2021 was 5.2 t/ha, as calculated through the Angus and Sandras model (updated French and Scultz). Realistically though, it is not common to achieve yields this high due to various environmental limitations.

When considering seasonal rainfall to date, the long-term season forecast, and the historical yield in each zone, it was decided that the yield potential was not the same at core 1 as it was at core 2. The core 2 site historically yields higher, so this was given a yield potential of 3.5 t/ha. Core 1 was matched to a yield potential of 2.5 t/ha, due to hostile soil conditions.

Core 1 Yield Potential: 3.5 t/ha | **Core 2 Yield Potential:** 2.5 t/ha

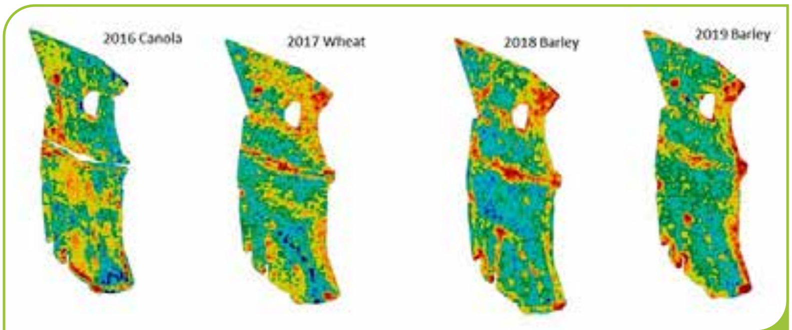


Fig 6 – The historical yield maps for Ruin paddock. The distinct zones and their yield potential are evident (blue/green – 3.5 t/ha, Red/Orange Zone 2.5 t/ha wheat yield potential for 2021)

Step 3 - Calculate units of N already available in the soil

The Deep N results provided the information for this part of the equation. It's important to consider the available nitrate in the upper and lower horizons and pair this with crop rooting depth.

Core 1: 0-30cm = **7 mg N/Kg** 30-60cm = **12 mg N/Kg** | Core 2: 0-30cm = **9 mg N/Kg** 30-60cm = **9 mg N/Kg**

Step 4 - Estimate mineralisation for the rate of the season

Factors that fed into the mineralisation calculation, included; the organic N within the soil, soil organic carbon, soil temperature, previous crop rotations and moisture availability. The information was fed into a program called Back Paddock, which calculated the estimated N mineralisation at each depth at each core.

	Core 1		Core 2	
Analyte	***0-30cm***	***30-60cm***	***0-30cm***	***30-60cm***
Nitrate mg/kg	7	12	9	9
Estimated N Mineralisation	41	42	34	56

Step 5 - Calculate remaining N requirement to meet the yield potential

The last step was to calculate the gap between the amount of available N in the soil, and the requirement to meet the yield potential at each core site.

The N requirement at Core 1 (yield potential 3.5 t/ha) is 52 kg of N. With 83 kg of N available between the two depths, the urea requirement to meet yield potential at this site was 0 kg/ha.

The N requirement at Core 2 (yield potential 2.5 t/ha) is 37 kg of N. With 90 kg of N available between the two depths, the N requirement to meet yield potential at this site was 0 kg/ha.

	Core 1		Core 2	
Analyte	***0-30cm***	***30-60cm***	***0-30cm***	***30-60cm***
Nitrate mg/kg	7	12	9	9
Estimated N Mineralisation	41	42	34	56
Estimated Remaining N Requirement	*52 kg/ha*	*52 kg/ha*	*37 kg/ha*	*37 kg/ha*

SO, TO ANSWER THE QUESTIONS….

How much urea was required to meet the yield potential of the crop in 2021?

0 kg/ha - Through our four step calculation process we could determine the soil N requirement was adequate to meet the yield potential of the crop at both core site's, therefore no urea was applied.

Was a variable rate map an appropriate option given the field has significant yield variability?

In 2021, a variable map was not required, given that the total N requirement to meet the yield potential in each zone had already been met through fixed N. However, what the exercise did highlight, was that the yield potential in the different zone varies, as does the amount of available N. A variable rate N application will certainly be considered in the future to confirm this hypothesis.
After the decision was made to not spread the ruin paddock in August, the season began to shut off with the next significant rainfall event coming in late October. Despite the dry finish, and no top dressed N applied, the Koch's were able to produce a wheat crop that averaged 2.94 t/ha. In the future, the Koch's will utilise the knowledge gained from this exercise to spread from an N removal map, using the protein and yield maps from the harvester.

USING **SATELLITE MAPPING** TO **SUPPORT GRAZING DECISIONS** AT A **MIXED SPECIES PASTURE DEMONSTRATION SITE**

THE GROWERS:
Alison Henderson, Hendowie Poll Merinos

FARMING ZONE:
Caltowie, SA

PADDOCK LOCATION:
Caltowie/Appila

ANNUAL RAINFALL:
370mm

PADDOCK NAME:
AB17 'Sambells' block

Having a true understanding of the feed on hand is the key to unlocking grazing efficiencies. Through satellite imagery and trialling the performance of their flock grazing mixed species vs single species pastures, Alison and the team at Hendowie Poll Merino's could gain better insights for their management decisions

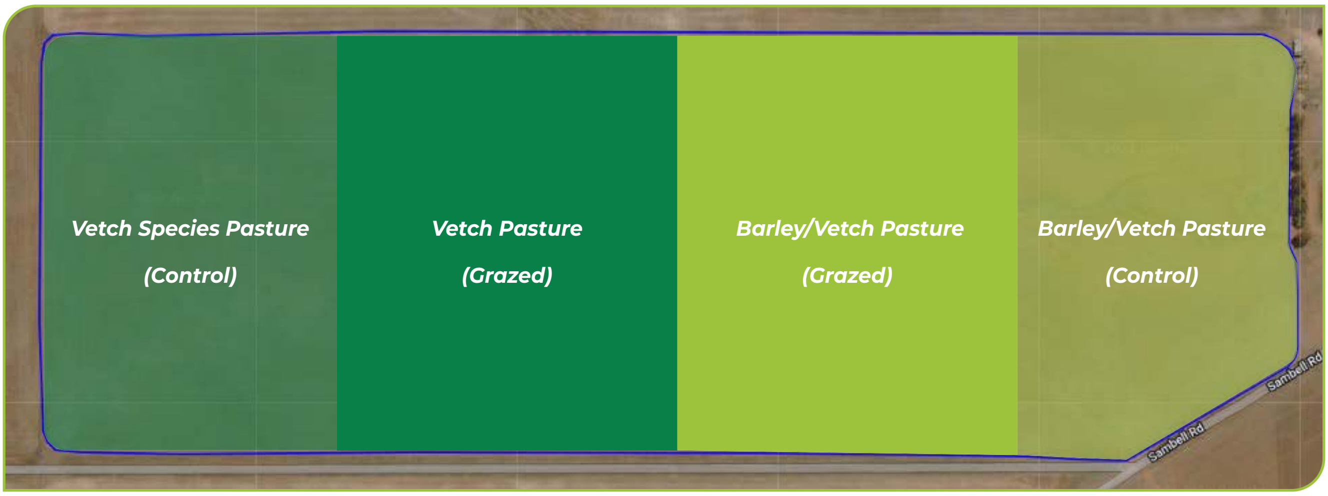
THE QUESTIONS

Will the performance (in terms of average weight gain) be improved on a multi species vs single species pasture?

Aim: Improve the pasture management systems using satellite Imagery to have a better understanding of the feed on offer.

THE PROCESS

To investigate these ideas, a pasture demonstration site was set up in a 50ha paddock on the Henderson's farm, with a fence running north-south through the centre. The concept was to put a mob of 96 sheep on each of the two pasture types for a one-month period, leaving a control zone on the outside(s).



The pastures were:

Single Species (Rasina vetch)

- to the left of the centre fence

Mixed species (Kraken barley/Rasina vetch)

- sown on the right of the centre fence

Both pastures were dry sown on April 23rd and germinated in June after an opening rain on the 30th of May. Prior to the sheep entering the paddock, the mixed pasture showed higher amounts of biomass using the satellite imagery. This is evident in the pre-graze image figure 8, below. The paddock had a large outcrop of Ryegrass and Medic present. The mobs were weighed and then put onto the respective demonstration sites on the 2nd of August, and then removed on the 29th of August and weighed again.

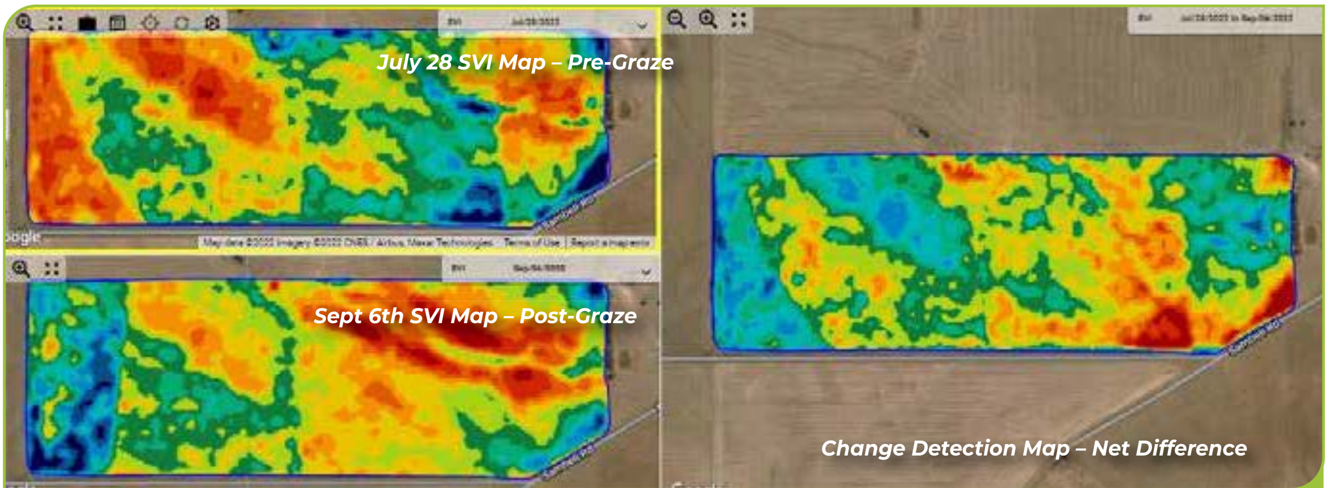


***Fig 8** – 'Change Detection Map' – Above right, shows the net difference in pasture vegetation over the grazing time – the mixed species was grazed more evenly. The vetch single species was more harshly grazed where there was an accumulation of ryegrass in a strip, explained more below.*

THE RESULTS

The key learnings from the demonstration site:

- Alison Henderson observed that the mixed species was grazed more evenly than the singles species. The change detection map highlights this.
- The animals on the mixed species (vetch/barley) gained an average of 1.25 kg more per animal over the grazing period (see figure 9)
- There was less variability in the average weight results across the mixed species mob compared to the single species
- The sheep from both pasture compositions were condition scored and weighed after the grazing period ended on the 29th of August, and the condition scores were higher for the mixed species mob - which is consistent with the weight gain results
- The Feed Tests confirmed that the dry matter (DM)% in the mixed species was 30.4% vs 26.3% in the vetch only, meaning the mob on the single species had to consume more pasture volume to obtain the same DM content

Vetch			Vetch/Barley		
Daily Weight Gain g/hd	Start Weight kg	End Weight kg	Daily Weight Gain g/hd	Start Weight kg	End Weight kg
146.87	46.22	50.01	266.38	47.47	55.4

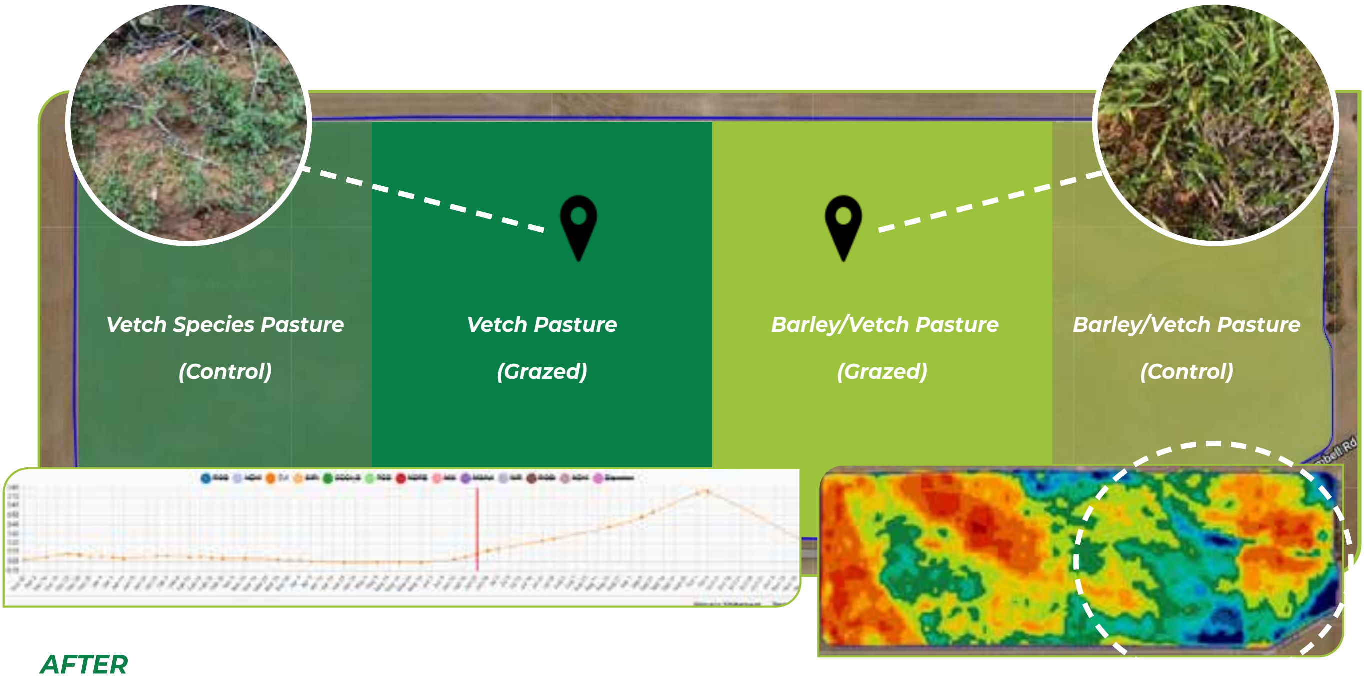
Fig 9 – *A summarised table of the weight gain of the mob on the vetch single species pasture, vs the vetch/barley mixed pasture*

PASTURE CUT OBSERVATIONS

Pasture cuts were taken pre-graze on the 1st of August and post-graze on the 14th September.

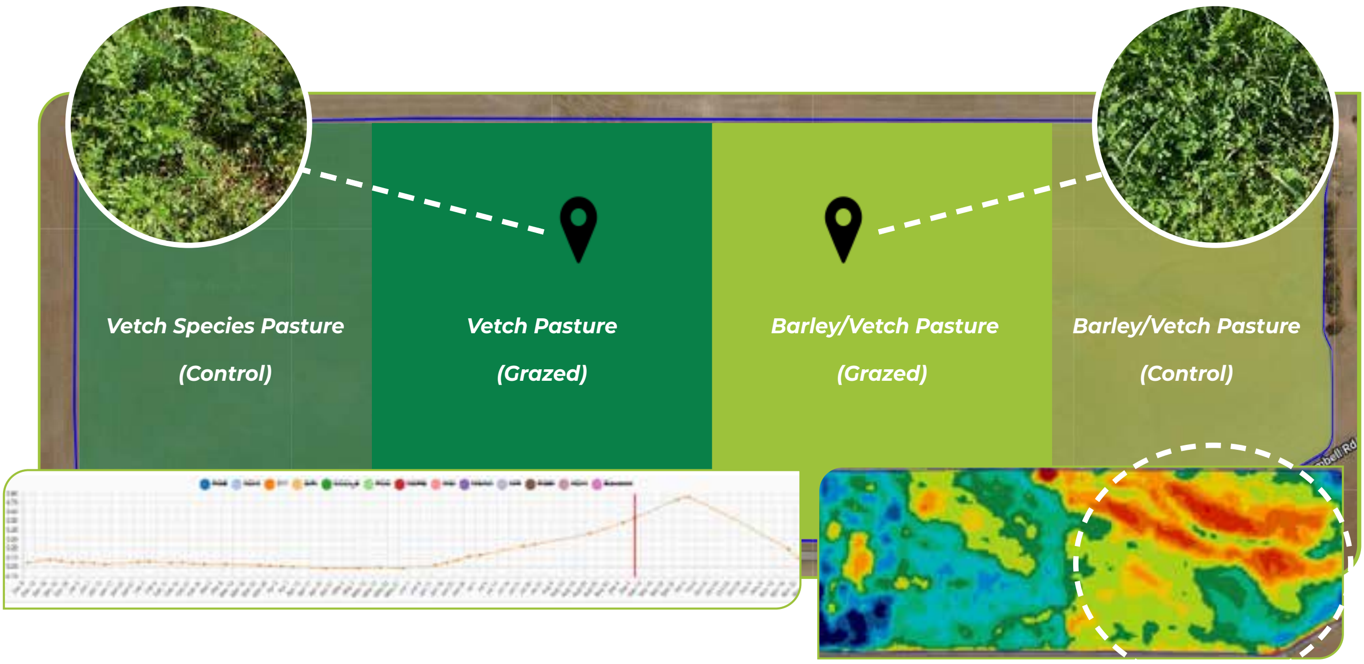
BEFORE

Prior to the graze (July 29th) the mixed pasture through the SVI satellite imagery indicated thicker or greener canopy cover than the single species. The pasture cuts from the two sites at this earlier date confirmed this through ground truthing.



AFTER

As the pasture demonstration zones were grazed, the mixed species pasture showed a more even grazing pattern. It also highlighted the effect of different soil types on the vigour of the pasture as the root systems ventured into the subsoil.



GROWER OBSERVATIONS

Alison observed that sheep grazed the mixed species side of the trial very uniformly. In contrast, the single species vetch pasture was slow to gain biomass at the beginning of the season, seen on the SVI image captured the 29th of July. Once livestock were added to the monoculture vetch pasture, sheep congregated throughout the middle of the paddock (the diagonal trend you can see in the SVI image from the 6th of September, see figure 8). They were selectively grazing this strip as there was ryegrass through this zone of the paddock they were seeking out. The patches with less ryegrass and more vetch were left to accumulate biomass, as sheep did not move out to these sections to graze the zone to its boundaries.

Summary

- In the mixed species pasture sheep were able to gain more weight in contrast to the mob in the vetch monoculture, as they were taking advantage of feed throughout the entire available pasture zone and hence had more 'feed on offer'. Conversely, the mob on the vetch were concentrating their grazing to a smaller section of their zone. This meant there was less feed for this mob and hence they gained less weight. This is reflected by the average weight gain values.
- There is a greater spread in the data for the mob on the vetch monoculture when considering the average weight gain. It appears selective grazing in this zone on the ryegrass patch led to a disadvantage for the 'shy feeders' in the mob, resulting in them gaining less weight.

'We are trying to achieve "Regenerative Grazing" which is ultimately about rotating animals through pastures at the right time. Satellite imagery will be a powerful tool to help make these decisions. The flow on effects of this information may also assist us manage pasture recovery and soil cover.' – Alison Henderson

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ACKNOWLEDGEMENTS

This fact sheet is part of the 'Using Satellite Imagery in the Growing Season to Inform Adaptive Management' Project' and the 'Pasture Demonstration Sites' funded by the SA Drought Hub, as an initiative of the Upper North Farming Systems.

The data and analysis were compiled and written by Jessica Koch of Breezy Hill Precision Ag Services together with Rachel Trengove, Upper North Farming Systems and Bethany Humphris, Elders Jamestown, with review from the Upper North Farming Systems committee and staff. Morgan McCallum conducted the plant counts and compilation of statistics.

A special acknowledgement to the growers – the Clarke, Clark, Koch and Henderson families for being generous with the use of their data and their input with interpretation and analysis.

Australian Government
Department of Agriculture, Fisheries and Forestry

Future Drought Fund

SA DROUGHT HUB

This program received funding from the Australian Government's Future Drought Fund

CROP AGRONOMY

CANOLA PROFITABILITY *as a* BREAK CROP *in the* UPPER NORTH?

Author: Jade Rose, *Upper North Farming Systems* | **Funded By:** *South Australian Grains Industry Trust*

Project code: *UNF-02822-R* | **Project Duration:** *2022-2025* | **Project Delivery Organisations:** *Upper North Farming Systems, AgXtra*

Key Points

- Canola varieties performed exceptionally well across all three trial locations, averaging between 2-3.5 t/ha in 2022. Longer maturing varieties and newer varieties generally outperformed the shorter season varieties.
- Oil content was high in most varieties at all trial sites (> 42%) with most averaging above that level, leading to oilseed premiums.
- All canola varieties at all trial locations were profitable in 2022, with gross margins ranging between $417- $1754 per hectare.
- At Melrose and Morchard growing all varieties of canola were more profitable than growing wheat. At Wandearah, several varieties (not all) were more profitable than wheat (treat results with caution, trial affected by weeds).

Background

This project aims to:

- Assess the profitability of different canola agronomy packages in local validation trials (GM vs
- open poll TT) against wheat over a three-year project.
- Inform grower decision making by exploring if new technology in canola could see it become a more reliable and viable break crop option in the Upper North Agricultural Zone (UN).
- A key factor of this project is improving the profitability and soil health of farming enterprises, particularly those without sheep in the system.

Methodology

There were three trial sites (Wandearah, Melrose and Morchard) based in the Upper North, to represent a vast and diverse area in terms of rainfall, rotations, and soil types of the region. Eight varieties of canola were selected for the trials (Table 1), these were selected after in-depth discussion from UNFS members and breeders. The varieties selected were based on their agronomy packages (TT, Truflex, RR, CL) pollination type, genetically modified and maturity characteristics.

Each trial included four replications and was a complete randomized block design (RCBD) with a separate row of wheat separated by a buffer.

Table 1 . *Treatment list including canola varieties and control (wheat) and trial layout in 2022 for sites at Wandearah, Melrose and Morchard.*

Trial Map Treatment Description

Trt	Code	Description
1		Canola cv. Hyttec trident
2		Canola cv. ATR Bonito
3		Canola cv. Emu
4		Canola cv. 43Y92CL
5		Canola cv. 44Y94CL
6		Canola cv. 44Y30RR
7		Canola cv. InVigour T 4510
8		Canola cv. AGTC0034
9	CHK	Wheat cv. Calibre

401 7	402 3	403 2	404 8	405 4	406 1	407 5	408 6		409 9
301 4	302 8	303 7	304 5	305 6	306 3	307 1	308 2		309 9
201 5	202 1	203 6	204 7	205 2	206 8	207 4	208 3		209 9
101 1	102 2	103 3	104 4	105 5	106 6	107 7	108 8		109 9

Table 2 . *Sowing details in 2022 for each trial site location, Wandearah, Melrose and Morchard, SA.*

Trial Location	Sowing Date	Details	Fertiliser
Wandearah	13th May 2022	Dry, 10mm depth	100kg Granulock Z + Flutriafol 2 x applications 80 L UAN
Melrose	3rd June 2022	Moist, 10mm depth	100kg Granulock Z + Flutriafol 2 x applications 80 L UAN
Morchard	3rd June 2022	Moist, 10mm depth	100kg Granulock Z + Flutriafol 2 x applications 80 L UAN

Table 3 . *Sowing details in 2022 for each trial site location, Wandearah, Melrose and Morchard, SA.*

Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Wandearah	23.2	7.8	0.0	4.0	38.6	19.2	6.4	39.0	51.2	77.0	64.4	15.6
Melrose	91.2	12.6	0.0	6.0	75.0	29.0	7.6	93.4	82.4	59.0	110.2	18.0
Morchard	21.2	8.5	5.5	2.5	20.0	10.75	1.0	33.75	63.5	64.25	66.5	19.5

Results and Discussion

The 2022 season had a late start for many areas in the region, resulting in these trials being sown later than anticipated. These trials also suffered moisture stress in the middle of the season with below average growing season rainfall (Table 3), however; this was followed by higher late spring rainfall. This resulted in a large variation in yields dependent on the location.

- In the Wandearah trial, on the 26th of August, Emu was flowering at 60% followed by Renegade at 40%, Pioneer 43Y92 at 30% and the remaining varieties at 20%. The variety Pioneer 44Y94CL performed well, yielding 3.1 t/ha, however yielded statistically equivalent to HyTTec Trident, ATR Bonito, Nuseed Emu TF and Pioneer 44Y30RR (Figure 1). The wheat yielded higher than canola at 4.94 t/ha, however, pressure from Turnip weed (Rapistrum rugosum) was high, therefore could affect overall results.
- In the Melrose trial, on the 5th of September, Emu was flowering at 20%, Renegade at 10%, Pioneer 43Y92 and Trident at 5% and remaining varieties at 0%. The variety Pioneer 44Y30RR performed well, yielding at 3.01 t/ha, which was statistically equivalent to Pioneer 44Y94CL yielding at 2.78 t/ha (Figure 2). Calibre wheat yielded at 2.14 t/ha, however, there was high ryegrass pressure within this treatment, which may have impacted results for this season.
- In the Morchard trial, all varieties were flowering by the 20th of September. The varieties Emu, Pioneer 43Y92CL, Pioneer 44Y94CL and GM variety Pioneer 44Y30RR all performed equally (Figure 3), yielding between 3.17-3.45 t/ha. These yields were exceptional and showcased the robustness of canola in some seasons, given that the trial had barely emerged by September 5th (Image 1) but still achieved a high load of biomass between September and October (Image 2).
- Canola at Melrose and Morchard achieved high oil content (> 42%) with most averaging above that level leading to oilseed premiums (Table 4). Canola at the Wandearah site averaged slightly below 42%, however; all Clearfield varieties (Pioneer 43Y92CL, Pioneer 44Y94CL and Pioneer 44Y30RR) averaged above 42%.

Table 4 . *Summary of oil content (%) for canola varieties trialled at Wandearah, Melrose and Morchard, SA in 2022. Shaded values in each column show the highest performing varieties for each location. Treatments with the same letter are not significantly different.*

Technology	Variety	Wandearah	Melrose	Morchard
		Oil Content %		
Triazine Tolerant and stacked	HyTTec Trident	41.85 c	45.92 ef	46.12 cd
	InVigour T 4510	41.62 c	45.33 f	45.62 d
	ATR Bonito	41.87 c	46.62 cd	47.97 a
	AGTC0034 (Renegade TT)	41.9 c	46.99 bc	46.85 bc
Roundup Ready®, TruFlex® and stacked	Nuseed Emu TF	42.72 bc	46 de	46.93 bc
Clearfield®	Pioneer 43Y92CL	45.06 a	47.25 abc	47.04 abc
	Pioneer 44Y94CL	44.55 ab	47.64 a	47.05 abc
	Pioneer 44Y30RR	43.38 abc	47.58 ab	47.33 ab
LSD P = 0.05		1.9	0.6	0.9

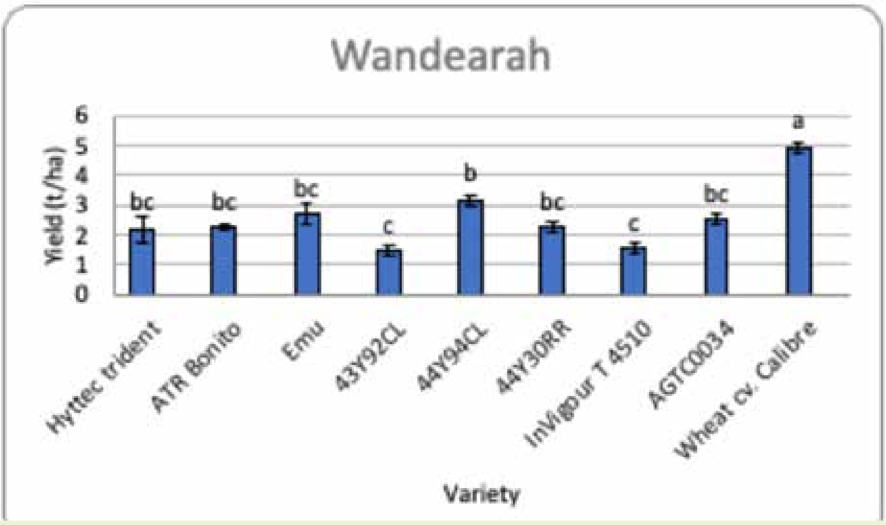

Figure 1 . *Yield data for canola varieties against wheat variety Calibre located at Wandearah, SA in 2022. Values are means of yield for each variety, error bar is (±SE). Treatments with the same letter are not significantly different.*

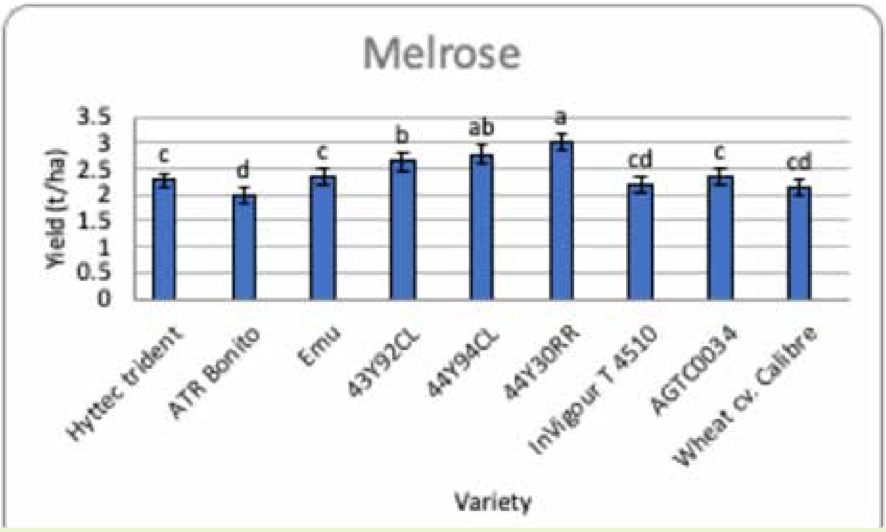

Figure 2 . *Yield data for canola varieties against wheat variety Calibre located at Melrose, SA in 2022. Values are means of yield for each variety, error bar is (±SE). Treatments with the same letter are not significantly different.*

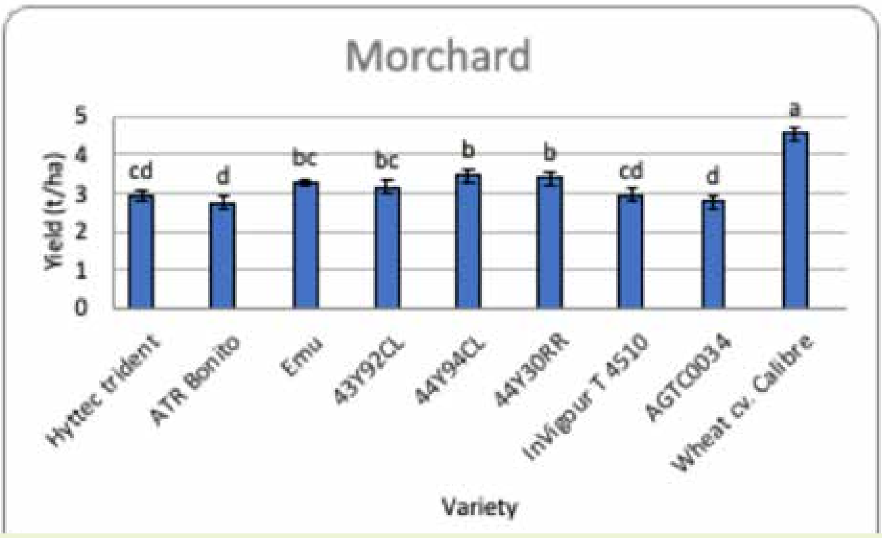

Figure 3 . *Yield data for canola varieties against wheat variety Calibre located at Morchard, SA in 2022. Values are means of yield for each variety, error bar is (±SE). Treatments with the same letter are not significantly different.*

Table 5 . *Indicative Gross margins for Canola and Wheat treatments in 2022. Price assumptions based on the PIRSA Gross Margin Guide 2022, prices forecast for LOW rainfall zone and contract rates for machinery Ops. Canola prices adopted by technology type: Clearfield = $750/tonne, RR = $720/tonne, Tri-Tolerant = $750/tonne. Wheat = $350/tonne.*

Wandearah									
Variety	HyTTec trident	ATR Bonito	Nuseed Emu TF	Pioneer®, 43Y92CL	Pioneer®, 44Y94CL	Pioneer®, 44Y30RR	InVigour T 4510	AGTC0034 (AGT Renegade TT)	Wheat cv. Calibre
Yield	2.2	2.2	2.7	1.5	3.1	2.2	1.5	2.5	4.9
Gross Margin ($/ha)	905	905	1258	417	1543	910	412	1116	1191
Melrose									
Yield	2.2	1.9	2.35	2.6	2.7	3.0	2.1	2.3	2.1
Gross Margin ($/ha)	905	694	1022	1191	1261	1473	834	975	310
Morchard									
Yield	2.9	2.7	3.2	3.1	3.4	3.3	2.9	2.7	4.5
Gross Margin ($/ha)	1397	1257	1595	1543	1754	1684	1397	1257	1065

**This data should only be used a guide, pricing sourced from 2022 forecasts.*

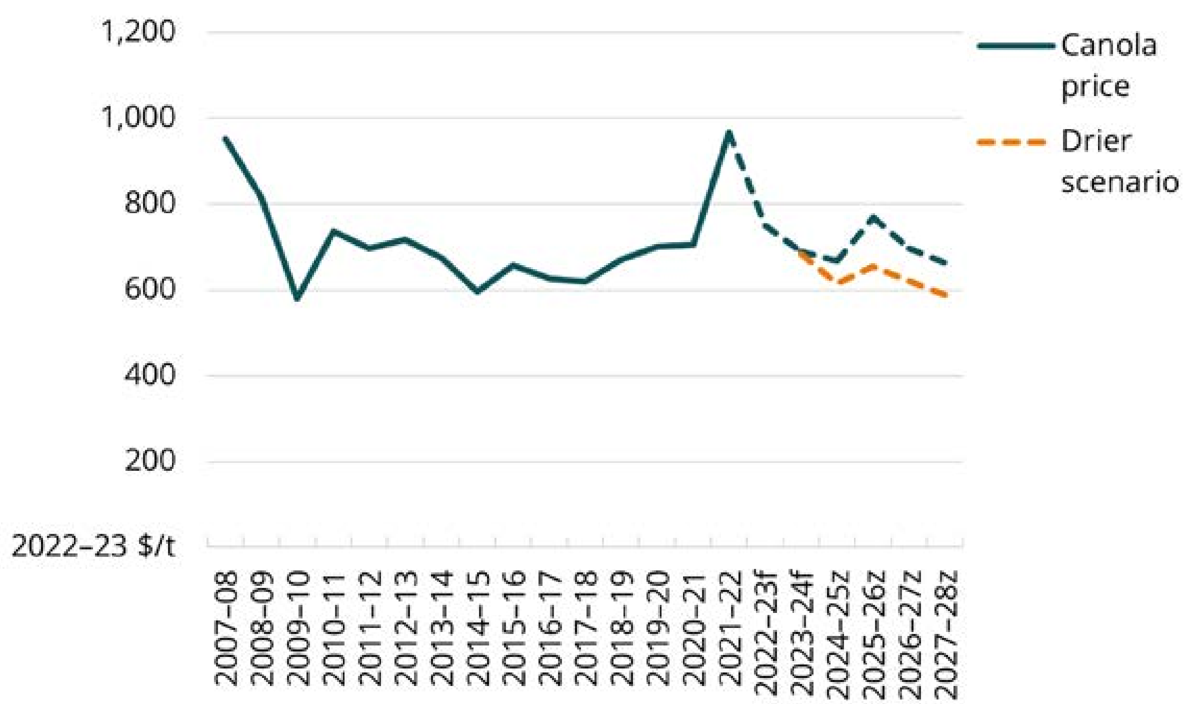

Figure 4 . *Real canola price, Australia, 2007-8 to 2027-28. ABARES forecast/projection.*

The value of Australian canola production was at a record high in 2022-2023 at 1% higher than 2021-2022 (Figure 4). It is expected that decreasing prices will drive the value of canola production down 37% in 2023-2024. It is also expected that canola production forecast will lower from 2023-2024 onwards due to drier conditions. It is also possible that the rising global supply of oilseeds especially Canadian canola is expected to weigh on canola prices. The Australian canola price is expected to average $720 per tonne in 2023-2024, decreasing 4% than the average in 2022-2023. It is expected that canola prices may range between $588 t/ha to $654 t/ha over the 2027-2028 period. Wheat = $350/tonne.

Image 1: *The canola trial at Morchard, SA on 5th of September 2022 (Left) and 6th October, 2022.*

Image 2: *The canola trial (birdseye) at Melrose, SA in September 2022.*

Acknowledgements

- Upper North Farming Systems would like to acknowledge SAGIT for funding this trial. We would also like to thank Pioneer®, Nuseed, BASF and AGT for providing seed.
- A big thankyou to our trial hosts Andrew Catford, Andrew Walter and Brendon Johns, we truly appreciate your help.

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Section Editor:
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Section
2

Farming Systems

Best practice for early sowing opportunities

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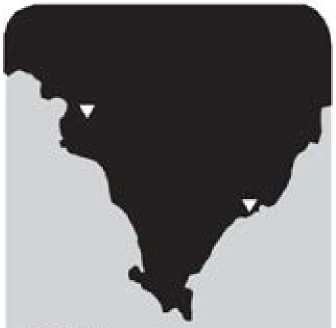

Location
Penong
Rainfall
Av. Annual: 317 mm
Av. GSR: 240 mm
2022 Total: 404 mm
2022 GSR: 331 mm
Paddock History
2021: Legume pasture
2020: Wheat
2019: Wheat
Soil type
Sandy loam pH($CaCl_2$): 7.7
Plot size
10 m x 1.5 m x 3 reps x 25.4 cm row spacing

Location
Cowell
Rainfall
Av. Annual: 260 mm
Av. GSR: 125 mm
2022 Total: 510 mm
2022 GSR: 235 mm
Paddock History
2021: Pasture (ploughed with offset in November)
2020: Barley
2019: Wheat
Soil type
Sandy loam pH($CaCl_2$): 7.4
Plot size
10 m x 1.5 m x 3 reps x 25.4 cm row spacing

Key messages

- **Early sowing did not mean dry sowing in 2022 due to available soil water.**
- **Urea placed with the seed lowered plant establishment at Cowell when combined with both DAP and MAP, but only reduced early dry matter when placed with DAP.**
- **Fertiliser type and placement did not influence grain yield at either site.**
- **Seed priming did not improve crop establishment or grain yield.**
- **Calibre long coleoptile wheat did not improve crop establishment but gave the highest yield at Cowell of 3.0 t/ha.**

Why do the trial?

A workshop held in Wudinna by the South Australian Drought Resilience Adoption and Innovation Hub (SA Drought Hub) in August 2021 identified early sowing as a priority topic for the Hub's Minnipa Node, which covers the upper Eyre Peninsula (EP). The workshop was attended by growers, industry organisations, farmer groups, researchers and community members.

As a result, the 'Best practice for early sowing opportunities' project, led by AIR EP and delivered by SARDI Minnipa Agricultural Centre, was developed to extend the results of the SAGIT investment into "Improving the early management of dry sown cereal crops" (EPFS Summary 2021, p. 76).

The key findings from the SAGIT research project (2019-2021) were:

- Greater plant establishment was achieved with fertiliser placed 3 cm below the seed.
- Lower plant establishment occurred when urea was placed with the seed.
- If fertiliser separation cannot be achieved due to seeding systems, then MAP (10:22) with the seed is a safer option than DAP (18:20) with the seed.
- New long coleoptile wheats may provide another option for early plant establishment and vigour in areas where soil moisture is available up to 10 cm deep.
- It is important to sow seed at a depth sufficient for utilising soil moisture for germination.

How was it done?

Demonstration sites were established in low-rainfall farming systems to:

1. Showcase practices to reduce fertiliser toxicity and increase plant establishment in early sowing situations.
2. Determine if seeding opportunities and crop establishment can be improved by using newly developed long coleoptile wheat varieties and/or seed priming.
3. Determine if early sowing offers other measurable benefits to the farming system, such as biomass production (for livestock feed), weed control or yield.

Sites were sown on 22 April 2022 at Penong (Cade Drummond) on a calcareous red sandy loam, and on 23 April 2022 at Cowell (Tyler Kaden) on a sandy loam. Either Scepter wheat @ 72 kg/ha and 3.5 cm deep or Calibre wheat @ 72 kg/ha at a depth of 6 cm was seeded. Penong was sprayed with Trifluralin @ 1.5 L/ha, LI700 @ 500 ml/100 L, Weedmaster DST @ 3 L/ha and Hammer @ 80 ml/ha. Cowell was sprayed with Weedmaster DST @ 2 L/ha, LI700 @ 400 ml/100 L, Hammer @ 80 ml/ha and Estericide xtra 680 @ 400 ml/ha. The Cowell site was also sprayed with Lorsban @ 2L/ha to target grasshoppers and both sites were treated with mouse bait.

Fertiliser rates were the district practice of 60 kg/ha DAP, or MAP sown at 55 kg/ha plus 5 kg N/ha as urea (sown 3 cm below the seed) to provide the same amount of nitrogen as with DAP. In addition, 25 kg/ha of urea was applied either with the seed or 3 cm below, depending on the treatment.

Seed was primed by soaking for 4 hours in water or in potassium sulphate solution and then air-dried before sowing (Table 1).

Early dry matter (DM) cuts were taken on 22 June at Penong and 23 June 2023 at Cowell. Late DM cuts were taken on 13 September at Penong and 5 October 2022 at Cowell.

Wheat was harvested at Penong on 24 November and Cowell on 17 November 2022.

What happened?

Early sowing in 2022 did not mean dry sowing at these sites with Penong having adequate soil moisture and Cowell very wet soil on the day of seeding. Crop establishment averaged 142 plants/m² at Penong and 124 plants/m² at Cowell, both well below the target of 180 plants/m². Seed priming did not improve crop establishment at either site, which is not surprising given that seedbeds were moist for both trials (Table 2). At Penong, Calibre had the highest plant counts, but was similar to several other treatments sown at the normal seeding depth (Table 2). Potassium sulphate in furrow did not improve crop establishment in this one season.

Wheat sown with DAP, MAP or no fertiliser all had similar crop establishment due to the ideal seeding conditions experienced at the two sites (Table 2). Plant establishment at Cowell was poorer when NP fertiliser and urea were placed with the seed, compared to when it was placed below the seed.

Table 1. Early sowing treatments at Penong and Cowell in 2022. Scepter was used in all treatments except for first two (Calibre was used).

Treatment	Seeding strategy
Calibre, primed	Sown at 6 cm with 55 kg/ha MAP + 5 kg/ha urea
Calibre, unprimed	
DAP + urea below seed	60 kg/ha DAP + 25 kg/ha urea applied 3 cm below seed
DAP + urea with the seed	60 kg/ha DAP + 25 kg/ha urea applied with the seed
DAP with seed	60 kg/ha DAP applied with seed
MAP + urea below seed	55 kg/ha MAP + 30 kg/ha urea applied 3 cm below seed
MAP + urea with the seed	55 kg/ha MAP + 30 kg/ha urea applied with the seed
MAP with seed	55 kg/ha MAP + 5 kg/ha urea applied with the seed
Nil fertiliser	No fertiliser
Primed with K_2SO_4 normal depth	55 kg/ha MAP + 5 kg/ha urea applied with seed primed in K_2SO_4 for 4 hours
Unprimed, K_2SO_4 fluid, normal depth (control)	55 kg/ha MAP + 5 kg/ha urea applied with the seed, K_2SO_4 solution with seed
Primed, normal depth (4 hours)	55 kg/ha MAP + 5 kg/ha urea applied with the seed primed in water for 4 hours
Unprimed, normal depth (control)	55 kg/ha MAP + 5 kg/ha urea applied with the seed

Table 2. Crop establishment at Penong and Cowell with different seeding strategies in 2022 (plants/m²). Scepter was used in all treatments except for first two (Calibre was used).

Treatment	Penong (plants /m²)	Cowell (plants /m²)
Calibre long coleoptile primed (4 hours)	155 a	131 a
Calibre long coleoptile unprimed	166 a	132 a
DAP + urea below seed	148 ab	137 a
DAP + urea with the seed	114 b	85 b
DAP with seed	127 b	118 ab
MAP + urea below seed	146 ab	147 a
MAP + urea with the seed	113 b	95 b
MAP with seed	146 ab	119 ab
Nil fertiliser	151 ab	138 a
Primed K_2SO_4 seed normal depth (4 hours)	126 b	138 a
Unprimed seed K_2SO_4 fluid normal depth (control)	144 ab	126 a
Primed seed normal depth (4 hours)	152 ab	126 a
Unprimed seed normal depth (control)	154 a	119 ab
LSD (P = 0.05)	*27*	*30*

Unprimed Calibre had the highest early dry matter (DM) at Penong and visually appeared to be growing the most vigorously (Table 3). At Cowell, early DM production of Calibre was similar to most of the Scepter treatments. At Cowell, DAP and urea placed with the seed resulted in lower early DM than when the fertiliser was placed below the seed (Table 3). When MAP fertiliser was used, there was no reduction in DM when urea was placed with the seed at either site. Wheat without fertiliser (Nil fertiliser) resulted in the least vigorous growth and DM at both sites of all treatments and comparable to DAP + urea with the seed at Penong.

Grain yields were lowest with the nil fertiliser treatment at both sites, however at Penong this yield was still similar to five of the other treatments, including the MAP with seed treatment. At Cowell, unprimed Calibre yielded better than all the other treatments (Table 4). Fertiliser type and placement did not influence grain protein at either site but at Penong proteins were higher with extra urea.

Table 3. Early dry matter (t/ha) and with different seeding strategies at Penong and Cowell, 2022.

Treatment	Penong Early DM (t/ha)	Cowell Early DM (t/ha)
Calibre long coleoptile primed (4 hours)	1.00 ab	1.57 ab
Calibre long coleoptile unprimed	1.17 a	1.44 ab
DAP + urea below seed	0.69 bc	1.66 a
DAP + urea with the seed	0.60 c	1.30 b
DAP with seed	0.67 bc	1.43 ab
MAP + urea below seed	0.75 bc	1.52 ab
MAP + urea with the seed	0.81 bc	1.49 ab
MAP with seed	0.94 ab	1.25 b
Nil fertiliser	0.56 c	0.94 c
Primed K_2SO_4 seed normal depth (4 hours)	0.88 b	1.30 b
Unprimed seed K_2SO_4 fluid normal depth (control)	1.08 ab	1.32 b
Primed seed normal depth (4 hours)	0.84 bc	1.45 ab
Unprimed seed normal depth (control)	1.15 a	1.29 b
LSD (P = 0.05)	*0.25*	*0.29*

Table 4. Wheat grain yield (t/ha) and protein (%) with different seeding strategies at Penong and Cowell, 2022.

Treatment	Penong Grain Yield (t/ha)	Penong Grain Protein (%)	Cowell Grain Yield (t/ha)	Cowell Grain Protein (%)
Calibre long coleoptile primed (4 hours)	1.68 bc	9.0 b	2.82 b	10.9
Calibre long coleoptile unprimed	1.74 b	9.2 b	3.02 a	11.2
DAP + urea below seed	2.03 ab	10.4 a	2.73 bc	10.8
DAP + urea with the seed	1.57 bc	10.3 a	2.56 c	10.7
DAP with seed	1.86 ab	10.0 ab	2.59 c	10.9
MAP + urea below seed	1.86 ab	10.1 ab	2.59 c	10.8
MAP + urea with the seed	1.86 ab	10.3 a	2.51 c	11.2
MAP with seed	1.59 bc	9.3 b	2.57 c	10.8
Nil fertiliser	1.36 c	8.8 b	2.20 d	11.3
Primed K_2SO_4 seed normal depth (4 hours)	1.67 bc	8.5 b	2.54 c	11.2
Unprimed seed K_2SO_4 fluid normal depth (control)	1.78 b	9.4 b	2.58 c	10.9
Primed seed normal depth (4 hours)	1.81 ab	9.4 b	2.59 c	10.8
Unprimed seed normal depth (control)	2.13 a	9.5 b	2.50 c	10.8
LSD (P = 0.05)	*0.33*	*0.7*	*0.18*	*NS*

What does this mean?

With wet seeding conditions and above average growing season rainfall across the upper EP, this was a demonstration of early sowing practices rather than dry sowing practices.

Urea placed with the seed lowered plant establishment at Cowell when combined with either DAP or MAP, demonstrating that better crop establishment can still be achieved by placing urea 3 cm below the seed, even in wet seeding conditions. Urea with the seed only reduced early DM when placed with DAP. MAP is preferred to DAP in situations where fertiliser is being placed in seed rows.

However, reduced crop establishment from urea in the seed row did not decrease grain yield or quality in these results of one season only.

Seed priming did not improve crop establishment or grain yield as all the seeds had access to good soil moisture at germination. Potassium sulphate solution applied in furrow at seeding also did not improve crop establishment in this one season.

As the wet seed beds negated any advantage to better access sub-soil moisture for seed germination, Calibre did not improve plant establishment but still performed very well compared to Scepter.

This demonstration trial will be continued in 2023 to allow another year for comparison of findings.

Acknowledgements

This project is supported by the South Australian Drought Resilience Adoption and Innovation Hub, which is one of eight Hubs established across Australia through the Australian Government's Future Drought Fund. The SA Drought Hub brings together a dynamic network of primary producers, industry groups, researchers, government agencies, universities, agribusinesses, traditional owners and others to work towards a common vision to strengthen the drought resilience and preparedness of farms and regional communities in South Australia. This project received funding from the Australian Government's Future Drought Fund.

Thank you to Cade Drummond and Tyler Kaden for hosting the demonstration sites on their farms; and to Katrina Brands and Rebbecca Tomney for their assistance in completing field work.

Australian Government Department of Agriculture, Fisheries and Forestry · Future Drought Fund · AIR EP Ag Innovation & Research Eyre Peninsula · The University of Adelaide · Flinders University · SA Drought Hub · Government of South Australia Department of Primary Industries and Regions · SARDI South Australian Research and Development Institute

EFFECT OF SEED RATE X HERBICIDES *on annual* RYEGRASS MANAGEMENT *in* WHEAT *(Gladstone, SA)*

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Key Points

A field trial was undertaken at Gladstone in 2022 to investigate combinations of wheat seed rate and herbicide treatments on annual ryegrass (ARG) control. Even though the increase in wheat plant density from 100 to 250 plants/m² reduced ARG spike density by 19%, this was not statistically significant (P=0.225). However, ARG spike density was significantly affected by different herbicide treatments (P<0.001). Surprisingly Sakura® (pyroxasulfone) was relatively ineffective with more than 700 spikes/m². In contrast, Overwatch® (bixlozone) treatment had significantly less ARG spike density. The most effective herbicide treatment was the combination of Overwatch® immediately before crop sowing (IBS) with early post-emergent (EP) Mateno Complete® (aclonifen, pyroxasulfone, and diflufenican). Overwatch® by itself produced wheat yield of 6.2 t/ha, which was almost 1 t/ha higher than Sakura®. The highest crop yield (7.03 t/ha) was achieved in the treatment where Overwatch® was followed by early post-emergent application of Mateno Complete®. There was a clear negative relationship between ARG spike density and wheat grain yield. These results clearly highlight the competitive effect of ARG on wheat, even in an above-average rainfall growing season.

Background

Crop seed rate has been shown to provide weed suppression in many weed species including ARG. Crop seed rate is an easy tactic for the growers to adopt provided they are convinced of its benefits for weed management and profitability. Higher crop density can provide improved weed suppression especially when used in conjunction with effective pre-emergent herbicides.

This field trial at Gladstone was undertaken to investigate factorial combinations of wheat seed rate and herbicides on the management of ARG.

Methodology

Trial design: Factorial randomised block design
Replicates: 3
Measurements: crop density, ARG spike density, ARG seed production, wheat grain yield and quality.

Table 1. *Key management operations undertaken.*

Operation	Details
Location	Gladstone, SA
Plot size	1.83 m x 10 m
Fertiliser	At sowing – DAP + zinc + impact (18:20:0:2) @ 100 kg/ha. Urea (46:0:0) @ 100kg/ha late tillering (August 1) Urea (46:0:0) @ 100kg/ha at GS32 (September 13)
Variety	Scepter wheat
Seeding rate	100 seeds/m² 150 seeds/m² 200 seeds/m² 250 seeds/m²
Crop sowing date	June 16
Herbicides	Pre-emergent treatment spray: June 16 (applied just before seeding - IBS), Early post-emergent EP treatments applied 15 July (wheat GS 11-12, ARG GS11) Refer to Table 1 for information on herbicide treatments.

Table 2. *Rainfall received at Gladstone in 2022 and the long-term average for the site.*

Rainfall (mm)		
Month	2022	Long-term rainfall
Jan	35.2	20.4
Feb	14.6	18.9
Mar	3.8	18.9
Apr	3.8	30.3
May	65.4	41.9
Jun	30.0	47.7
Jul	12.4	47.1
Aug	83.0	48.8
Sep	81.4	47.2
Oct	138.6	41.0
Nov	44.0	30.1
Dec	23.4	24.0
Annual total	535.6	416.3
GSR total	414.6	304

In 2022, the annual rainfall and growing season rainfall at Gladstone was well above the long-term average for the site (Table 2). Consistent with other areas in SA, the autumn was extremely dry but good rainfall received at the end of May. Rainfall in early winter (Jun-Jul) was below average but Aug-Nov rainfall was much higher than the long-term average, which was conducive for high yields.

Results and Discussion

Wheat plant density

As expected, wheat seed rate had a significant effect on crop density (P<0.001, Table 3). It is worth noting that the seed rate treatments were able to achieve wheat plant densities close to the target density.

Table 3. *Effect of wheat seed rate on plant density (P<0.001) established in the field trial at Gladstone*

Wheat seed rate (seeds/m²)	Crop density (plants/m²)
100	115.1
150	152.3
200	192.0
250	232.2
P	<0.001
LSD (P=0.05)	9.5

Annual ryegrass spike density

ARG spike density was significantly affected by the herbicide treatments (Table 4). None of the herbicide treatments prevented ARG from producing spikes or setting seed. Surprisingly Sakura® (pyroxasulfone) was relatively ineffective with more than 700 spikes/m². In contrast, Overwatch® (bixlozone) treatment had significantly less ARG spike density. The most effective herbicide treatment was the combination of Overwatch® IBS with EP Mateno Complete (aclonifen, pyroxasulfone, and diflufenican) (Table 4). Below average rainfall at Gladstone in June-July may have reduced Sakura efficacy in this field trial. As a result of an extremely delayed harvest at Gladstone in 2022, ARG samples are still being processed to determine seed production.

Table 4. *The effect of herbicide treatments (P<0.001) on annual ryegrass spike density in the field trial at Gladstone.*

Herbicide treatment	Annual ryegrass spikes/m²
Overwatch® 1.25 L/ha IBS	408
Overwatch® 1.25L/ha IBS fb Mateno Complete® 1L/ha EP [1]	180
Sakura® 118g/ha IBS	715
Sakura® 118g/ha IBS fb Boxer Gold® 2.5L/ha EP	442
Trifluralin 2L/ha + Avadex Xtra® 2L/ha IBS	659
Trifluralin 2L/ha + Avadex Xtra® 2L/ha IBS fb Boxer Gold® 2.5L/ha EP	586
P	<0.001
LSD (P=0.05)	140.1

[1] EP = early post-emergent was used at the 1-leaf stage of annual ryegrass

Wheat grain yield

High seasonal rainfall in 2022 was reflected in excellent grain yields of up to 7 t/ha (Table 5), which was significantly affected by the seed rate (P<0.001) and herbicide treatments (P<0.001). Wheat grain yield increased steadily from 5.35 t/ha at 100 plants/m² to 6.24 t/ha at target wheat plant density of 250 plants/m². Given the high wheat grain price in 2022 (>400/t), higher seed rate treatments are likely to enhance gross margins.

The lowest wheat grain yield was obtained in Trifluralin + Avadex Xtra® (triallate) treatment, which produced a similar yield to Sakura® (Table 6). As mentioned previously, unexpectedly low crop yield in this treatment could be associated with below-average rainfall in June and July. Sequential application of Boxer Gold® (prosulfocarb and s-metalachlor) after Sakura® or Trifluralin plus Avadex Xtra® increased wheat yields by about 0.5 t/ha as compared to when these products were used on their own. Overwatch® by itself produced wheat yield of 6.2 t/ha, which was almost 1 t/ha higher than Sakura®. The highest crop yield (7.03 t/ha) was achieved in the treatment where Overwatch® was followed by EP application of Mateno Complete®.

Table 5. *The effect of target wheat plant density on wheat grain yield (P<0.001) in the field trial at Gladstone.*

Wheat target density (plants/m²)	Grain yield (t/ha)
100	5.35
150	5.78
200	6.09
250	6.24
P	<0.001
LSD (P=0.05)	0.287

Table 6. *The effect of herbicide treatments on wheat grain yield (P<0.001) in the field trial at Gladstone.*

Herbicide treatment	Wheat grain yield (t/ha)
Overwatch® 1.25 L/ha IBS	6.21
Overwatch® 1.25L/ha IBS fb Mateno Complete® 1L/ha EP1	7.03
Sakura® 118g/ha IBS	5.26
Sakura® 118g/ha IBS fb Boxer Gold® 2.5L/ha EP	5.72
Trifluralin 2L/ha + Avadex Xtra® 2L/ha IBS	5.23
Trifluralin 2L/ha + Avadex Xtra® 2L/ha IBS fb Boxer Gold® 2.5L/ha EP	5.73
P	<0.001
LSD (P=0.05)	0.351

As expected, there was a clear negative relationship between ARG spike density and wheat grain yield (Figure 1). These results clearly highlight the competitive effect of ARG on wheat even in an above-average rainfall growing season.

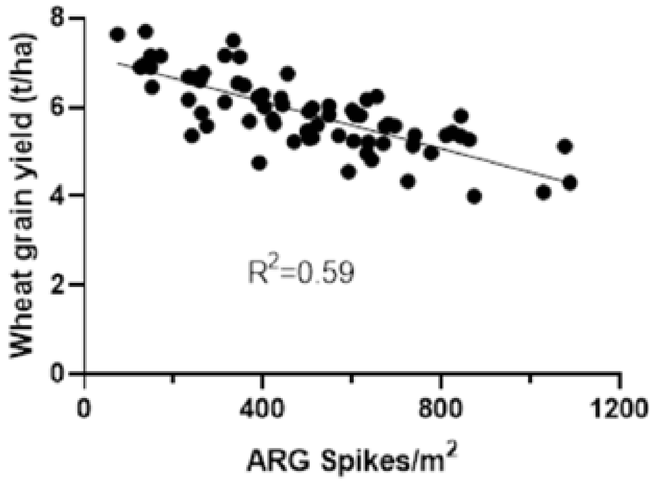

Figure 1. *The relationship between annual ryegrass pressure (ARG spikes/m²) and wheat grain yield (t/ha), R^2=0.59.*

Acknowledgements

The authors would like to acknowledge GRDC for providing initial funding for project 9175134 and to thank James Heaslip for providing this trial site. Also to UNFS for helping to coordinate options for potential sites and the Clare SARDI team for seeding and harvesting trial plots.

EFFECT *of* WHEAT SEED RATE *and* HERBICIDE *on annual* RYEGRASS CONTROL

(Roseworthy, SA)

Author: Ben Fleet and Gurjeet Gill
University of Adelaide, Roseworthy Campus, GRDC project 9175134

Key Points

A field trial was undertaken at Roseworthy in 2022 to investigate the effect of combinations of wheat seed rate and herbicide treatments on crop yield and annual ryegrass (ARG) control. The increase in wheat plant density in the range of 100 to 300 plants/m^2 improved suppression of ARG seed production (17-30%) and increased wheat grain yield (15-21%).

However, herbicide treatments were the major driver of wheat grain yields and ARG suppression. The trial site had a large ARG seedbank that resulted in heavy and prolonged weed establishment. This was evident from inadequate ARG control achieved with pre- emergent herbicides alone. The trial site also had a detectable level of trifluralin resistance, which would have reduced efficacy of Trifluralin + Avadex Xtra® treatment. The sequential application of pre-emergent herbicides followed by an early post-emergent herbicide reduced ryegrass seed set by 94% compared to the untreated control and increased wheat yield by 4.57 t/ha. There was an exponential correlation between nitrogen recovery by wheat and ARG seed set, which accounted for >89% of the variation. Wheat plant density and herbicides treatments had a significant influence on nitrogen recovery in grain where only 300 wheat plants/m^2 recovered nitrogen equivalent to fertiliser N applied. Only herbicide treatments achieving >60% ARG suppression achieved nitrogen recovery greater or equivalent to applied fertiliser N.

Background

As a result of widespread resistance in annual ryegrass (ARG) to post-emergent herbicides in Australia, growers are now relying heavily on pre-emergent herbicides. This reliance on pre-emergent herbicides combined with resistance to established pre-emergent herbicides like Boxer Gold® and high levels of resistance to trifluralin has facilitated adoption of new pre-emergent herbicides Luximax® (Cinmethylin), Overwatch® (Bixlozone) and Mateno Complete® (Aclonifen + Diflufenican + Pyroxasulfone). The efficacy of pre-emergent herbicides can be negatively influenced by delayed emergence of ARG populations due to selection for increased seed dormancy. There is an increasing trend in the grains industry to follow up pre-emergent treatment with another herbicide treatment at 1-2 leaf stage of ARG (early post-emergent). This early post-emergent treatment has the desirable effect of extending the residual herbicide activity and often leads to improved weed control.

In an effective integrated weed management strategy as many control tactics should be utilised including non-chemical strategies. Increase in crop plant density has also been shown to improve weed suppression. In research by Lemerle et al. (2004), doubling wheat plant density from 100 to 200 plants/m^2 halved ryegrass shoot biomass. Therefore, higher wheat plant densities can be an effective component of weed management and should be integrated with herbicides.

This field trial at Roseworthy was undertaken to investigate factorial combinations of wheat seed rate, and herbicides packages on wheat grain yield and the management of annual ryegrass.

Methodology

***Table 1.** Details of management practices used for crop and weed management.*

Operation	Details
Location	Roseworthy, SA
Seedbank soil cores	Early June, 2022
Plot size	1.5 m x 10 m
Variety	Scepter wheat
Seeding date	18 June 2022
Fertiliser	At sowing: DAP (18:20) @ 120 kg/ha In season: 100 kg/ha urea (46:0:0) at mid tiller, 100 kg/ha urea Z30-31
Crop and variety	Scepter wheat
Seeding rate targets	1. SR 100, 100 wheat plants/m² 2. SR 200, 200 wheat plants/m² 3. SR 300, 300 wheat plant/m²
Herbicide applications	1. IBS: herbicides applied to soil immediately before seeding pass (18 June). 2. EP: early post emergent, when wheat 1-2 leaf, and annual rye-grass 1 leaf stage (15 July).
Herbicides	All herbicides applied just before seeding 1. Untreated control 2. Trifluralin @ 2 L/ha + Avadex Xtra® @ 2 L/ha IBS 3. Sakura Flow® @ 210 mL/ha IBS 4. Overwatch® @ 1.25 L/ha IBS 5. Trifluralin @ 2 L/ha + Avadex Xtra® @ 2 L/ha IBS fb Boxer Gold® EP 6. Trifluralin @ 2 L/ha + Avadex Xtra® @ 2 L/ha IBS fb Mateno Complete® @ 1L/ha EP 7. Sakura Flow® @ 210 mL/ha IBS fb Boxer Gold® @ 2.5L/ha EP 8. Overwatch® @ 1.25 L/ha IBS fb Mateno Complete® @ 1L/ha EP

Trial design: factorial randomised block design

Replicates: 3

Measurements: pre-sowing weed seedbank, crop density, weed density, ARG spike density, ARG seed production, grain yield, grain protein, test weight and 1000-grain weight.

Rainfall received at Roseworthy during the growing season was 30% above the long-term average for the site. Total annual rainfall was 46% above the long-term average for the site.

The year was characterised by a very dry autumn, only breaking with reasonable rains at the end of May, July had below average rainfall, while October and November had well above average rainfall. The November rainfall, though classed as outside of growing season rainfall (April-October), it was still of great use with the late maturing wheat crop of 2022 utilising the moisture (Table 2).

***Table 2.** Rainfall received at Roseworthy in 2021 and the long-term (1997-2023) average for the site.*

Rainfall (mm)		
Month	2022	Long-term rainfall
Jan	64.6	18.3
Feb	5.8	19.0
Mar	11.4	16.7
Apr	6.8	29.9
May	78.8	39.5
Jun	52.8	45.5
Jul	26.0	43.7
Aug	49.2	45.9
Sep	56.8	45.5
Oct	99.8	34.7
Nov	107.0	29.6
Dec	14.0	23.8
Annual total	573.0	392.3
GSR total	370.2	284.7

Crop plant density

As expected, increase in wheat seed rate resulted in a significant increase in wheat plant density ($P<0.001$). Wheat plant density achieved ranged from 99 plants/m² (low), 168 wheat plants/m² in the medium seed rate and 249 wheat plants/m² in the high seed rate treatments.

There was no significant effect from the herbicide treatments on wheat plant density relative to the untreated control. This suggests herbicide treatments investigated had good crop safety.

Annual ryegrass plant density and seedbank

The seedbank of annual ryegrass (ARG) at the site in the autumn of 2022 was 13708 seeds/m². Such a high weed seedbank is expected to provide an extremely uniform weed infestation for research.

As expected, wheat seed rate had no impact on ARG plant density (P=0.86). However, ARG plant density was significantly affected by the herbicide treatment (P<0.001) (Table 3). Untreated control plots had a mean ARG plant density of 1142 ARG plants/m². Herbicide treatments varied in efficacy from 55% to 98% control compared to the untreated control. Trifluralin + Avadex Xtra® IBS (425 ARG plants/m²) provided 63% control of ARG plants.

Application of early post-emergent (EP) Boxer Gold® to plots sprayed with Trifluralin + Avadex Xtra® IBS improved ARG control by only 9% (non-significant). In contrast, when Mateno Complete® EP was applied after Trifluralin + Avadex Xtra® IBS, ARG control was increased by 21%. This was similar to the weed control improvement achieved when Mateno Complete® EP followed Overwatch® IBS and ARG control improved from 80% to 98%, respectively. When Boxer Gold® EP was added to Sakura® IBS ARG control improved from 55% to 72% (Table 3). These results are encouraging and clearly show that the use of EP herbicide options can improve herbicide activity against ARG.

Table 3. *The effect of herbicide treatment on ARG plant density; means followed by a different letter indicate significant differences (P=0.05).*

Herbicide treatment	ARG plant density (plants/m²)
Untreated	1142 ***d***
Trifluralin + Avadex Xtra® IBS	425 ***c***
Sakura® IBS	513 ***c***
Overwatch® IBS	223 ***b***
Trifluralin + Avadex Xtra® IBS fb Boxer Gold ® EP	315 ***bc***
Trifluralin + Avadex Xtra® IBS fb Mateno Complete® EP	178 ***ab***
Sakura® IBS fb Boxer Gold® EP	318 ***bc***
Overwatch® IBS fb Mateno Complete® EP	27 ***a***
P<0.001, LSD = 154.6, cv rep = 13.6%	

Among pre-emergent herbicides used on their own, Overwatch® provided the highest level of ARG control (80%). Sakura® IBS (55%) was relatively ineffective and provided weed control similar to Trifluralin + Avadex Xtra® IBS (63%). As a cautionary note, it needs to be mentioned that the high seedbank present at this trial site (13,000 seeds/m²) resulted in prolonged weed establishment and would have been an important factor in reducing herbicide efficacy.

Annual ryegrass spike density

Both wheat seed rate (P=0.003) and herbicide treatment (P<0.001) had a significant influence on ARG spike density, which in turn would affect ARG seed set. While increasing wheat seed rate had no influence on ARG plant density, it caused a significant reduction ARG spike density (Figure 1). ARG spike density declined from 551spikes/m² at SR100 to 410 spikes/m² at SR300, a reduction of 26% (Figure 1). These results support previous work in this project, which showed that ARG control can be significantly improved by using high wheat seed rate in conjunction with pre-emergent herbicides.

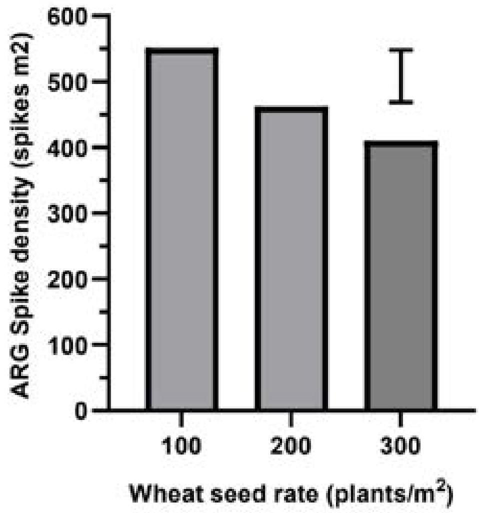

Figure 1. *Influence of increasing wheat seed rate on ARG spike production, vertical line represents LSD (79.3 ARG spikes/m²), cv rep = 3.6%, P=0.003.*

Different herbicide treatments provided between 24% and 95% suppression of ARG spike density as compared to the untreated control (Figure 2). While the Trifluralin + Avadex Xtra® IBS treatment reduced ARG plant density by 63% (Table 3), it only suppressed ARG spike density by 24%. This disparity between plant density and spike density in Trifluralin + Avadex Xtra® IBS treatment indicates that survivors of this treatment were relatively unaffected. Presence of trifluralin resistance at this site, would have contributed to poor performance of this herbicide treatment. In contrast, Sakura® IBS treatment, which had similar ARG plant density as Trifluralin +

Avadex Xtra®, had significantly lower ARG spike density. This result suggests that more persistent herbicides such as Sakura® continue to suppress surviving ARG later into the season and reduce its seed set potential. A similar trend can be seen in all treatments that included pyroxasulfone (Sakura® IBS or Mateno Complete®). The results from this trial support the importance of extending persistence of pre-emergent herbicides in soil through the use of sequential EP herbicide applications, especially in situations with large ARG seedbank and a long growing season.

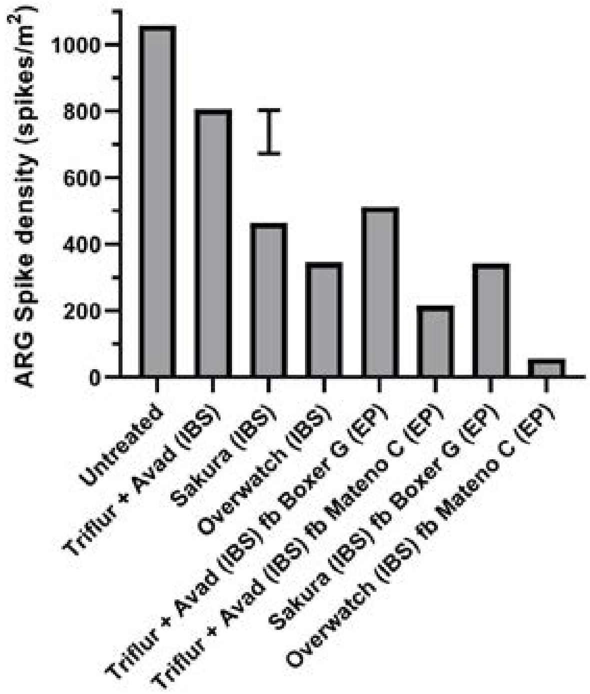

Figure 2. *Influence of herbicide treatments on ARG spike production, vertical line represents LSD (129.5 spikes/m²), cv rep = 3.6%, P<0.001.*

Annual ryegrass seed production

Both wheat seed rate (P<0.001) and herbicide treatment (P<0.001) had a significant influence on ARG seed production, which is the source of future ARG infestations. When wheat seed rate was increased from SR100 to either SR200 (17%) and SR300 (30%) ARG seed production was significantly suppressed (Figure 3). This result supports previous research by the authors that increasing wheat seed rate is an effective non-chemical management tool to enhance crop competition and suppress ARG. It is a relatively inexpensive non-chemical control option that can be easily adopted and used in conjunction with variable rate technology.

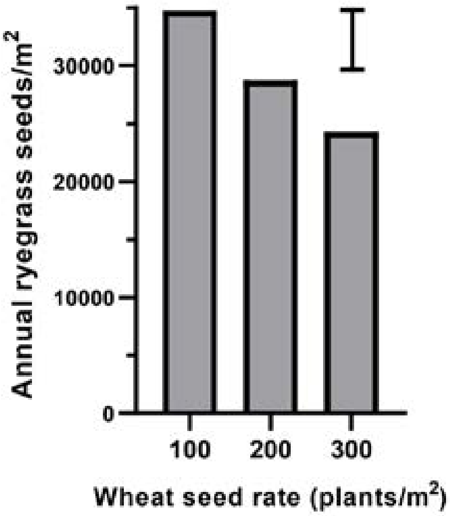

Figure 3. *Influence of increasing wheat seed rate on ARG seed production, vertical line represents LSD (5128 seeds/m²), cv rep = 4.8%, P<0.001.*

Herbicide treatments provided between 10% and 94% suppression of ARG seed production compared to the untreated control (59272 ARG seeds/m²) (Figure 4). Trifluralin + Avadex IBS despite controlling 63% of ARG plant density, suppressed ARG seed set by only 10% compared to the untreated control. Overwatch® IBS fb Mateno Complete® EP provided the highest suppression of ARG seed production at 98% compared to the untreated control. The next highest was Trifluralin + Avadex Xtra® IBS followed by Mateno Complete® EP at 77% ARG seed suppression. The use of EP herbicides seems to have an excellent potential to improve efficacy of pre-emergent herbicides in wheat. However, achieving these improvements in ARG control is highly dependent on soil moisture status and weed growth stage.

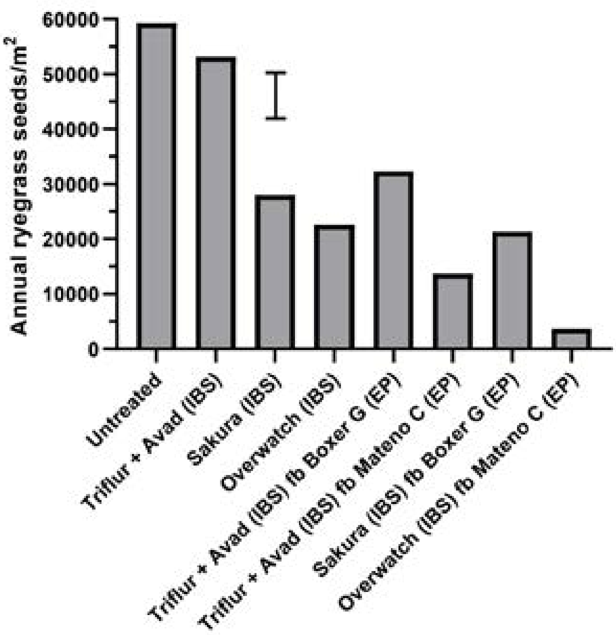

Figure 4. *Herbicide treatment effect on ARG seed production, vertical line represents LSD (8374 ARG seeds /m²), cv rep = 4.8%, P<0.001.*

Grain yield and quality

Wheat grain yield across all treatments at the site averaged 5.038 t/ha. Grain yield was significantly influenced by wheat seed rate (P<0.001) and herbicide treatment (P<0.001). In this trial, increased wheat seed rates significantly improved ARG suppression (Figures 1 and 2) and wheat grain yield (Table 4). Such results should be reassuring for growers considering this practice where high ARG populations are present.

Table 4. *Influence of wheat seed rate on grain yield (t/ha); means followed by a different letter indicate significant differences (P=0.05).*

Wheat seed rate (plants/m^2)	100	200	300
Wheat grain yield (t/ha)	4.507 ***c***	5.173 ***b***	5.435 ***a***
P<0.001, LSD = 0.2384 t/ha, cv rep = 4.4%			

Herbicide treatment also had a significant influence on both wheat grain yield (P<0.001) and grain protein (P<0.001). When averaged across seed rates, grain yields ranged 2.845 t/ha for the untreated control to 7.412 t/ha for Overwatch® IBS fb Mateno Complete® EP (Figure 5). There was a general trend for higher grain yields in treatments with effective ryegrass control.

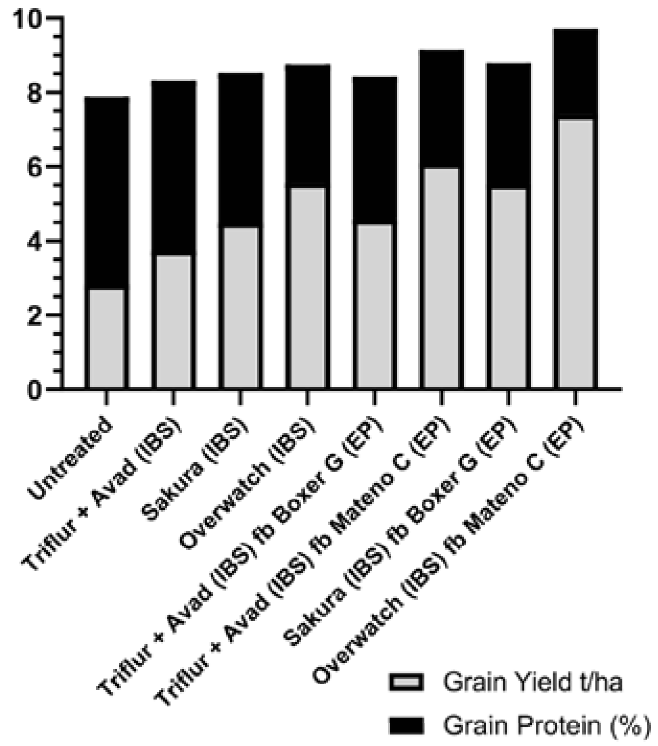

Figure 5. *Influence of herbicide treatment on wheat grain yield (t/ha) and protein (%). Grain yield, LSD = 0.3893 t/ha, cv rep = 4.4%, P<0.001. Grain protein, LSD = 0.2203%, cv rep = 0.8%, P<0.001.*

Grain proteins were generally low across the site. Wheat seed rate did not affect grain protein (P=0.23). Herbicide treatments resulted in grain protein ranging from 7.88% in the untreated to 9.71% in the Overwatch® IBS fb Mateno Complete® EP. Grain yield followed improved ARG suppression as did grain protein. In this trial grain protein increased as grain yield increased, despite the effect of dilution of protein as yields increase. This suggests that nitrogen uptake by ryegrass in weedy plots not only reduced grain yield but also grain protein.

Grain test weight was high across the site with a mean of 81.26 kg/hL, and it was unaffected by wheat seed rate (P=0.49) and herbicide treatment (P=0.09).

The mean wheat grain size (1000 grain weight) for the site was 48.2 g/1000 grains and was significantly influenced by wheat seed rate (P<0.001) and herbicide treatment (P<0.001).

There was an interaction between wheat seed rate and herbicide treatment (P=0.003). Data not shown, but seed rate did not change grain size in any herbicide treatment except for Overwatch® IBS fb Mateno Complete® EP, where 1000 grain size increased from SR100 (48.59 g/1000 grains) to SR200 (49.73 g/1000 grains) and SR300 (50.193 g/1000 grains).

There was a strong exponential relationship between ARG seed production (i.e., weed control) and grain yield, which accounted for >88% of variation in the data (Figure 6). These results highlight that ARG present at high densities can be highly competitive with wheat and yields respond positively to effective herbicide treatments. The curve is steepest at lower ARG pressures, highlighting the importance of managing ARG even when weed pressure is low.

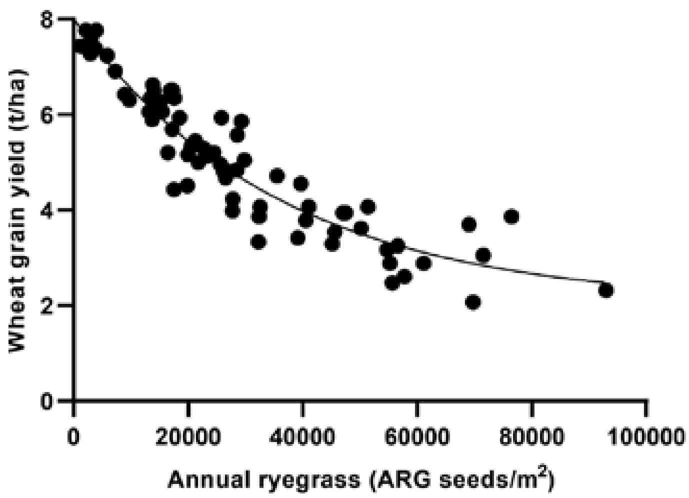

Figure 6. *The relationship between ARG pressure (ARG seeds/m^2) and wheat grain yield (t/ha), R^2=0.88.*

Nitrogen recovery

Nitrogen efficiency is topical in 2022 due to the substantial cost of nitrogen. The impact of ARG on nitrogen recovery was investigated. Grain nitrogen recovery kg N/ha was calculated by the following calculation:

Grain N recovery (kg N/ha) = Wheat grain yield (t/ha) x Grain protein (%) x 2.34

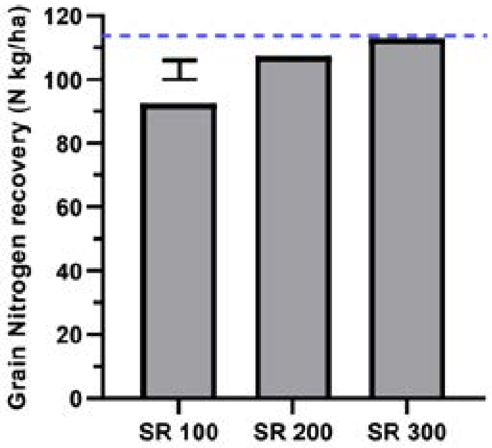

Figure 7. *Influence of wheat seed rate on grain nitrogen recovery (kg N/ha), horizontal blue dashed line represents fertiliser applied nitrogen (113.6 kg N/ha), vertical line represents LSD (6.13 kg N/ha), cv rep = 5.2%, P<0.001.*

Wheat seed rate had a significant impact on Grain N recovery (GNR) (P<0.001). GNR increased with wheat seed rate (Figure 7), which is most likely related to yield improvement from increased ARG suppression. Averaged across herbicide treatments only SR300 achieved GNR equivalent to the rate of fertiliser N applicationHerbicide treatment had a significant influence on GNR (P<0.001) (Figure 8). GNR ranged from 52.4 kg N/ha in the untreated control to 168.5 kg N/ha for the Overwatch® IBS followed by Mateno Complete® EP. This is a remarkable result indicating that ARG was able to take up more 100 kg N/ha, thereby reducing yield potential of wheat. Only the Trifluralin + Avadex Xtra® IBS fb Mateno Complete® EP and the Overwatch® IBS fb Mateno Complete® EP had a GNR higher than the fertiliser nitrogen applied (113.6 kg N/ha). The Overwatch® IBS and Sakura® IBS fb Boxer Gold® EP treatments achieved GNR just above fertiliser N rate applied. Comparing these results with the ARG suppression (Figure 4), herbicide treatments needed to achieve >60% control of ARG to achieve a GNR equal or greater than fertiliser nitrogen applied.

A partial nitrogen balance (PNB) was also calculated for each plot (Figure 9). It was calculated using the following:

Partial nitrogen balance (PNB) = Grain nitrogen removal (kg N/ha) ÷ Nitrogen supplied (kg N/ha)

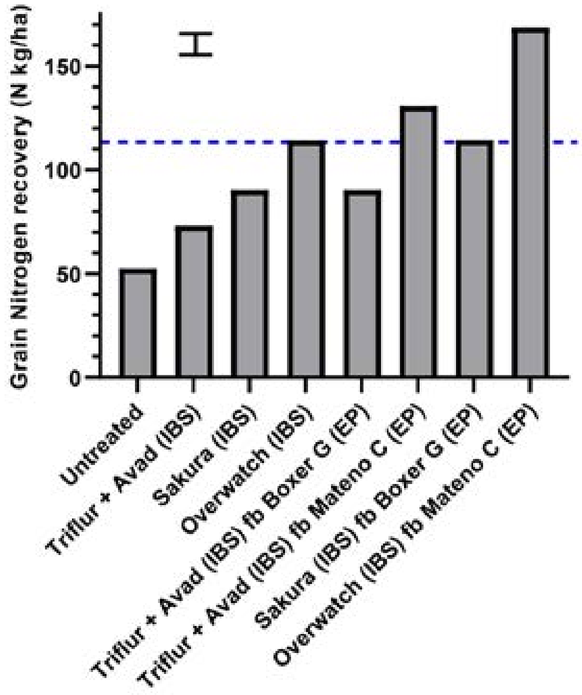

Figure 8. *Effect of herbicide treatment on grain nitrogen recovery (kg N/ha), horizontal blue dashed line represents fertiliser applied nitrogen (113.6 kg N/ha), vertical line represents LSD (10.01 kg N/ha), cv rep = 5.2%, P<0.001.*

There was a strong exponential relationship between ARG seed production (i.e., weed control) and PNB in grain yield, which accounted for >89% of variation in the data (Figure 9).

At a PNB of ≥1.00 the plot utilised ≥ nitrogen supplied by fertiliser. Where PNB <1.00, wheat was unable to acquire nitrogen due to competition from ARG. These results highlight that ARG present at high densities can be highly competitive with wheat for nitrogen and PNB responded positively to effective ARG control. The curve is steepest at lower ARG pressures, highlighting the importance of managing ARG even when weed pressure is low and crop nitrogen efficiency will be very low where ARG pressure is high as ARG is very competitive and its root system is highly effective at absorbing soil nitrogen.

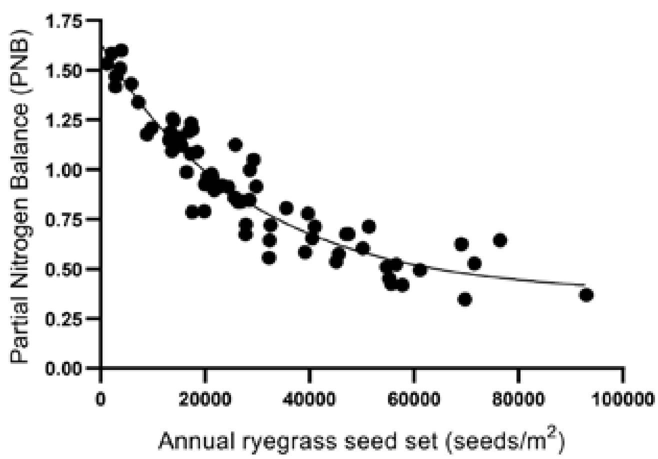

Figure 9. *The relationship between ARG pressure (ARG seeds/m^2) and partial nitrogen balance, R^2=0.8988.*

PEST & DISEASE MANAGEMENT

WHEAT DISEASE UPDATE – SEPTORIA TRITICI BLOTCH *and* STRIPE RUST

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Keywords

- integrated disease management, septoria tritici blotch, stripe rust.

Key Points

- Above average rainfall in 2022 favoured disease development.
- 2022 season resulted in high stripe rust disease.
- Septoria tritici blotch, usually damaging in the HRZ, caused yield losses of 20% in the LRZ.
- Inoculum levels will be high going into 2023: green bridge control, variety selection and fungicide strategies should be prioritised.

Background

The 2022 growing season in South Australia received above average rainfall in most areas of the state (Figure 1). Wet conditions continued late into spring and early summer affecting grain fill and harvest. These conditions were very conducive for foliar disease development and wheat crops particularly suffered from powdery mildew, stripe rust and septoria tritici blotch. Many paddocks experienced yield losses, reduction in grain quality and/or increased grain defects from disease pressure. Integrated disease management strategies were particularly important in this season with variety selection, proactive fungicide management and non-chemical farm management (for example, green bridge control, crop rotation and stubble management) providing the best opportunity for effective disease control.

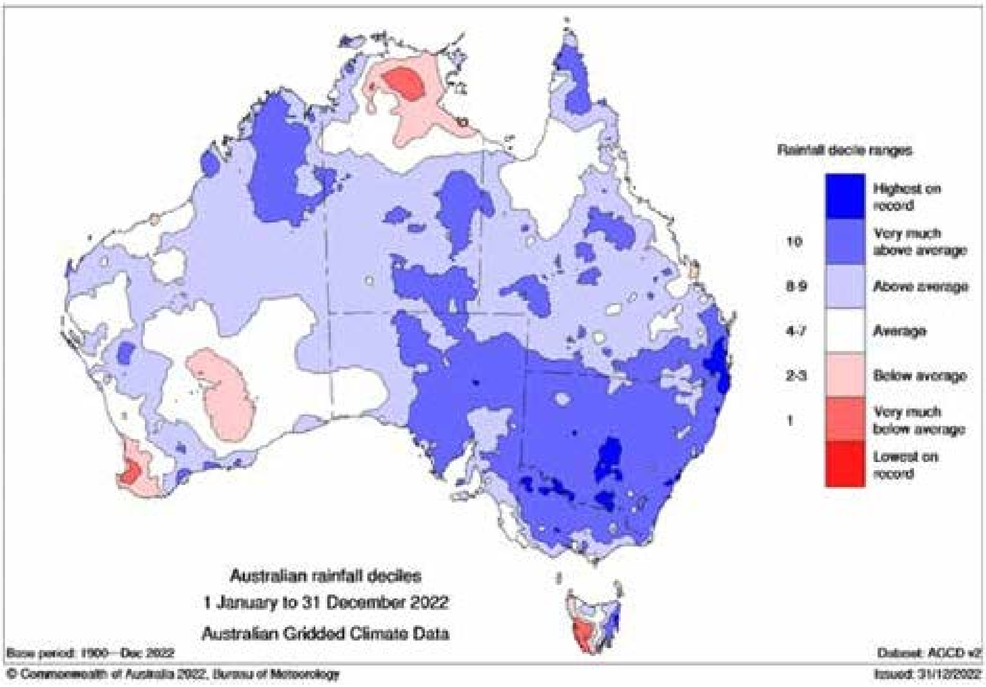

Figure 1. *Australian rainfall deciles for 2022 showing above average rainfall in South Australia, ommonwealth of Australia 2022, Bureau of Meteorology.*

Wheat stripe rust

Stripe rust caused substantial damage and yield loss to wheat crops in the eastern states in 2022. Summer rainfall through 2021 and 2022 caused flooding in QLD and NSW, driving a green bridge between the growing seasons and allowing stripe rust inoculum to proliferate. Stripe rust epidemics began early in these growing regions in 2022 and South Australia followed suit with the first stripe rust report in late July. Wet cool conditions for the remainder of the season maintained a high level of disease pressure from stripe rust in susceptible varieties. Paddocks that avoided susceptible varieties, had fungicides applied at seeding, and had timely foliar fungicide applications achieved the greatest stripe rust control.

The stripe rust disease risk is expected to be high in 2023 with high inoculum loads across the state from the 2022 season. Green bridge control will be essential in the lead up to sowing, as volunteers host the rust inoculum. Growers should be prepared for the rust epidemic to begin early in the season and have an integrated disease management plan ready to implement. A successful stripe rust integrated disease management plan will include:

- green bridge control
- variety selection – avoid susceptible varieties
- up front fungicide applications – seed dressings, fungicide coated fertiliser
- proactive foliar fungicide applications
- use of support tools such as the StripeRustWM App.

Septoria tritici blotch

Septoria tritici blotch (STB) was prevalent across the state in 2022, with higher-than-average spring rainfall causing substantial disease development in some areas. The disease is spread via rain splash and infection on the top three leaves is the main contributing factor for yield loss. Typically, yield losses are observed in the high rainfall zones (HRZ) of the state, but seasons such as 2022 were conducive to yield losses in low and medium rainfall zones (LRZ, MRZ respectively).

In 2021 and 2022, SARDI in conjunction with Agriculture Victoria and the GRDC have conducted field trials in low and medium rainfall zones to quantify yield losses in wheat varieties. Six varieties were selected based on their disease resistance ratings to STB. Ratings for stripe rust and powdery mildew were taken into consideration as well. Varieties and STB resistance ratings were as follows: LRPB Impala^A (SVS), Calibre^A (S), Scepter^A (S), Razor CL Plus^A (S), Hammer CL Plus^A (MSS) and LRPB Lancer^A (MS).

Trials were a split-plot design with disease-inoculated plots ('plus-disease') and disease-controlled plots ('minus-disease') for each variety. Treatments were replicated six times and were blocked by disease treatment, with plot size of 10m x 1.5m. In South Australia, trials were located at Hart Field Site and Booleroo Centre.

Plus-disease plots were inoculated at seedling and mid-tillering stages using a conidial suspension in water applied as a spray. Fungicides were applied to minus-disease plots at GS 31 and GS 39. The GS 31 spray consisted of Elatus® Ace (250g ai/L propiconazole + 40g ai/L benzovindiflupyr) at 500mL/ha and the GS 39 spray was epoxiconazole (500g ai/L) at 125mL/ha. Disease assessments were conducted at flowering by assessing percentage of leaf area infected on each leaf of 10 plants/plot. Single site statistical analysis was conducted with Genstat 20th Edition.

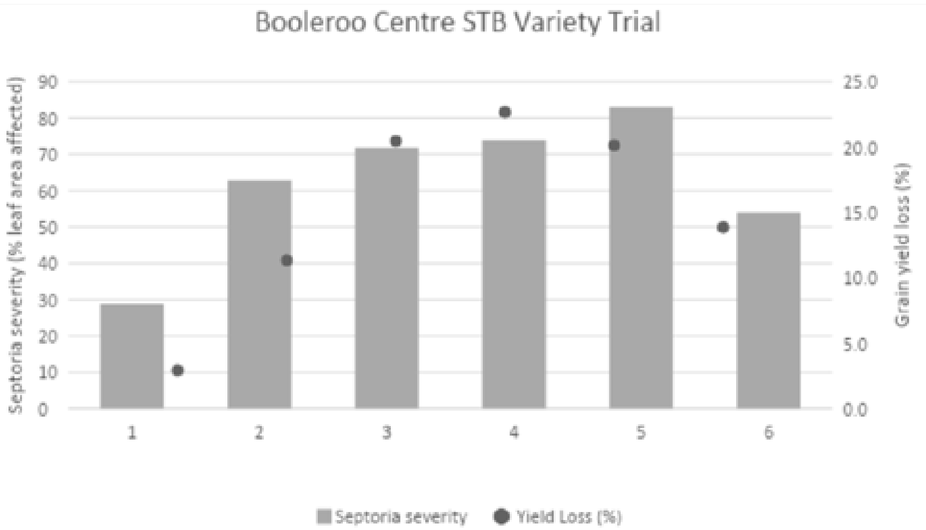

Figure 2. *Grain yield losses and STB disease severity at Booleroo Centre STB variety trial in 2022. Yield losses were significant in Hammer CL Plus^A, Scepter^A, Calibre^A, Razor CL Plus^A and LRPB Impala^A.*

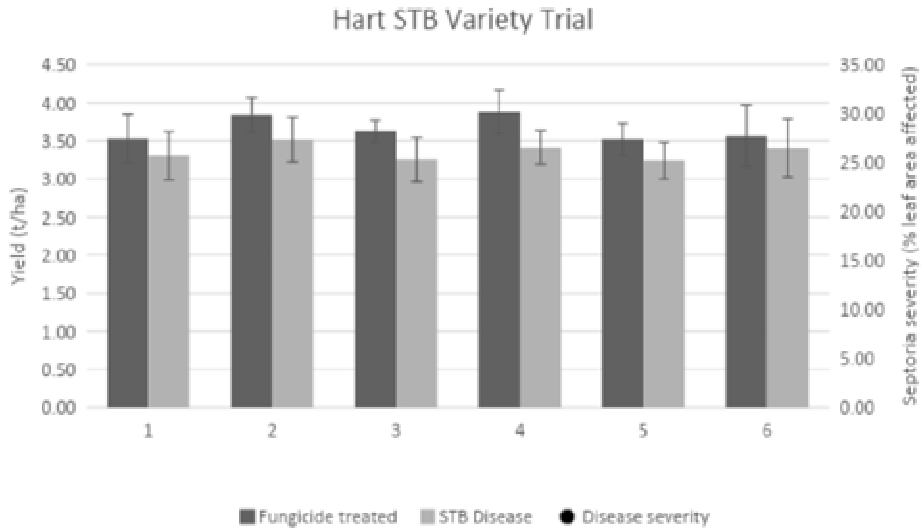

Figure 3. *Grain yields and STB disease severity at Hart Field Site STB variety trial in 2022. No significant yield losses were recorded.*

The Booleroo Centre site received higher than average rainfall in 2022 with 330mm of growing season rainfall (April–November) compared to the 305mm average. The late winter and spring months were the major contributors to this rainfall total. Resultingly, both yields and Septoria disease severity were high at the site and yield losses from STB were recorded in all varieties except in the moderately susceptible (MS) variety LRPB Lancer^A^. The yield average at the site was 5.7t/ha and yield losses were highest in susceptible (S) varieties Calibre^A^, Scepter^A^ and Razor CL Plus^A^ with corresponding disease severities of 74%, 72% and 83% at early milk development, respectively.

The Hart field site had above average growing season rainfall with 417mm (April–November) and a yield average of 3.5t/ha. The disease severity at the site was lower than at the Booleroo Centre site with the highest level in Scepter^A^ at 30% at the end of flowering.

The 2021 growing season was not as conducive for STB disease development with the highest levels at the Hart field trial in SVS variety Impala at 11 % at flowering time. Disease levels at the Booleroo Centre field trial were very low and neither site recorded yield losses associated with the disease. The takeaway message from the past two years of trials was that in 2021 it was not economical in the LRZ and MRZ to control STB, but in 2022, STB control increased yield by 22% in susceptible varieties at the Booleroo Centre LRZ site.

Inoculum levels from the 2022 season will be high and growers should be aware of the disease risk going into 2023. STB inoculum carries over on stubble and spores can be spread long range early in the growing season. Therefore, to reduce disease risk in 2023, it is important to implement crop rotation and avoid growing wheat on wheat stubble, as well as selecting a variety with some level of STB disease resistance.

Powdery mildew

SARDI Cereal Pathology received a large number of powdery mildew disease reports throughout the 2022 growing season. Areas of the state most affected were the Lower Eyre Peninsula, Yorke Peninsula, South East and the Mallee. Development of the disease in the Mallee region is an uncommon occurrence and was likely due to regular but low volume rainfalls during late winter and early spring. Many reports from across the state highlighted the difficulty in controlling the disease and the current prevalence of wheat powdery mildew strobilurin fungicide resistance and DMI reduced fungicide sensitivity were questioned. Current commonly sown varieties in South Australia have very poor genetic resistance to the disease and varieties rated very susceptible to susceptible (VS–S) dominate much of the cropping area. These factors, combined with a conducive growing season, produce a system in which substantial disease levels, yield loss and reduced grain quality are likely.

More detailed information on powdery mildew fungicide management strategies can be found in a separate GRDC update paper from Sam Trengove and respective authors at Trengove Consulting.

Wheat head diseases

Moist conditions continued throughout grain fill in the eastern parts of the state, causing impacts on grain quality. SARDI Cereal Pathology have been investigating the causes of quality reduction and grain damage and have received samples from all growing regions of the state. Grain samples have predominantly shown symptoms of severe grain shrivelling, fungal staining, black point as well as white and pink grains. A multitude of factors as well as fungal pathogens are likely to have contributed to these symptoms, with many samples displaying more than one impaired trait.

Causes of defected grain detected in SA in 2022:

- white grain disorder
- Fusarium head blight (*Fusarium pseudograminearum* – spread from crown rot infection)
- field moulds (*Alternaria* spp., *Eppicoccum* spp., *Cladosporium* spp.)
- foliar pathogens – loss of leaf area limiting yield, infected glumes, infection at flowering (stripe rust and septoria tritici blotch)
- black point (physiological – but there is varietal variation)
- frost
- Septoria nodorum blotch.

Growers are advised to assess their seed quality going into the 2023 growing season and select a cleaner seed source if necessary.

Conclusion

The 2022 growing season had exceptional rainfall conditions in late winter and spring resulting in high wheat foliar disease pressure. Yield losses and reduced grain quality were common across the state and, in some areas, difficult to avoid without dedicated integrated disease management. Stripe rust, septoria tritici blotch and powdery mildew were the most damaging diseases and inoculum levels of these diseases will be high going into 2023. Growers should plan integrated disease management for 2023, with a focus on variety selection, green bridge control, crop rotation and proactive fungicide plans.

Acknowledgements

The research undertaken as part of this project is made possible by the significant contributions of growers through both trial cooperation and the support of the GRDC, the authors would like to thank them for their continued support. Funding for this work was provided by the South Australian Government and the GRDC through the GRDC projects: DJP2104-004TRX, DAS1905-013SAX, UOA2104-012RTX. The authors would also like to acknowledge the SARDI Cereal Pathology team, as well as collaborators on the STB project including Agriculture Victoria, Hart Field Site Group, Upper North Farming Systems, Birchip Cropping Group, AgXtra and the growers hosting sites, and the University of Sydney Cereal Rust Program.

Useful resources

Australian cereal rust survey (https://www.sydney.edu.au/science/our-research/research-areas/life-and-environmental-sciences/cereal-rust-research/rust-reports.html)

Retaining seed fact sheet (https://grdc.com.au/resources-and-publications/all-publications/factsheets/2021/grdc-fs-retainingseed)

Proactive fungicide management maintains disease-free crops (https://groundcover.grdc.com.au/weeds-pests-diseases/diseases/proactive-fungicide-management-maintains-disease-free-crops)

NVT disease ratings (https://nvt.grdc.com.au/nvt-disease-ratings)

Recent and historical rainfall maps (http://www.bom.gov.au/climate/maps/rainfall/?variable=rainfall&map=decile&period=12month&region=nat&year=2022&month=12&day=31)

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WHITE GRAIN *in the* 2022 WHEAT HARVEST

Authors: Dr Margaret Evans[1] and Dr Tara Garrard[2,3]
[1]Evans Consulting; [2]SARDI, Plant Research Centre, [3]University of Adelaide Affiliate-Senior Lecturer.

Key Points

- White grain expression in 2022 was caused by fusarium head blight (FHB) as well as white grain disorder (WGD) and by other, undetermined, factors.
- FHB was mainly caused by *Fusarium pseudograminearum* and to a much lesser extent by F. culmorum – these fungi normally cause crown rot.
- SA has not previously experienced an FHB outbreak and the mycotoxin levels produced by local isolates of *F. pseudograminearum* and *F.culmorum* are unknown and still of concern in relation to export markets.
- Managing a problem like white grain, which occurs only rarely and is caused by a complex of fungal species in a season such as 2022 which was very conducive to the expression of many fungal diseases was extremely difficult.
- Based on diagnostics for white grain samples and after discussions with affected growers and advisors, funding is being sought for research that addresses the issues of both WGD and FHB.

Background

White grain describes the chalky white appearance of grain affected by a number of species in the fungal *genera Eutiarosporella* and *Fusarium*. Visually, white grain symptoms resemble those produced by infection with *F. graminearum* (fusarium head blight - FHB) which is also known as head scab (HS) and has been called "tombstone grain" in North America. Grain infected with *F. graminearum* carries toxins that mean the grain cannot be used for human or animal consumption. This makes white grain in wheat a problem for Australian export markets, however *F. graminearum* is not known to occur in SA.

White grain first appeared at levels causing rejection and downgrading of grain loads in 2010 and 2011 in SA and was a particular issue on Upper Eyre Peninsula at Buckleboo, Kimba and Cleve. It was unclear what fungi were causing the problem, but molecular studies later identified the fungi associated with the white grain as *E. tritici-australis, E. darliae* and *E. pseudodarliae*. The name white grain disorder (WGD) was then given to this disease. For more on the 2010/2011 WGD outbreak see EPFS 2011 p 81.

Over the period 2011-2018 research was done by the Cereal Pathology Group at SARDI to better understand the biology and management of WGD. As this disease was unlikely to express reliably in the field, all research was undertaken in pots and small plots where misting could be applied after artificial inoculation to encourage infection and disease expression. Findings included the following:

1. Varietal resistance in Australian germplasm was limited and was not considered a useful management tool for WGD.
2. Heads at flowering are most susceptible to infection by WGD spores, but infection can occur at any time during grain filling.
3. Fungicide needs to be applied within 24 hours of WGD spores contacting heads to be effective.
4. Even where artificial inoculation (followed by up to 36 hours of misting) is undertaken twice, a large proportion of infected grain is likely not to express WGD symptoms.
5. Where there was a delay in harvesting mature heads and conditions were moist and warm, findings indicated that infected but non-symptomatic grain began to exhibit WGD symptoms.

What happened in 2022?

For over 10 years no significant levels of WGD have been seen, so the appearance of white grain at high levels during the 2022/23 harvest caught the Grains Industry unprepared. Initially there were significant levels of load rejection due to the presence of white grain. The worst affected areas were Upper Eyre Peninsula (particularly Buckleboo and Kimba), the Upper North (particularly areas from Laura to Orroroo) and the South East.

Viterra responded to the situation by creating a segregation for the 2022/23 harvest to allow receivals with higher levels of white grain. At receivals, white grain falls into the defect category WGD/HS as per the Grain Trade Australia standards and normally levels of 1% or higher are cause for rejection. However, the 2022/23 grade of SWGD (stockfeed white grain disorder) allows up to 20% WGD/HS defect. This segregation was open at the Port Pirie site with a lower price point than feed grade (FED1), sitting more than $170/t below H1 grain (as at 27/01/23).

The cool to warm, overcast (low light intensity), wet and humid conditions during flowering and grain filling provided perfect conditions for a range of fungal pathogens to infect and cause disease on the stems, leaves, heads and grain of cereal crops. SARDI Cereal Pathology have received over 85 samples for diagnostic testing of head disease or grain related issues from the 2022 season to date. It is clear from the results of this testing, that WGD is not the only cause of the white grain symptoms seen during 2022.

Of the 85 samples, 4% have tested positive for WGD, while 45% have tested positive for FHB, mainly due to *F. pseudograminearum* and to a lesser extent to *F.culmorum*. *F. graminearum* was not identified in any white grain samples from 2022 or from 2011 (100 samples), supporting the contention that *F. graminearum* is not an issue in SA grain. It is not clear what is causing the (apparent) white grain symptoms not associated with WGD or FHB.

Sample processing is ongoing, and more positives of WGD are expected as WGD reports were received at harvest whilst FHB reports started and samples were sent earlier - during grain filling. FHB has been detected in samples from all growing regions of the state but so far WGD has only been detected in samples from the South East, Eyre Peninsula and Upper North.

SA has not experienced an FHB outbreak prior to 2022/23 and the mycotoxin levels produced by local isolates of *F. pseudograminearum* and *F.culmorum* are unknown. *F. pseudograminearum* has not been shown to produce the same types and levels of toxins as F. graminearum but is still of concern in relation to export markets.

So what can we do?

There is no evidence to suggest SA varieties have resistance to the fungi causing white grain symptoms. Fungicides can be effective, but timing is critical (a 24 hour window after spores land on plants) and there are likely to be multiple spore showers. Added to this, weather conditions conducive to white grain outbreaks occur rarely – never known before for FHB and over 10 years ago for WGD. This means that prophylactic fungicide management every season will not be economic and may encourage fungicide resistance in other diseases.

If we knew the field weather conditions conducive to expression and when spore showers were likely, it is possible that a single fungicide application at flowering could be applied to prevent or reduce white grain expression. Prediction of conditions conducive to white grain expression would also allow Industry to be prepared for the issue.

Anecdotal evidence from affected growers and advisors suggests:

- Time of flowering influenced white grain expression.
- Some varieties were less affected – but this might just have been a flowering time effect, not resistance.
- Fungicide application by boom-spray was more effective than aerial application for targeting heads.

Based on white grain sample results and after discussions with affected growers and advisors, funding is being sought for research that addresses both WGD and FHB, including:

1. Early warning for disease risk (including interrogating historical weather and spore trap data)
2. Improving in-crop management by assessing grain from 2022 crops and trials and by gathering agronomic information about those crops and trials
3. Rapid diagnostics (DNA-based) for use during grain delivery
4. Improving visual identification for grain handlers
5. Mycotoxin risks in infected grain

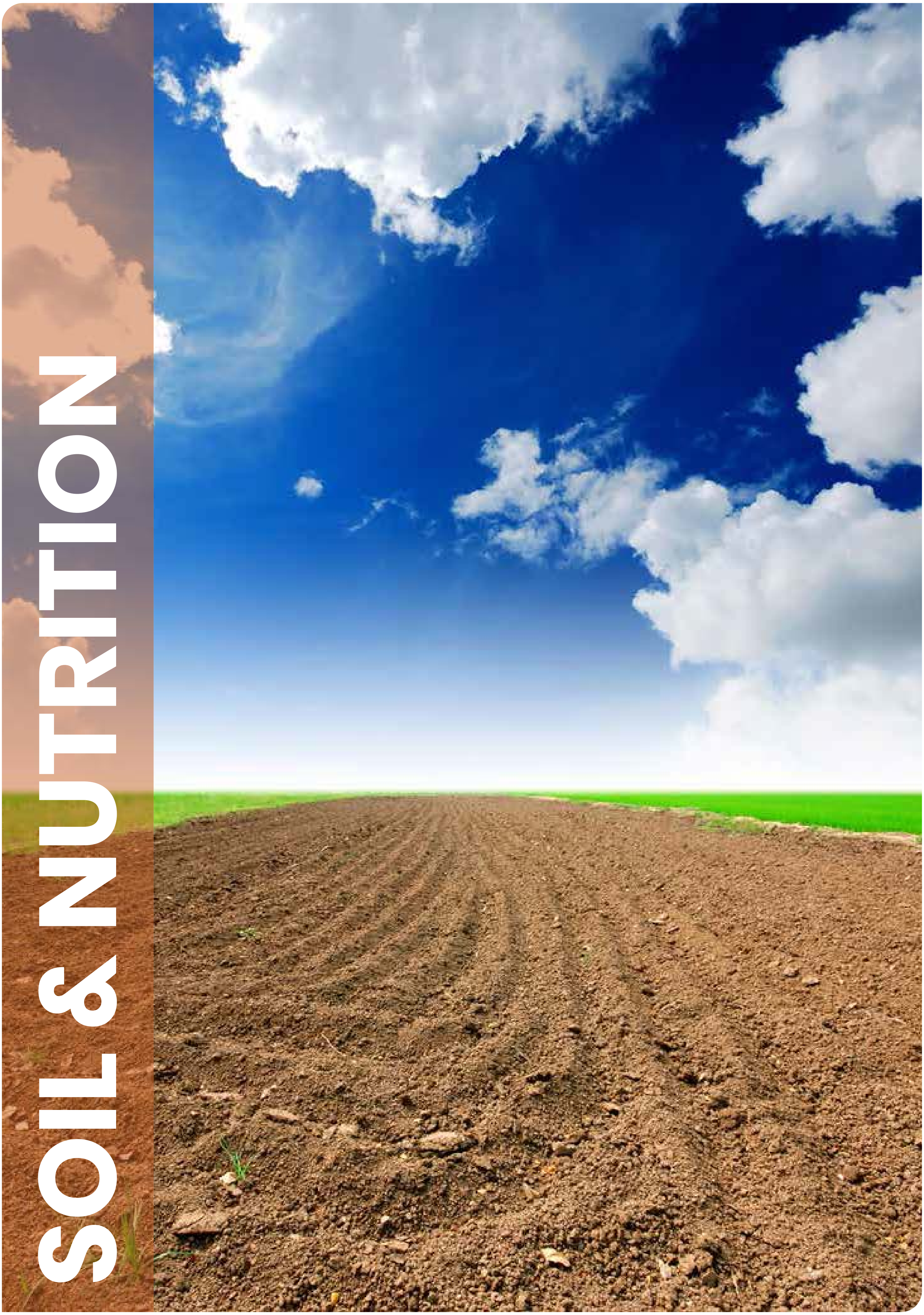
The information collected will form the base for an Industry risk management plan for white grain outbreaks.

Acknowledgements

Thanks to all the growers and advisors who have assisted SARDI studies by providing affected grain samples along with crop and fungicide application information. Thanks also to the Molecular Diagnostics Group at SARDI for DNA analysis of grain samples.

Research over the period 2011-2018 was funded by SAGIT (S1206 "Strategies to reduce white grain on Eyre Peninsula") and GRDC (DAS00139 "Improving grower surveillance, management, epidemiology knowledge and tools to manage crop disease in South Australia"; DAS00154 "White grain disorder in wheat"; DAS00137 "National improved molecular diagnostics for disease management.").

SOIL & NUTRITION



BUILDING SOIL KNOWLEDGE

and capacity to implement change in the farmers of the Upper North Agricultural zone of South Australia. Improving soil structure and function to improve plant health, landscape function and farming system resilience

2022 Review

Author: Beth Humphris

Funded By: *National Landcare Program: Smart Farms Small Grants Round 4*

Project Title: *Building Soil Knowledge* | ***Project Duration:*** *2020 - 2023* | ***Project Delivery Organisations:*** *UNFS, Elders Jamestown*

Background

The aim of this project is to provide Upper North (SA) farmers with local examples of practical and cost-effective soil remediation activities. It addresses best practice soil management focusing on subsoil constraints and impacts on plant available water, water use efficiency and plant nutrient availability. Ultimately, each case study associated with this project will demonstrate and therefore extend examples of beneficial management practices in UN cropping paddocks and their ability to improve plant resilience, water retention, soil health and farming system profitability.

Outcomes

The project commenced in mid 2020, beginning with a grower and agronomist survey. The survey results were used to identify growers' concerns around soil management in addition to baselining localised soils knowledge. Using results from the survey, five case studies were developed, as listed below.

1. Soil erosion in annual vetch pastures; This case study is investigating the best management strategy for the pasture phase of cropping rotations to minimise damage to soils. Typically, vetch is used as part of the rotation and results in low ground cover leading to soil erosion. This case study aims to match crop type/mix and grazing technique to impacts on soil erosion. This will focus on soil erosion over the summer fallow period and the impacts this has on the overall soil health and function of the farming system.
2. Understanding water movement throughout different soil profiles across the Upper North; This case study aims to link how soil constraints impact ability of soils to harvest water, translating into yield potential. The study looked at water movement throughout five different soil profiles. Soils range from unconstrained to compacted, calcareous, acidic and saine.

Figure 1. *Soil pit dug in a constrained sandy soil type, blue dye was used to exemplify how water moves throughout the soil profile in relation to structure type, soil horizons and soil constraints.*

3. **Amending sub-soil constraints including acidity, sodicity and compaction layers using deep ripping and soil fracture;** A deep ripping trial, aiming to move soil ameliorates into the sub-soil resource and hence correct issues found at depth (below the tillage pan). This is a trial site based out at Melrose, which was established at the beginning of 2022. Lime, gypsum and compost treatments were added both separately and in combination. Ripping was completed to 30 and 50 cm, with and without inclusion plates. Final measurements will be collected at the end of 2023 to determine if deep ripping is suited to your local clay soil types.
4. **Use of precision agriculture mapping to identify and ameliorate soil acidity;** A case study looking at high resolution soil map layers and how soil variation changes over time with site specific management of pH. This case study is using map layers pulled from archives, allowing us to see how paddock variation has changed over a 6-year period by applying lime variably to target problem areas of the paddock.

Figure 2. *Deep ripping trial site out at Melrose, with the amendments spread prior to ripping (Left). Drone photo taken in spring, showing how plant establishment varied after the deep ripping before seeding 2022 (right).*

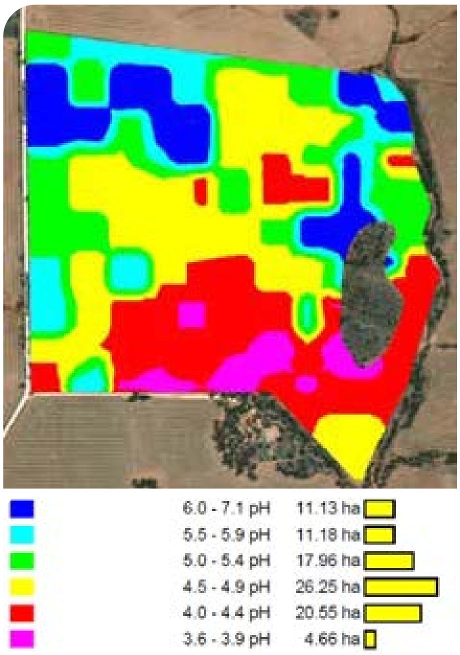


Figure 3. *pH ($CaCl_2$) taken on the top 0-10 cm's of soil in June 2015, prior to any application of lime. The lowest pH value was 3.6, with the highest pH value 7.1, equating to an average pH across the paddock of 5.0.*

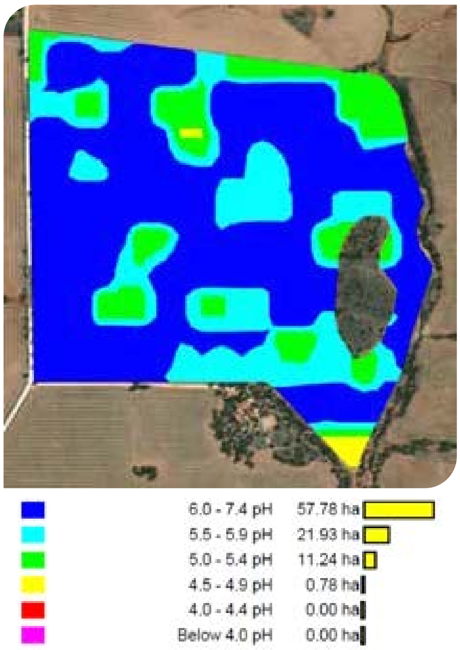


Figure 4. *pH ($CaCl_2$) taken on the top 0-10 cm's of soil in January 2021, six seasons after the initial application of lime and two season following the second application of lime.*

Another outcome from this project was the Literature review and podcast, which was developed at the beginning of 2022. These resources aimed to upskill growers and advisors in the language of soils.

Acknowledgements

- Upper North Farming Systems would like to acknowledge the National Landcare Program: Smart Farms Small Grants Round 4 for funding this project. We would also like to thank Elders, Jamestown for the project delivery
- Thankyou to the growers involved in this project who have volunteered their land, data and expertise.

EXPLORING SURFACE SPREAD AMENDMENTS *to* IMPROVE CROP ESTABLISHMENT *on* SALINE SOIL

Author: *Stefan Schmitt, Agricultural Consulting and Research*
Funding *provided by the Future Drought Fund Drought Resilient Soils and Landscapes Project* ***"Building resilience to drought with landscape scale remediation of saline land"***

AGRICULTURAL CONSULTING & RESEARCH

Australian Government

Future Drought Fund

Key Points

- Surface spread straw increased crop canopy size and plant establishment.
- Unfortunately yield data could not be obtained due to crop failure.

Background

Dryland salinity is an issue limiting agricultural production in the lower Broughton River catchment region. This region consists of ancient flood plain characterised by alluvial soils with moderate to high salt content and poor soil structure. Accumulation of salts in the surface soil, limits crop establishment, unless flushed from the surface with rainfall. Improving ground cover decreases salt accumulation in the topsoil, by reducing the capillary rise of salt to the surface as water evaporates.

The aim of this trial is to quantify the impact of surface spread amendments such as straw, gypsum and sand on barley establishment, groundcover and yield on land impacted by dryland salinity. Innovative farmers in this region have experimented with these amendments in the past on a small non replicated scale. This trial aimed to produce replicated data to support farmer decision making on the use of these amendments. Both sand and straw act like a mulch when spread on the soil surface decreasing the accumulation of salts which favours crop establishment. Gypsum whilst not acting like a mulch, improves soil structure (decreasing slaking) and has the ability to help flush magnesium salts from the surface.

Methodology

Sowing Date	2/5/2022
Soil Type	Hard clay loam over dispersive red clay, hard sodic clay restricts root growth. High boron, high ESP and moderate – high salinity at depth
Fertiliser	MAP @ 60 kg/ha
Crop Type	Commodus Barley
Growing Season Rainfall	220 mm (May-Oct 30) trial experi-enced extreme water stress in July. Plant death occurred in patches of the trial
Condition Post Sowing	15 mm rainfall received within 24 hours of sowing
Pre-Emergent Chemicals	Nil

Treatments

Treatment Number	Treatment	Application Rate
1	Straw	10 t/ha
2	Sand	500t/ha
3	Gypsum	10t/ha
4	Nil	

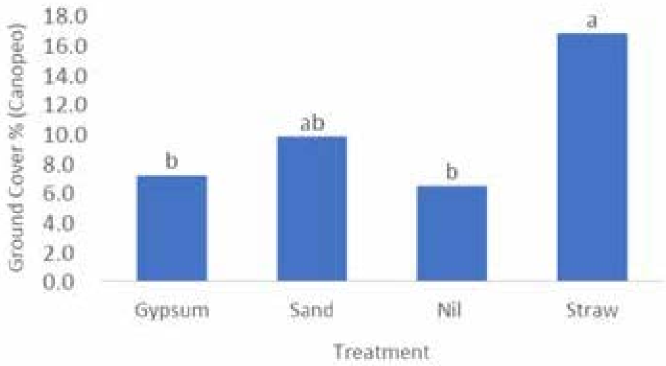


Figure 1. *Mean ground cover percentage by treatment measured using Canopeo app. An analysis of variance (ANOVA) was conducted on the data using R statistical software. Treatment means were separated using Tukey's HSD Post Hoc at the 95% level of probability. Treatments with letters in common are not significantly different from one another.*

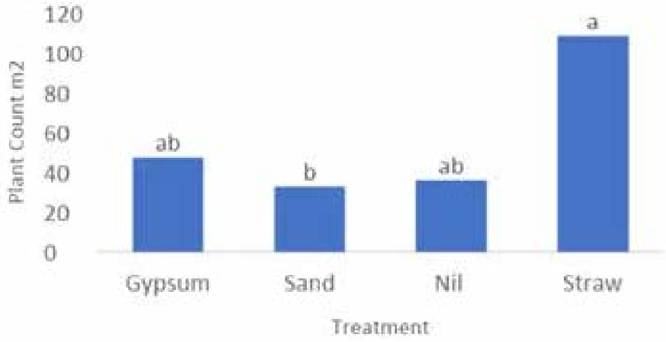


Figure 2. *Mean plant count per treatment. An analysis of variance (ANOVA) was conducted on the data using R statistical software. Treatment means were separated using Tukey's HSD Post Hoc at the 95% level of probability. Treatments with letters in common are not significantly different from one another.*

Discussion

The 2022 cropping season in the lower Broughton region was particularly challenging with crops experiencing extreme water stress in July and August. Ironically the season started and finished with good rainfall; however, crops were unable to recover from the water stress experienced mid-season. Unfortunately, because of this, the trial was unable to be harvested. A limited amount of data was able to be captured mid-season which is presented above. At this time there had been some plant death at the trial site which may confound results, results should therefore be treated with caution.

The main outcome from this work was that the addition of surface spread straw at 10 t/ha significantly increased ground cover percentage and plant numbers. Straw was applied directly after sowing the plots, ideally it would have been applied two to three months before sowing, which may have achieved a better result. The sand treatment also saw improved establishment and ground cover. This has not been reflected in the data as at the time of measurement this treatment was extremely water stressed. Again, ideally the sand and gypsum treatments would have been applied earlier in the season, which possibly would have increased the impact on establishment and groundcover. This trial will be sown over again with cereal this season, hopefully resulting in residual effects from these treatments.

SEED *and* SEED ZONE MANIPULATION *to* IMPROVE CROP ESTABLISHMENT *on* SALINE SOIL

Author: *Stefan Schmitt, Agriculture Consulting and Research*

Funding *provided by the Future Drought Fund Drought Resilient Soils and Landscapes Project* ***"Building resilience to drought with landscape scale remediation of saline land"***

Key Points

- In this season there was no significant difference between the ground cover % and establishment of applied treatments when compared to the control (nil treatment).
- Results should be treated with caution, as the trial site experienced extreme water stress conditions during early tillering. Plant death was observed and was variable across the trial site which may have confounded results.

Background

Dryland salinity is an issue limiting agricultural production in the lower Broughton River catchment region. This region consists of ancient flood plain characterised by alluvial soils with moderate to high salt content and poor soil structure. Accumulation of salts in the surface soil, limits crop establishment, unless flushed from the surface with rainfall. Improving ground cover decreases salt accumulation in the topsoil, by reducing the capillary rise of salt to the surface as water evaporates.

The aim of this trial was to explore novel methods of improving crop establishment on soil affected by dryland salinity. Treatments in this trial included in-furrow application of granulated gypsum, seed priming and the use of an in-furrow humectant/wetter (Se14).

Granulated gypsum - Gypsum has the ability to displace sodium (salt) in soils through the displacement of sodium ions on soil colloids with calcium supplied by gypsum. A secondary benefit of this is improved soil structure and reduction is dispersion (sealing over). It was hoped that including gypsum in the furrow directly with the seed, might help reduce the sodium concentration in-furrow and improve wetting ability.

Se14 – Se14 is a moisture retention agent produced by Sacoa. Se14 is a unique formulation of surfactants and retention agents. Sacoa claims Se14 has the ability to hold moisture and nutrients in the seeding furrow when banded within close proximity to the seed. *SE14™* is designed to improve early seedling emergence and vigour, particularly in non-wetting soils and/or dry seeding situations.

Seed priming – This process involves soaking seed in water or a salt solution which initiates the first reversible stage of germination before the first shoot (radicle emerges). Seed can then be dried, stored and sown at a later time. Seed priming has shown in field trials to improve germination percentage and rate in high salinity, low water potential environments. Other benefits included faster and more synchronized germination and resistance to abiotic stress.

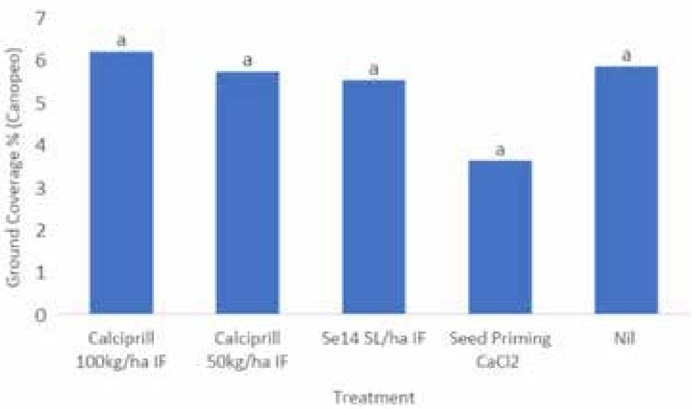
Methodology

Sowing Date	2/5/2022
Soil Type	Hard clay loam over dispersive red clay, hard sodic clay restricts root growth. High boron, high ESP and moderate – high salinity at depth
Fertiliser	MAP @ 60 kg/ha
Crop Type	Commodus Barley
Growing Season Rainfall	220 mm (May-Oct 30) trial experienced extreme water stress in July. Plant death occurred in patches of the trial
Condition Post Sowing	15 mm rainfall received within 24 hours of sowing.
Pre-Emergent Chemicals	Nil

Treatments

Treatment Number	Treatment	Notes
1	Calciprill 100kg/ha (prilled gypsum)	Applied with seed
2	Calciprill 50kg/ha	Applied with seed
3	Se14 5L/ha (humectant / surfactant mix)	Applied with seed as liquid in furrow
4	Seed Priming CaCL2 12H	
5	Nil	

Results



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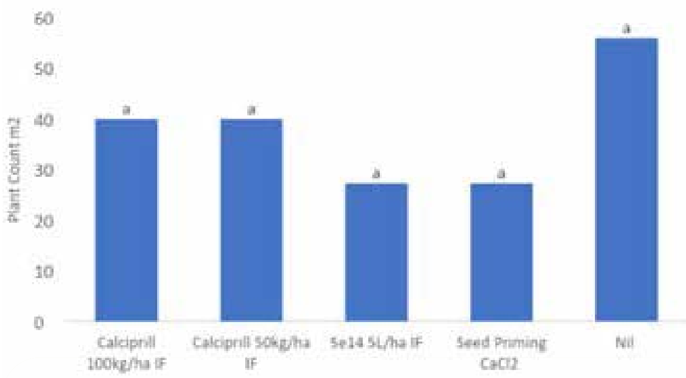


Figure 2. *Mean plant count per treatment. An analysis of variance (ANOVA) was conducted on the data using R statistical software. Treatment means were separated using Tukey's HSD Post Hoc at the 95% level of probability. Treatments with letters in common are not significantly different from one another.*

Discussion

The 2022 cropping season in the lower Broughton region was particularly challenging with crops experiencing extreme water stress in July and August. Ironically the season started and finished with good rainfall; however, crops were unable to recover from the water stress experienced mid-season. Unfortunately, because of this, the trial was unable to be harvested. A limited amount of data was able to be captured mid-season which is presented above. At this time there had been some plant death at the trial site which may confound results, results should therefore be treated with caution.

In this season there was no significant difference between the canopy size % or plant establishment between the applied treatments and the control. This trial will be repeated again, hopefully it is possible to test these treatments under more favourable conditions.

Photographs of lower Broughton trial site:

MANAGEMENT OPTIONS *for* DRY SALINE SOILS *on* UPPER YORKE PENINSULA

Authors: *Sam Trengove, Stuart Sherriff, Jordan Bruce and Sarah Noack*

Project Delivery: *Trengove Consulting | This program received funding from the Australian Government's Future Drought Fund project title '**Building resilience to drought with landscape scale remediation of saline land**.'*

Australian Government | Future Drought Fund

Key Points

- 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 trialled.

Background

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 e.g., 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 29th April 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.

Stubble cover score	Sample depth	pH 1:5 water	Chloride	Salinity EC1:5 (soil:water)	ECe (estimated)	Boron
	cm		mg/kg	dS/m	dS/m	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	-

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

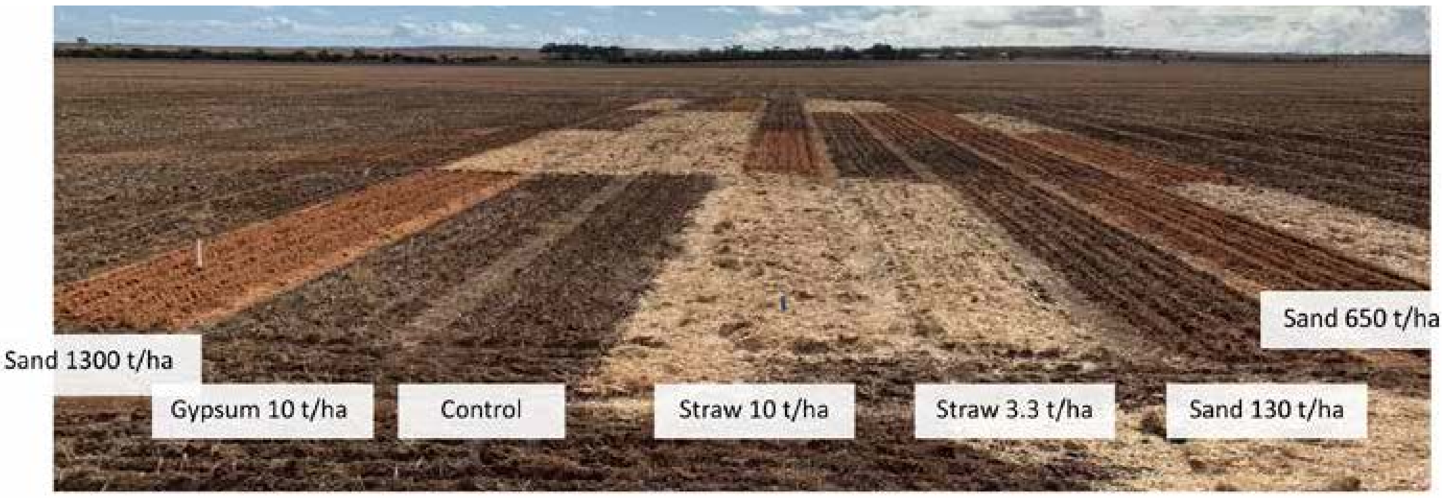
Boron levels across the site and soil depths ranged from 8 – 38 mg/kg. Boron toxicity for sensitive crop generally occurs at levels > 5 mg/kg and at levels > 15 mg/kg it is considered toxic for dryland cereals (Hughes 2020).

Sand, gypsum and straw amelioration trial

Sand and gypsum treatments were spread on the soil surface 3rd May 2022. Straw treatments (from baled wheat) were applied post seeding on 27th May 2022. Treatments included; control, gypsum 10 t/ha, straw 3.3t/ha, straw 6.6t/ha, straw 10t/ha, sand 130 t/ha, sand 650 t/ha and sand 1300 t/ha (photo 1). 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 26th May 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.

Photo 1. *Sand, gypsum and straw amelioration treatments post seeding at salinity management trial Tickera, SA (taken 27th May 2022).*



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 26th May 2022. BoxerGold @ 2.5L/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/m²)	Expected tolerance to soil salinity level (ECe)
Barley	Compass	150	10
Oats	Mulgara	240	5.4
Triticale	Yowie	200	8
Wheat	Glad_V13*	180#	-
	Glad_V26*	180#	-
	Glad_V3*	180#	-
	Gladius	180	7.5
	Scepter	180	7.5
Lentil	Bolt	120	-
	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 21st June 2022, ranging from 0 (no plant emergence) – 10 (full plant emergence). A Greenseeker was used to measure NDVI on 12th July 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 17th November 2022 using a plot header. Safflower was harvested on 6th Jan 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 compare 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.

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 (0.05)	28	0.24

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

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.

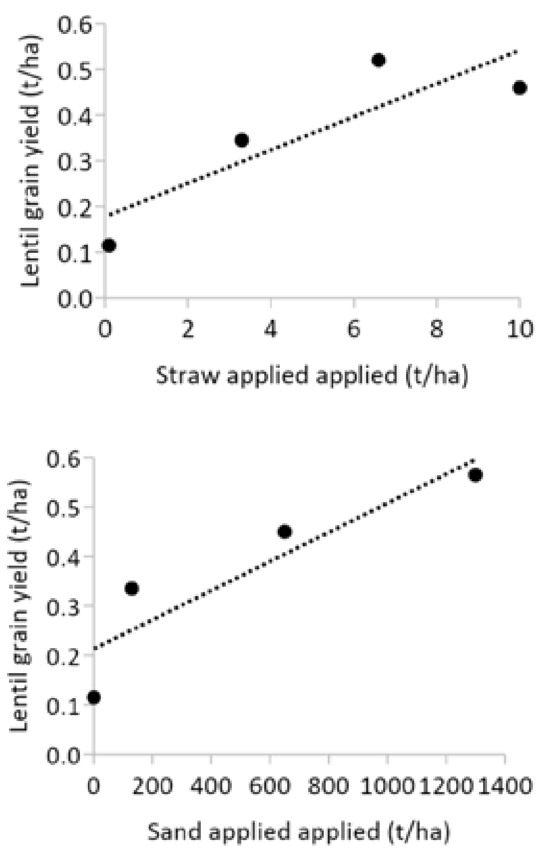


Figure 1. *Lentil grain yield response in relation to straw (left, y = 0.0816ln(x) + 2.972, R^2 = 0.918) and sand (right, y = 0.0579ln(x) + 0.0983, R^2 = 0.9501) rates applied in salinity management trial Tickera, SA.*

Crop type and variety trial

There was 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 2). 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.

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 (0.05)	1.36	0.032	22	0.42

Photo 2. *Crop type and variety treatments in the salinity management trial at Tickera, SA. Photo taken 23rd September 2022.*

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, barely 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

This program received funding from the Australian Government's Future Drought Fund project title 'Building resilience to drought with landscape scale remediation of saline land'. Thank you to our project partners Mallee Sustainable Farming. We also acknowledge the support of local growers; Michael Barker trial host, Andrew Bruce supplied sand, Josh Flowers freight and Bruce Bros baled straw.

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THE PERFORMANCE *of* pHnNDVI *in* 2022 *and the* EFFECTS *of* CUMULATIVE P APPLICATIONS *on* SOILS *in the* MID NORTH *of* SA

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Keywords

- Phosphorus Availability, Phosphorus Economics, Replacement Phosphorus

Key Points

- The pHnNDVI methodology for predicting crop P response was able to accurately predict the P fertiliser rate required at Booleroo Centre in 2022.
- pHnNDVI was not able to accurately predict grain yield response to P on Black and Grey Vertosols or a Red Sodosol at Clare.
- Application of high rates of P in 2021 was able to increase grain yield of lentil in the 2022 season with standard rates of P fertiliser.
- Repeated applications of high rates of P (50 and 90 kg P/ha) produced the highest lentil grain yield at two sites in 2022.

Background

High fertiliser prices have increased grower interest in phosphorus (P) responses on variable soil types and improving returns from P fertiliser inputs. Recently, two SAGIT funded projects (TC219 and TC221) have examined P fertiliser response on a range of soil types with varying soil P availability. The trial locations were determined using soil pH maps and satellite NDVI imagery. To date 41 P response trials have been established in the Mid North and upper YP regions to validate the pHnNDVI methodology (refer to method section) of predicting P response based on these data layers. Most of the sites predicted to be P responsive in this dataset are calcareous loams or sands. The non-responsive sites have comprised of Red Chromosols, Red Sodosols, and Red Dermosols. In 2022 we wanted to test the relationship in other areas of the Mid North and on different soil types.

Three long term (3 year) trials were established in 2021 (TC221) at Spalding, Crystal Brook and Hart. These three sites are highly P responsive alkaline soil types, and the project aims to examine the effects of cumulative P fertiliser rates on crop performance. This report summarises the longer-term effects of the 2021 P rates and repeated applications of high and low P on grain yield of lentil (Crystal Brook and Hart) and barley (Spalding) in 2022.

Eight additional trial sites were established based on the pHnNDVI methodology, 4 in a paddock near Clare and 4 in a paddock near Booleroo Centre. This report also examines how the P response at these sites fit the pHnNDVI methodology.

Methodology

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

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

Areas of a paddock with high soil pH (>7) and low relative normalised NDVI (<0.8) result in a high pHnNDVI value and are likely to be highly responsive to applied P. Areas with low pH (<6) and high relative NDVI (>1.1) result in a low pHnNDVI value and are likely to be unresponsive to applied P in the paddocks tested. This methodology has proven informative in trial paddocks tested across the Mid North and northern YP.

Single year trials

In 2022 two paddocks were identified at Booleroo Centre (Figure 1) and Clare (Figure 2). In each paddock four trials were (eight trials total) established to cover a range of pHnNDVI values (Table 1). There was also a spread in soil P levels based on both DGT-P (60 ug/L critical limit for wheat) and Colwell P (<35 mg/kg is marginal) soil tests across the eight sites (Table 1).

All trials were randomised complete block designs with three replicates and seven P fertiliser rates including 0, 7.5, 15, 22.5, 30, 50 and 90 kg P/ha. Phosphorus was applied as MAP (10:22) and nitrogen was balanced with urea at seeding to match the 90 kg P/ha (409 kg MAP/ha = 41 kg N/ha) treatment. Booleroo Centre trials were sown to Spartacus Barley on 12th May 2022 and no additional N was applied. The Clare trials were sown to Scepter wheat on 28th May 2022 and the trials were all spread with 160 kg/ha urea post emergence.

Measurements at these sites included NDVI, tissue tests, grain yield and quality. Partial gross margin analysis was conducted by fitting a response curve (exponential rise to max) for each site. Partial gross margins (PGMs) were calculated using 2022 pricing and assumed MAP = $1200/t, wheat = $400/t, lentil = $800/t and barley = $300/t.

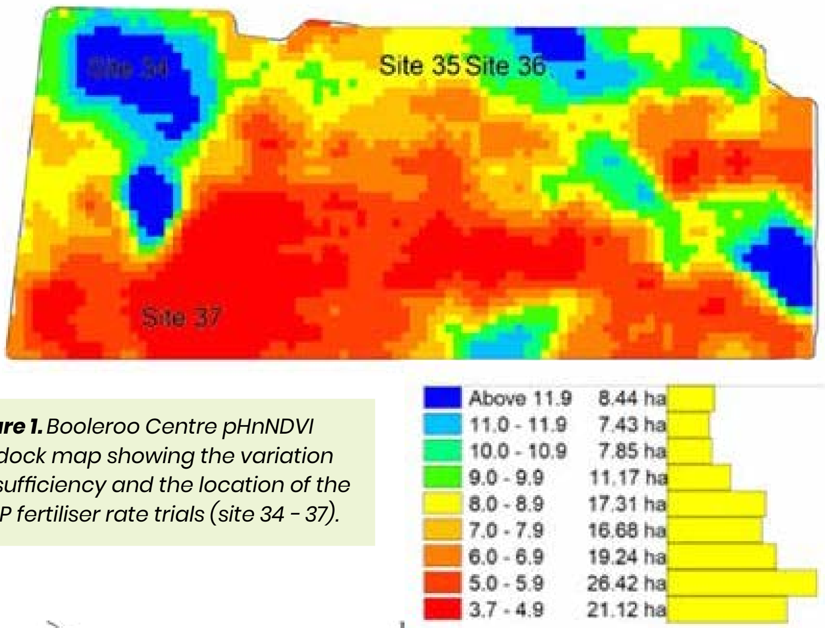

Figure 1. *Booleroo Centre pHnNDVI paddock map showing the variation in P sufficiency and the location of the four P fertiliser rate trials (site 34 - 37).*

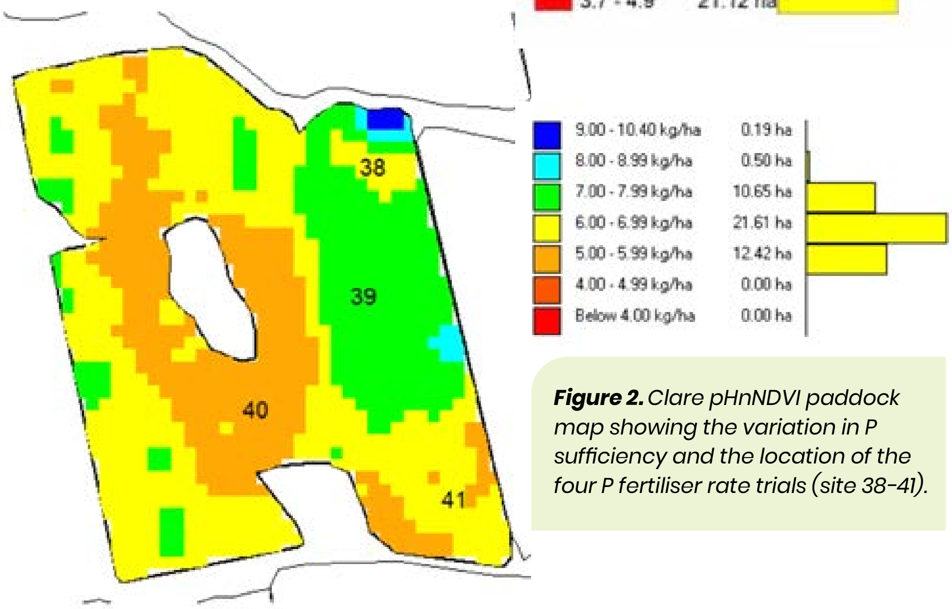

Figure 2. *Clare pHnNDVI paddock map showing the variation in P sufficiency and the location of the four P fertiliser rate trials (site 38-41).*

Table 1. *Growing season rainfall (GSR = April – October) and soil properties for 2022 single year trials at Booleroo Centre and Clare.*

Location	Site	pH $CaCl_2$	DGT P µg/L	Colwell P mg/kg	PBI	pHnNDVI
Booleroo Centre Ave GSR 276mm 2022 GSR 250mm	34	7.61	38	40	114	12 (responsive)
	35	7.72	57	34	106	8.5 (moderately responsive)
	36	7.7	45	30	89	10.5 (responsive)
	37	6.53	96	55	69	4 (non-responsive)
Clare Ave GSR 395mm 2022 GSR 431mm	38	6.7	40	34	104	6.7 (moderately responsive)
	39	7.62	14	18	165	7.7 (moderately responsive)
	40	5.63	83	39	55	5.5 (non-responsive)
	41	6.07	97	55	73	6.3 (non-responsive)

Long term sites

Highly P responsive sites were identified using the P sufficiency index methodology in 2021. Crops were sown in each year to match the trial paddock and are described in Table 2. Soil pH and DGT-P levels ranged from 7.7 – 7.9 pH CaCl2 and 18 – 23, respectively (Table 2). Treatments applied to each of these sites are shown in Table 3.

Table 2. *Growing season rainfall (GSR = April – October), soil properties and sown crops for long term P response sites established in 2021.*

Location	Soil pH $CaCl_2$	DGT P µg/L	Colwell P mg/kg	PBI	P sufficiency index	2021 crop	2022 crop
Crystal Brook Ave GSR 289mm 2022 GSR 289mm	7.8	23	29	88	12	Compass barley	PBA Highland XT lentil
Spalding Ave GSR 268mm 2022 GSR 410mm	7.7	18	20	77	11.7	Scepter wheat	Spartacus CL barley
Hart Ave GSR 291mm 2022 GSR 355mm	7.9	17	40	110	10	Scepter wheat	PBA Jumbo 2 lentil

Table 3. *Treatment list for long term P response trials in 2021 and 2022.*

Treatment number	2021 P rate (kg P/ha)	2021 MAP rate (kg MAP/ha)	2022 P rate (kg P/ha)	2022 MAP rate (kg MAP/ha)	Total MAP and chicken litter applied 2021 and 2022
1	0	0	0	0	0
2	0	0	15	68	68
3	7.5	34	15	68	102
4	15	68	15	68	136
5	22.5	102	15	68	170
6	30	136	15	68	205
7	50	227	15	68	295
8	90	409	15	68	477
9	Spread MAP 90	409	15	68	477
10	CL 90	6250 kg CL + 68 kg MAP	15	68 kg MAP	6250 kg CL + 136 kg MAP
11	7.5	34	7.5	34	68
12	22.5	102	22.5	102	205
13	30	136	30	136	273
14	50	227	50	227	455
15	90	409	90	409	818

Phosphorus fertiliser was applied to the sites as MAP and nitrogen was balanced at seeding with urea to the 90 kg P/ha treatment. In the main treatments, the fertiliser was applied below the seed using a knife point press wheel system on 250 mm row spacing.

In treatment 9, spread MAP 90, 75 kg P was applied as MAP in a broadcast application prior to seeding in 2021 and then followed with 15 kg P/ha as an application below the seed to make a total of 90 kg P/ha.

In treatment 10, CL 90, 75 kg P/ha was broadcast as chicken litter (6250 kg chicken litter/ha) and then followed with 15 kg P/ha as an application below the seed to make a total of 90 kg P/ha. The chicken litter used had a Phosphorus concentration of 1.48%, total nitrogen concentration of 4.14% and moisture content of 15.4%. Total applied N and P nutrients in the chicken litter in this treatment were 78 kg P/ha and 219 kg N/ha.

Results and discussion

2022 SINGLE YEAR TRIALS

Grain yield and quality

Grain yields at Booleroo Centre were above average in 2022 (Figure 2, Table 4). The average barley grain yield across the four sites was 3.77 t/ha at the P application rate of 15 kg/ha.

Grain yields were correlated to crop NDVI recorded on 2nd August at the three P responsive sites (34, 35 and 36). This indicates early biomass was an important factor to producing higher grain yields at these sites. The remaining site (37) was predicted to be non-responsive to P. At this site there was a crop NDVI response however, no increase in grain yield was observed (Figure 2).

Phosphorus fertiliser rate improved grain yields at the three responsive sites. The highest grain yields came from the highest P rate of 90 kg P/ha (Table 4). As expected from the pHnNDVI, there was no yield response to P fertiliser application at site 37.

There were minor differences in grain quality across the sites at Booleroo Centre (data not presented) in 2022. Increasing P rate reduced screenings and increased grain retention at responsive sites. Protein declined with increasing yields at P responsive sites however, all treatments met malt grade.

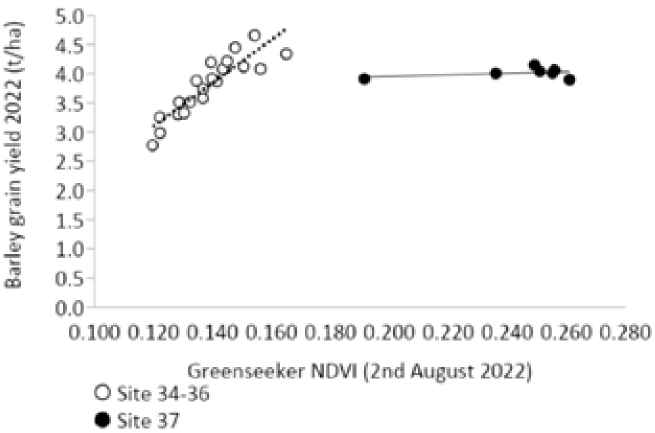

Figure 2. *Relationship between Greenseeker NDVI recorded 2nd August and grain yield (t/ha) at responsive sites 34 – 36 ($y = 37.035x - 1.437$, $R^2 = 0.798$, and site 37 ($y = 1.3643x + 3.6796$, $R^2 = 0.142$) at Booleroo Centre, 2022.*

At the Clare sites, the pHnNDVI was related to soil test values, where higher pHnNDVI had low DGT-P and higher PBI. Early crop NDVI increased with P rates at all sites (Table 5). Site 39 was the site with the highest pHnNDVI (7.7) value and as expected required the highest P rate of all sites in this paddock to reach maximum NDVI in early August. However, site 40 had a low pHnNDVI value (5.5) and responded to high rates of P (>30 kg P/ha) to achieve maximum NDVI. This was unexpected as other sites in the trial series with low pHnNDVI values have generally only responded to low rates of P.

P Rate (kg P/ha)	Site 34	Site 35	Site 36	Site 37
	Grain yield (t/ha)			
0	2.78 f	3.52 e	3.33 e	3.91 a
7.5	2.98 e	3.74 de	3.58 de	4.01 a
15	3.25 d	3.87 cd	3.92 cd	4.04 a
22.5	3.31 d	4.12 ab	4.08 bc	4.01 a
30	3.51 c	4.09 bc	4.21 bc	4.06 a
50	3.88 b	4.08 bc	4.45 ab	4.15 a
90	4.20 a	4.34 a	4.66 a	3.90 a
Pr (>F)	<0.001	<0.001	<0.001	0.6022
LSD (0.05)	0.18	0.24	0.39	ns

Table 4. *Grain yield response to increasing P rates at 4 single year sites near Booleroo Centre 2022.*

The average grain yield for all Clare sites was 5.53 t/ha at the district practice rate of 15 kg P/ha. Wheat grain yield was affected by P rate at two of the four sites at Clare (Table 5). Site 38 which had a pHnNDVI value of 6.7 and was expected to be moderately responsive (Table 2). Site 40 had the lowest pHnNDVI in this paddock and adequate soil test values, but did produce a significant yield response up to 15 kg P/ha. This unexpected response was similar to NDVI response at this site, and more investigation is required. Site 39 was expected to be responsive with a pHnNDVI value of 7.7 and low DGT-P. However, despite a crop NDVI response there was no grain yield differences.

Grain quality at the Clare sites was excellent, with no differences between treatments at any site (data not shown). Grain test weight, screenings and protein at these sites averaged 80.8 kg/hL, 1.5% and 10.16%, respectively.

P Rate (kg P/ha)	Site 38 NDVI	Site 38 Grain yield (t/ha)	Site 39 NDVI	Site 40 NDVI	Site 40 Grain yield (t/ha)	Site 41 NDVI
0	0.557 c	3.52 e	3.33 e	3.91 a	4.09 c	0.602 c
7.5	0.602 b	3.74 de	3.58 de	4.01 a	4.61 b	0.666 b
15	0.639 a	3.87 cd	3.92 cd	4.04 a	4.80 ab	0.696 ab
22.5	0.664 a	4.12 ab	4.08 bc	4.01 a	4.82 ab	0.706 a
30	0.645 a	4.09 bc	4.21 bc	4.06 a	4.97 ab	0.696 ab
50	0.652 a	4.08 bc	4.45 ab	4.15 a	5.31 a	0.707 a
90	0.661 a	4.34 a	4.66 a	3.90 a	4.92 ab	0.716 a
Pr (>F)	<0.001	<0.001	<0.001	0.6022	<0.001	<0.001
LSD (0.05)	0.029	0.24	0.39	ns	0.51	0.035

Table 5. *Greenseeker NDVI 1st August 2022 for the Clare P rate trials and grain yield for site 38 at Clare.*

Partial gross margin analysis and testing pHnNDVI

Partial gross margin (PGM) analysis has been performed on each of the 41 sites in the trial series by generating a P response curve for grain yield. PGM for each site can then be used to test the accuracy of predicting P response using the pHnNDVI methodology. Until 2022, most sites predicted to be P responsive were located on calcareous loams or sands on the upper Yorke Peninsula or in the Mid North, with non-responsive sites comprised of Red Chromosols, Red Sodosols and Red Dermosols. In 2022 we wanted to test the relationship on different soil types and environments. Sites 34 – 37 at Booleroo Centre were located on similar soil types (Calcarosols and Red Dermosol/Chromosol) to those included previously but in a lower rainfall environment. Sites 38 – 41 at Clare were in a similar environment but on different soil types, including Black and Grey Vertosols (clay soils with shrink-swell properties) and Red Sodosols. A point of difference here is the sites predicted to be more P responsive were Vertosols, whereas in most other trial paddocks it has been Calcarosols.

Figure 3 shows the relationship between pHnNDVI and the P rate that returns the maximum partial gross margin for a given site based on 2022 pricing for fertiliser and grain. The 2019 and 2021 trials produce a relationship where the optimum P rate is equal to 4.235 * pHnNDVI – 23.242.

When the 2022 data is applied to this graph it shows that the Booleroo Centre trials fit the relationship well, where increasing pHnNDVI requires higher P rate to maximise PGM. It should be noted that the grain yields at Booleroo Centre were above average, and this may not reflect a normal season at these sites.

At the Clare sites the relationship does not fit the line as well as other paddocks with site 40, a Red Sodosol, having high P requirement despite having a low pHnNDVI value and adequate soil test value. Site 39, a Grey Vertosol with pHnNDVI 7.7, produced significant early NDVI responses to high rates of P but the site did not have any yield response and therefore the P rate at maximum PGM is 0 kg P/ha. Site 39 does fit within a cluster of other sites with similar pHnNDVI values. The pHnNDVI at the Clare sites was related to soil P test values, however, it does not have a strong relationship with P response. These soils require further investigation to understand what is driving / limiting their response to P fertiliser.

Long term sites

As predicted, all three sites were highly responsive to P applications in the two trial seasons to date. Maximum grain yields were produced from repeated applications of 90 kg P/ha at the sites sown to lentil in 2022 (Crystal Brook and Hart) or the chicken litter 90 treatment at Spalding which was sown to barley. In 2022 grain yield at all three sites was correlated to the cumulative P applications in 2021 plus 2022 (Figure 4). Increasing P application rate in either 2021 or both 2021 and 2022 led to higher grain yields.

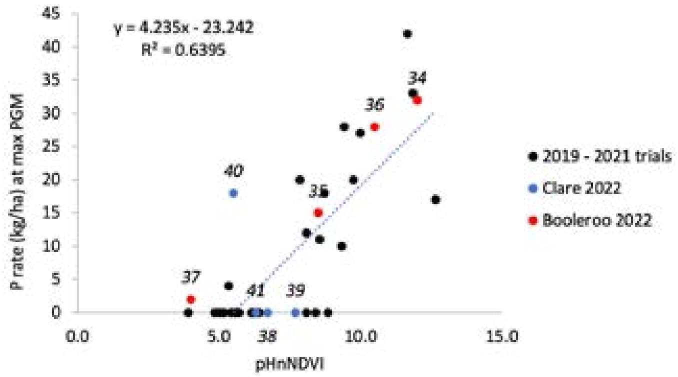

Figure 3. *Relationship between pHnNDVI and P fertiliser rate (kg/ha) that returns the maximum partial gross margin for 41 sites in the Mid North, Yorke Peninsula and Upper North. Numbers in italics show site number.*

Crystal Brook and Hart (lentil)

Increasing the P application rate in 2021 caused an increase in crop NDVI and grain yield in the year after application (Table 6 and 7). Repeated applications of high rates produced larger responses with grain yields maximised with two applications of 50 kg P/ha. Increasing P rates to two applications of 90 kg P/ha did not increase lentil performance further.

The method that 90 kg P/ha was applied in 2021 influenced grain yield in 2022 at Crystal Brook. The 90 kg P/ha applied below the seed as MAP (T8) produced the highest grain yields at Crystal Brook compared to broadcasting 83% of the MAP prior to seeding (T9) or applying 83% of P as chicken litter prior to seeding (T10). The NDVI values recorded in October show T8 had more biomass compared to the other treatments. This effect was not observed at Hart with these three treatments producing similar grain yields.

Spalding (barley)

At the Spalding site, increasing the application rate of MAP in 2021 influenced early NDVI in 2022. The 50 and 90 kg P/ha treatments produced higher NDVI compared to the 0 kg P/ha (Table 8). Grain yield increased slightly when the 2021 P rate was greater than 50 kg P/ha. There were three treatments that received 90 kg P/ha in 2021, T8, T9 and T10. Of these treatments, chicken litter 90 treatment (T10) produced the highest NDVI and yields in the whole trial. The chicken litter 90 treatment also produced the highest grain protein at this site (11.3%). This increase in both grain yield and protein indicates a nitrogen response. Above average spring rainfall resulted in higher-than-expected grain yields which had high crop N demand in 2022. The chicken litter treatment had more N applied in 2021 compared to all other treatments. There was 219 kg N/ha + 6.7 kg N/ha applied in the chicken litter treatment compared to the other treatments that received 41 kg N/ha applied as either MAP or urea or both. Therefore, it is not surprising that in this season of exceptionally high yields there was a crop N response in addition to any P response. This indicates that treatments were N limited and this may have masked some P response.

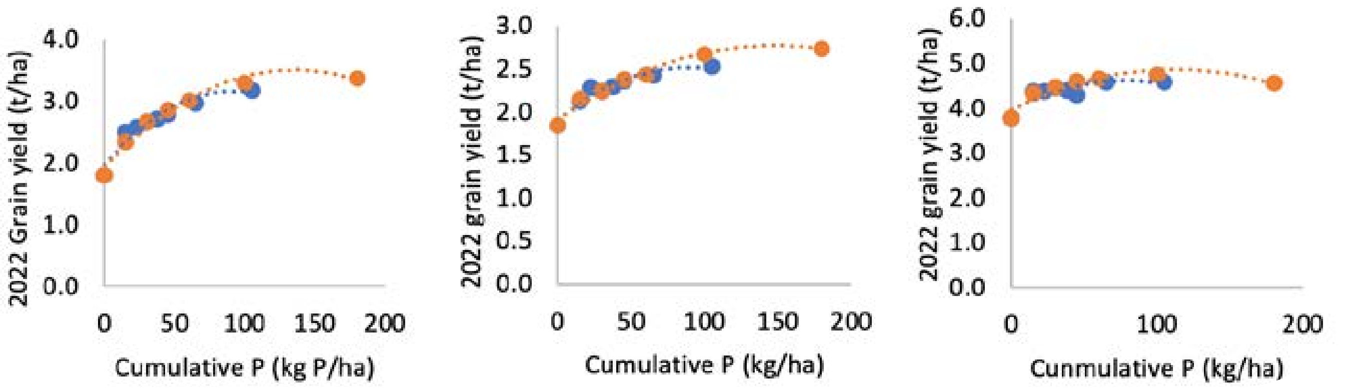

Figure 4. *Lentil grain yield at Crystal Brook (left) and Hart (middle) and barley grain yield at Spalding in 2022 (right) compared to the cumulative P rate over 2021 and 2022 seasons. Blue dots represent treatments that had varying P rates in 2021 and were treated with 15 kg P in 2022 and the orange dots represent treatments that had repeated applications of the same rate in 2021 and 2022.*

Treatment number	2021 P rate (kg P/ha)	2022 P rate (kg P/ha)	NDVI Aug 8 22	NDVI Oct 11 22	Grain yield (t/ha)	Cumulative yield (t/ha)
1	0	0	0.188 f	0.723 f	1.80 j	4.48 i
2	0	15	0.192 ef	0.808 e	2.50 h	5.30 h
3	7.5	15	0.196 ef	0.810 de	2.58 gh	5.91 g
4	15	15	0.200 cde	0.825 c	2.67 fg	6.49 f
5	22.5	15	0.200 cde	0.828 c	2.72 ef	6.86 e
6	30	15	0.199 de	0.825 c	2.79 de	6.98 de
7	50	15	0.200 cde	0.825 cd	2.96 c	7.56 c
8	90	15	0.212 b	0.843 ab	3.18 b	7.98 ab
9	Spread90	15	0.202 bcde	0.835 bc	3.05 c	7.74 bc
10	CL90	15	0.209 bcd	0.833 bc	3.07 c	7.74 bc
11	7.5	7.5	0.197 ef	0.809 e	2.34 i	5.75 g
12	22.5	22.5	0.197 ef	0.831 bc	2.85 d	6.93 e
13	30	30	0.210 bc	0.834 bc	3.01 c	7.25 d
14	50	50	0.209 bcd	0.846 ab	3.29 a	7.85 abc
15	90	90	0.224 a	0.853 a	3.37 a	8.12 a
Pr (>F)			<0.001	<0.001	<0.001	<0.001
LSD (0.05)			0.010	0.010	0.11	0.30

Table 6. *Lentil Greenseeker NDVI and grain yield for Crystal Brook long term P site 2022.*

Treatment number	2021 P rate (kg P/ha)	2022 P rate (kg P/ha)	NDVI Aug 8 22	NDVI Sept 15 22	Grain yield 2022 (t/ha)	Cumulative yield (t/ha)
1	0	0	0.194 f	0.636 i	1.84 i	4.03 j
2	0	15	0.205 e	0.716 h	2.12 h	4.43 i
3	7.5	15	0.213 cde	0.743 fg	2.29 ef	5.32 f
4	15	15	0.210 de	0.739 g	2.24 fg	5.12 gh
5	22.5	15	0.216 cd	0.753 defg	2.29 ef	5.23 fg
6	30	15	0.214 cde	0.751 efg	2.36 de	5.35 ef
7	50	15	0.221 abc	0.756 bcdef	2.42 cd	5.78 bc
8	90	15	0.217 bcd	0.773 ab	2.53 b	5.95 ab
9	Spread (90)	15	0.220 abc	0.754 cdefg	2.53 b	5.81 bc
10	CL (90)	15	0.230 a	0.766 abcde	2.47 bc	5.65 cd
11	7.5	7.5	0.206 e	0.716 h	2.15 gh	5.03 h
12	22.5	22.5	0.212 cde	0.757 bcdef	2.38 cde	5.54 de
13	30	30	0.209 de	0.769 abcd	2.44 bcd	5.55 de
14	50	50	0.219 bcd	0.771 abc	2.67 a	5.91 ab
15	90	90	0.227 ab	0.781 a	2.74 a	6.09 a
Pr (>F)			<0.001	<0.001	<0.001	<0.001
LSD (0.05)			0.01	0.0175	0.11	0.20

Table 7. *Lentil Greenseeker NDVI and grain yield for Hart long term P site 2022..*

Treatment number	2021 P rate (kg P/ha)	2022 P rate (kg P/ha)	NDVI 1st Aug 22	NDVI 8th Sept 22	Grain yield 2022 (t/ha)	Cumulative yield (t/ha)	Protein 2022 (%)
T1	0	0	0.234 g	0.619 g	3.78 g	6.50 h	10.9 ab
T2	0	15	0.315 e	0.735 def	4.38 ef	7.00 g	10.4 cde
T3	7.5	15	0.332 cde	0.738 def	4.39 ef	7.44 f	10.5 bcd
T4	15	15	0.328 de	0.739 def	4.47 cdef	7.71 ef	10.3 cde
T5	22.5	15	0.330 cde	0.732 ef	4.41 def	7.61 f	10.2 def
T6	30	15	0.330 cde	0.737 def	4.29 f	7.47 f	10.0 ef
T7	50	15	0.341 bcd	0.765 bcd	4.58 bcde	8.30 cd	10.3 def
T8	90	15	0.344 bcd	0.743 cdef	4.58 bcde	8.57 bc	10.2 def
T9	Spread (90)	15	0.349 abc	0.769 abc	4.70 b	8.55 bc	10.1 def
T10	CL (90)	15	0.364 a	0.799 a	5.04 a	9.17 a	11.3 a
T11	7.5	7.5	0.292 f	0.726 f	4.34 f	7.44 f	10.7 bc
T12	22.5	22.5	0.326 de	0.751 bcdef	4.61 bcd	8.03 de	10.4 cde
T13	30	30	0.348abc	0.759 bcde	4.66 bc	8.04 de	10.4 cde
T14	50	50	0.367 a	0.774 ab	4.74 b	8.72 b	10.2 def
T15	90	90	0.355 ab	0.749 bcdef	4.57 bcde	8.70 b	9.9 f
Pr (>F)			<0.001	<0.001	<0.001	<0.001	<0.001
LSD (0.05)			0.016	0.030	0.20	0.38	0.408

Table 8. *Barley Greenseeker NDVI and grain yield for Spalding long term P site 2022.*

Conclusions

The pHnNDVI methodology has been able to predict the response to P fertiliser for 38 out of 41 locations across the Mid North and Yorke Peninsula. In 2022 trials extended to the Upper North (Booleroo Centre) and these sites had similar soil types to those tested in previous years, these trials produced P responses as expected. In contrast soil types at Clare, included Black and Grey Vertosols and Red Sodosols and the pHnNDVI and accompanying soil tests were not as accurate at predicting P response. The measured P responses to the pHnNDVI on the Grey and Black Vertosols were similar to other sites with similar pHnNDVI values. However, one Red Sodosol at the Clare site was highly responsive to P despite having a low pHnNDVI value. This needs further investigation and trials will be conducted in the 2023 season to understand this response.

Long term trial sites established on highly P responsive sites at Crystal Brook, Hart and Spalding have demonstrated that application of high rates of P can influence crop performance in more than just the year of application. This was particularly the case when the second crop was sown to lentil. These trials will continue for a third season after which detailed financial analysis will be performed to determine the economics behind using high rates of P on Calcareous highly P responsive soil types.

Acknowledgements

The research undertaken as part of this project is made possible by the significant contributions of growers through both trial cooperation and the support SAGIT, the authors would like to thank them for their continued support. We would also like to acknowledge the growers involved in SAGIT funded project TC219 and TC221.

SAGIT

INCREASING PRODUCTION *on* SANDY SOILS – NARROWING DOWN WHAT *to do and* WHERE?

Authors: *Sam Trengove, Stuart Sherriff, Jordan Bruce and Sarah Noack*
Project Delivery: *Trengove Consulting | This program received funding from the Australian Government's Future Drought Fund project title '**Building resilience to drought with landscape scale remediation of saline land**.'*

Key Points

- The grain yield response to physical treatments (deep ripping and spading) and CL were typically greater than 10%, but the ranking of treatments varied at each of the sandy soil trial sites.
- The use of short and long inclusion plates (without CL) did not provide any yield benefit compared to deep ripping with no inclusion plates at any of the three sites in year one.
- Spading created a soft soil surface at seeding time, resulting in a deeper seeding depth at all sites. The wheat crop struggled to emerged and a lower NDVI was observed as well as reduced grain yields compared to the other physical treatments at some sites.
- At two out of the three sites, deep ripping to depth of 40 cm was sufficient to achieve maximum grain yield improvement. At the third site higher grain yields resulted from deeper ripping to 60 cm.

Background

It is estimated farmers manage 3 million hectares of sandy soils in the low-medium rainfall landscape of southeast Australia. These sandy soils can have a range of productions constraints including; compacted or hard-setting layer preventing root proliferation, a water repellent surface layer causing poor crop establishment, soil pH issues (both acidity and alkalinity) and/or poor nutrient supply. Sandy soils also respond differently to soil amelioration techniques and not a one size fits all approach. Understanding the constraints, appropriate amelioration tools and machinery set up that will best address the constraints are critical to success.

Local research (Parker et al. 2019; Ucgul et al. 2019) has developed guides on how spading and inclusion ripping machinery are best set-up and used. The incorporation by spading of a surface-applied amendment or the mixing of a constrained sublayer achieves variable levels of mixing uniformity within the profile, which is a function of speed, depth and spader design. The mixing by spading process is cyclical rather than continuous and controlled principally by the spading 'bite length.'

A lower risk soil profile amelioration method consists of inclusion plates fitted behind deep ripping tines which promote the natural inclusion of the top layer into the loosened profile. Substantially enhanced inclusion capacity can be obtained when operating in loose, flowable top-soil conditions with optimised plate design and set-up, such as the plate upper-edge length and its lower-edge depth of reach. The use of inclusion plate is also about trying to extend the length of the effect from deep ripping alone.

Reasons for using one technique or another will depend on the soil constraints being addressed. This project aims to establish field sites which demonstrate amelioration techniques that growers can use to address the specific sandy soil constraints for their local landscape type and where in the landscape different tactics are best deployed.

Methodology

Site Selection

Three sandy soil amelioration trial sites were identified at Bute, SA (Figure 1). The two sites located in the North paddock (Figure 1) were a duplex sand over loamy sand (North hill top) and a loamy sand transition to a deep sand (North mid slope). Site three was in the South paddock (Figure 1) and the soil was a deep sand (Table 1). Historic crop performance indicated the south paddock was poorer performing compared to the north.

The two deep sands were more acidic at depth (10-20 cm and 20-30 cm) compared to the North hill top site (Table 1). The South mid-slope soil had a lower PBI and CEC compared to the north sites (Table 2). Organic carbon was generally low across all three sites. Soil phosphorus levels were in the marginal (20-30 mg/kg) to adequate (30-45 mg/kg) ranges across the three sites (Hughes 2020). Sulphur levels were low (<5 mg/kg) at the South mid slope site and become low to marginal (5-10 mg/kg) at the North sites.

Surface soil samples were also assessed for water repellence. A water repellence rating (0-5) was given based on the concentration of ethanol required to penetrate the soil surface. The higher the rating, the more water repellent the soil. The North sites were not considered water repellent with 0 and 1 ratings (data not shown). The South mid slope site was moderately repellent, scoring 2 in both the 0-5 cm and 5-10 cm layers.

Figure 1. *Image showing the three trial locations (yellow dots) for the sandy soil amelioration sites at Bute, SA 2022.*

Table 1. *Soil pH for all three sandy soil types at Bute, SA.*

Depth	North hill top	North mid slope	South mid slope
0-5 cm	5.22	5.27	5.34
5-10 cm	4.71	4.53	4.90
10-20 cm	5.61	4.82	5.03
20-30 cm	7.62	5.36	6.15

Table 2. *Soil physical and chemical properties for all three sandy soil types at Bute, SA.*

Depth	Soil Texture	Organic Carbon	Colwell P	PBI	Sulphur	Conductivity		Exchangeable cations		
cm		%	mg/kg		mg/kg	EC1:5 dS/m	ECe	ECEC	ESP	
North hill top										
0-10	Sand	0.6	25	17	7.5	0.08	1.1	3.9	1.0	Non-sodic
10-30	Loamy sand	0.1	26	29	4.1	0.11	1.5	10.2	0.3	Non-sodic
30-50	Loamy sand	0.1	10	32	6.5	0.08	1.1	19.9	0.2	Non-sodic
50-100	Loamy sand	0.1	<5	41	4.6	0.08	1.1	21.7	0.2	Non-sodic
North mid slope										
0-10	Loamy sand	0.4	30	21	8.5	0.14	2.0	3.6	1.1	Non-sodic
10-30	Loamy sand	0.1	29	16	4	0.04	0.5	2.8	1.3	Non-sodic
30-50	Loamy sand	0.1	14	14	<2.5	0.04	0.6	2.8	1.2	Non-sodic
50-100	Sand	0.1	<5	16	2.5	0.06	0.8	4.5	0.8	Non-sodic
North mid slope										
0-10	Sand	0.4	31	14	3.8	0.04	0.5	2.0	1.7	Non-sodic
10-30	Sand	0.1	26	18	3.1	0.04	0.5	2.5	1.4	Non-sodic
30-50	Sand	0.1	11	13	2.9	0.04	0.5	3.1	1.1	Non-sodic
50-100	Sand	0.1	<5	30	5.1	0.07	1.0	6.2	1.1	Non-sodic

Trial design and treatments

At each of the three locations (Figure 1) two trials were established to assess depth of deep ripping (Table 3), soil amelioration practice and chicken litter addition (Table 4). The whole trial site was spread with 5 t/ha lime (district practice) on the 9th May 2022 to address surface and subsurface acidity.

All deep ripping and amendment treatments were implemented on 10th May 2022. Deep ripping and inclusion treatments were ripped at a speed of 4.5 km/h. Subsoil placement treatments were ripped at a speed of 2.5 km/h. In the topsoil and amendment inclusion trials the South mid slope site was ripped to a depth of 60 cm compared to the North hill top and North mid slope sites at 50 cm. Tine and inclusion plate setup can be seen in Figure 2. Soil profiles post amelioration for selected treatments can be seen in Figure 3.

Treatment	Depth (cm)
1	Nil
2	20
3	40
4	60

Table 3. *Treatment list for depth of ripping sandy soil trials.*

Treatment	Physical	Chicken litter (t/ha)
1	Nil	nil
2	Nil	10
3	Deep rip - no inclusion plates	nil
4	Deep rip - short inclusion plates (250 mm long)	nil
5	Deep rip - long inclusion plates (600 mm long)	nil
6	Deep rip - long inclusion plates (600 mm long)	10
7	Deep rip – no inclusion plates & place	10
8	Deep rip – no inclusion plates & place attempt 2	10
9	Spade	nil
10	Spade	10

Table 4. *Treatment list for topsoil and amendment inclusion sandy soil trials.*

All trials were sown to Razor CL Plus wheat at 110 kg/ha on the 31st May 2022. Fertiliser applied at seeding was MAP Zn at 80 kg/ha plus urea at 65 kg/ha. The site received 314 mm growing season rainfall (compared to long-term GSR 300 mm) in 2022. Urea was applied by the grower in-season at rates of 190 kg/ha at the North sites and 200 kg/ha at the South site.

Figure 2. *Deep ripper tine with short (250 mm) inclusion plates (left) and long (600 mm) inclusion plates (right).*

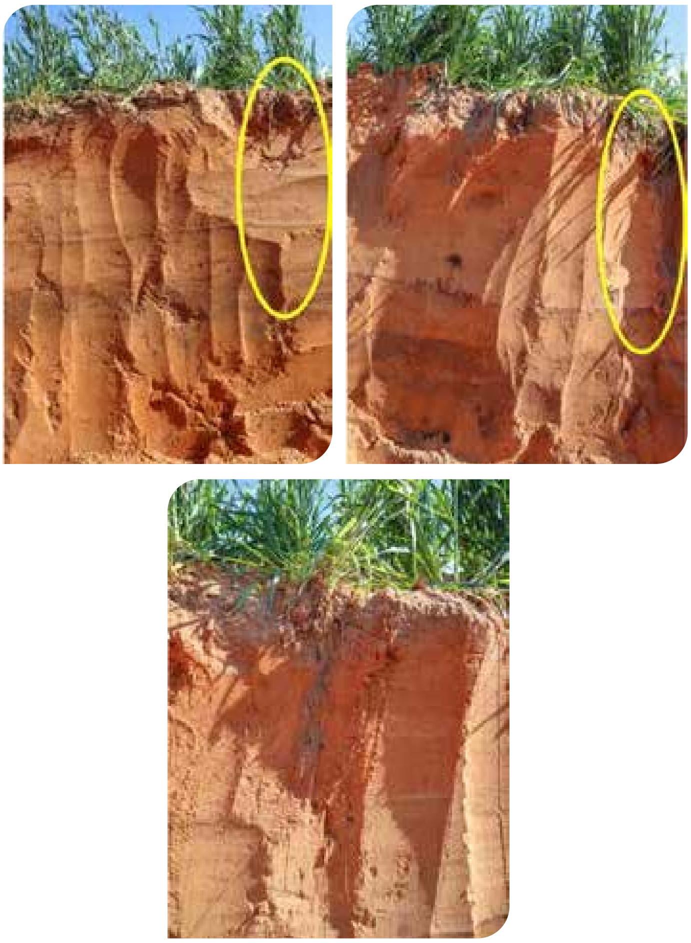

Figure 3. *North mid slope site treatments from left to right control, deep rip and place CL and deep ripping with long inclusion plates (no CL).*

Results and discussion

North hill top (most productive sandy site)

In early August crop biomass was assessed using NDVI and ranged from 0.426 – 0.637 across all treatments (Table 5). In general, all the physical treatments apart from spading had higher crop biomass compared to the control. The spading treatments were similar or slightly lower compared to the other physical treatments, likely due to issues at seeding. After spading the soil surface in these treatments was softer resulting in deeper seeding depth and crop establishment was poorer resulting in a lower NDVI assessment of crop biomass. This was a good example of why the spade and sow technique is preferable. Chicken litter (CL) applied to the soil surface with no physical incorporation had lower biomass compared to the physical treatments alone or with the addition of CL. Without incorporation the nutrient release or other benefits to soil structure from CL are likely to take longer to have an impact on crop growth.

Physical	Chicken litter (t/ha)	NDVI Aug 3rd	NDVI Aug 30th	Grain yield (t/ha)	Grain yield % of nil	Test weight (kg/hL)	Protein (%)
Nil	nil	0.426 e	0.696 e	4.70 d	100 d	79.4 cde	9.6 cde
Nil	10	0.465 de	0.751 cd	5.46 c	116 c	80.3 a	10.8 a
Deep rip - no inclusion	nil	0.556 bc	0.774 bc	5.31 c	113 c	79.0 de	9.1 e
Deep rip - short inclusion	nil	0.570 abc	0.769 bc	5.31 c	113 c	79.1 cde	9.3 de
Deep rip - long inclusion	nil	0.541 bcd	0.780 b	5.40 c	115 c	78.7 e	9.1 e
Deep rip - long inclusion	10	0.637 a	0.809 a	5.82 ab	124 ab	79.7 abc	9.9 bc
Deep rip & place	10	0.592 ab	0.814 a	6.15 a	131 a	79.4 cde	9.8 bcd
Deep rip & place attempt 2	10	0.614 ab	0.812 a	6.07 a	129 a	79.5 bcd	10.3 ab
Spade	nil	0.501 cde	0.739 d	5.61 c	119 bc	80.2 ab	9.9 bc
Spade	10	0.617 ab	0.778 bc	5.92 ab	126 ab	79.7 abcd	10.6 a
	Pr(>F)	<0.001	<0.001	<0.001	<0.001	0.027	<0.01
	LSD (0.05)	0.080	0.027	0.345	7%	0.68	0.5

Table 5. *Greenseeker NDVI, grain yield (t/ha), grain yield % of untreated control and grain quality for depth of ripping trial* ***North hill top*** *sandy soil amelioration site, 2022.*

Grain yields were high ranging from 4.70 t/ha in the control up to 6.15 t/ha in the deep rip and CL placement (Table 5). All physical and CL amendment treatments improved grain yield compared to no amelioration in year one. All physical treatments where CL was incorporated at depth had the highest grain yields. This included deep dripping (130% of untreated control), long inclusion plates (124%) and despite lower NDVI early, spading (126%). Where plots were deep ripped (with or without inclusion plates) or spaded without CL, grain yields were lower ranging from 5.31 t/ha to 5.61 t/ha.

There were small differences measured in test weight however, all treatments were above 76 kg/hL (minimum required for maximum grade). Similarly, there were minor differences observed in grain screenings but, all treatments were below the maximum value of 5% (data not shown). Grain protein levels ranged from 9.1% to 10.8%. Higher protein was observed in treatments where CL was applied either on the surface or incorporated by spading, deep ripping with or without long inclusion plates. Higher protein levels can be attributed to the additional nitrogen supplied in the CL.

Results from the depth of ripping trial showed NDVI and grain yield for ripping depths of 40 cm or 60 cm provided greatest benefit at the North hill site (Table 6). In August the 20 cm ripping depth increased NDVI compared to the nil however at harvest grain yield was similar at 4.97 t/ha. Previous research (DPIRD 2020, McBeath et al. 2022) has shown grain yield response from ripping depth can be linked to a reduction in soil strength. However, the response will change depending on site and there is also little understanding on how long this impact maybe sustained.

Test weight and screenings were not affected by ripping depth averaging 79.2 kg/hL and 2.6% for all treatments (Table 6). Grain protein was the only quality parameter to be impacted by ripping depth. Protein was reduced in the 40 cm and 60 cm depths and this result relates to yield dilution effects (higher yield = lower protein).

Depth of ripping (cm)	NDVI Aug 3	NDVI Aug 30	Grain yield (t/ha)	Grain yield % of untreated control	Test weight (kg/hL)	Screenings (%)	Protein (%)
0	0.470 c	0.470 c	4.95 b	100 b	79.3	2.7	10.2 a
20	0.565 b	0.565 b	4.97 b	100 b	79.2	2.5	10.1 a
40	0.635 a	0.635 a	5.36 a	108 a	79.3	2.6	9.3 b
60	0.573 ab	0.573 ab	5.32 a	107 a	79.1	2.5	9.4 b
Pr(>F)	0.006	0.006	<0.001	<0.001	0.687	0.886	0.036
LSD (0.05)	0.068	0.068	0.29	6	ns	ns	0.7

Table 6. *Greenseeker NDVI, grain yield and grain quality for depth of ripping trial North hill, 2022.*

North mid slope

Physical	Chicken litter (t/ha)	NDVI Aug 3rd	NDVI Aug 30th	Grain yield (t/ha)	Grain yield % of nil	Test weight (kg/hL)	Protein (%)
Nil	nil	0.330 f	0.578 e	3.94 f	100 e	78.8	10.5 b
Nil	10	0.382 f	0.636 d	3.97 f	101 e	78.9	11.9 a
Deep rip - no inclusion	nil	0.526 bcd	0.701 bc	4.67 bcd	119 bcd	79.0	10.3 b
Deep rip - short inclusion	nil	0.543 bcd	0.692 c	4.49 de	114 cd	78.9	10.0 b
Deep rip - long inclusion	nil	0.505 cd	0.696 bc	4.61 cde	117 bcd	79.5	10.0 b
Deep rip - long inclusion	10	0.647 a	0.747 a	4.50 de	114 cd	79.3	11.6 a
Deep rip & place	10	0.574 abc	0.745 a	4.83 b	123 b	79.6	11.7 a
Deep rip & place attempt 2	10	0.572 ab	0.758 a	4.72 bc	120 bc	79.3	12.0 a
Spade	nil	0.400 e	0.676 c	5.1a	131 a	79.6	10.1 b
Spade	10	0.493 d	0.734 ab	4.44 e	113 d	79.3	11.8 a
	Pr (>F)	<0.001	<0.001	<0.001	<0.001	0.182	<0.001
	LSD (0.05)	0.057	0.039	0.21	5%	ns	0.6

Table 7. *Greenseeker NDVI, grain yield (t/ha), grain yield % of untreated control and grain quality for depth of ripping trial North mid slope, 2022.*

In early August NDVI ranged from 0.330 – 0.647 compared to late August 0.578 – 0.758 across all treatments (Table 7). In general, all of the physical treatments with the exception of spading had higher crop biomass compared to the nil. The spading treatments were slightly lower in early August however, by the end of the month spading plus CL was no different to the other treatments at the North flat site. As outlined above issues within the spading treatments were related to seeding depth. Another similar result at the North hill and mid slope sites was CL applied to the soil surface without physical incorporation had lower biomass compared to the physical treatments alone or with the addition of CL.

Grain yield response was different at the mid slope versus hill top site. At the mid slope site spading with no CL was the highest yield treatment at 5.1 t/ha (131% of untreated). There were small differences among the remaining physical treatments with and without CL (Table 7). Of the physical treatments, lowest yields come from spading with CL. All physical treatments increased grain yield compared with CL surface applied and nil. The addition of CL with deep rip and place, spading and long inclusion were the highest NDVI treatments in late August, but this did not translate into yield, which was a surprise given the long cool spring and high yield potential. Powdery mildew was present at the three sites and infection may have been more severe in treatments with high NDVI (biomass) leading to a reduction in grain yield.

There were no differences in test weight for any treatment averaging 79.2 kg/hL (Table 7). There were minor differences observed in grain screenings but, all treatments were below maximum value of 5% (data not shown). Grain protein levels ranged from 10.0% to 12.0%. Higher protein was observed in treatments where CL was applied either on the surface or physically incorporated.

Results from the depth of ripping trial showed NDVI for depths of 40 cm or 60 cm provided the highest biomass response at the North flat site (Table 8). The difference in ripping depth had a large impact on grain yield, at 60 cm 4.92 t/ha (121% of untreated control) followed by 4.55 t/ha for the 40 cm depth. This result was different compared to North hill site (40 cm adequate to provide highest grain yield) and highlights ripping depth needs to be adjusted based on constraint depth. The shallowest ripping depth of 20 cm did not improve NDVI or grain yield compared to untreated control.

Grain quality was generally not impacted by ripping depth at the North mid slope (Table 8). Small differences were observed in test weight however, all treatments were above 76 kg/hL. Screenings and protein displayed no difference for any treatment averaging 2.7% and 10.6%.

Depth of ripping (cm)	NDVI Aug 3	NDVI Aug 30	Grain yield (t/ha)	Grain yield % of untreated control	Test weight (kg/hL)	Screenings (%)	Protein (%)
0	0.355 b	0.567 c	4.08 c	100% c	78.7 b	2.6	10.7
20	0.394 b	0.604 b	4.08 c	100% c	78.9 b	3.3	10.8
40	0.572 a	0.700 a	4.55 b	112% b	79.2 ab	2.3	10.6
60	0.551 a	0.719 a	4.92 a	121% a	79.6 a	2.4	10.2
Pr (>F)	<0.001	<0.001	<0.001	<0.001	0.024	0.248	0.376
LSD (0.05)	0.040	0.034	0.14	3%	2.7	ns	ns

Table 8. *Greenseeker NDVI, grain yield and grain quality for depth of ripping trial North flat, 2022.*

South mid slope site (least productive sandy site)

Physical	Chicken litter (t/ha)	NDVI Aug 3rd	Grain yield (t/ha)	Grain yield % of nil	Test weight (kg/hL)	Protein (%)
Nil	nil	0.316 de	3.10 e	100 e	75.4 d	13.0 ab
Nil	10	0.363 bcd	3.60 de	116 de	76.7 abc	12.8 ab
Deep rip - no inclusion	nil	0.425 abc	4.93 ab	159 ab	77.3 ab	10.8 d
Deep rip - short inclusion	nil	0.361 bcd	4.87 ab	157 ab	77.7 a	11.0 d
Deep rip - long inclusion	nil	0.370 bcd	5.24 a	169 a	77.6 a	11.2 d
Deep rip - long inclusion	10	0.501 a	4.61 bc	148 bc	76.7 abc	12.8 ab
Deep rip & place	10	0.419 abc	5.27 a	170 a	76.6 abc	12.2 bc
Deep rip & place attempt 2	10	0.434 ab	5.33 a	172 a	77.3 ab	11.8 cd
Spade	nil	0.279 e	4.09 cd	132 cd	75.7 cd	12.6 bc
Spade	10	0.347 cde	4.08 cd	131 cd	76.4 bcd	13.8 a
	Pr (>F)	<0.001	<0.001	<0.001	0.007	<0.001
	LSD (0.05)	0.082	0.55	18%	1.18	1.0

Table 9. *Greenseeker NDVI, grain yield (t/ha), grain yield % of untreated control and grain quality for depth of ripping trial South mid-slope, 2022.*

In early August NDVI ranged from 0.279 – 0.501 for all treatments at the South mid-slope site (Table 9). The NDVI readings where generally higher at both the North sites. All of the physical treatments with the exception of spading had high NDVI compared to the nil at all three sites. At the south site the nil plus surface applied CL was also high. The south mid-slope site was the least productive of all three sands and it is not surprising the addition of CL applied to the surface may have increased nutrient uptake and crop growth. The spading treatments were low and similar to the nil due to issues at seeding.

Large grain yield responses, up to 172% of the untreated control were measured at the South mid-slope site (Table 9). The responses at the more productive North sites were not as large up to 131% at both sites. High grain yields were achieved from deep ripping treatments (no inclusion, short or long inclusion) with or without CL ranging from 4.61 t/ha - 5.33 t/ha. Similar to NDVI, issues with poor crop emergence in the spading treatments carried through to reduced grain yields of 4.08 t/ha and 4.09 t/ha. In year one the use of short or long inclusion plates did not provide any grain yield benefit to deep ripping.

There were small differences in test weight ranging from 75.4 kg/hL in the nil to 77.7 kg/hL in the short inclusion (Table 9). While range in test weights was small most treatments were only just above 76 kg/hL (minimum value for maximum grade) at this site. The nil and spade without CL were the only treatments to fall below 76 kg/hL. There were minor differences observed in grain screenings but, all treatments were below maximum value of 5% (data not shown). Grain protein levels ranged from 10.8% to 13.8%. Deep ripping without, short and long inclusion plates (no CL) resulted in grain quality for APW (10.5% to 11.5%) classification. Similar to the North mid slope site, where CL was applied at depth or on the surface grain quality met H2 (11.5% to 13%) or H1 (>13%) standard.

Results from the depth of ripping trial showed NDVI for ripping depths of 40 cm or 60 cm provided highest biomass response at the South mid slope site (Table 10). These treatments were also the highest yielding at 5.21 t/ha (166% of untreated control) for the 60 cm depth and 4.69 t/ha (149% of untreated control) for the 40 cm depth. This result was similar to the North hill site. All three sites showed ripping to a depth of 20 cm did not improve NDVI or grain yield compared to untreated control.

Test weight and screenings were not affected by ripping depth averaging 77.0 kg/hL and 2.8% for all treatments (Table 10). Grain protein was the only quality parameter to be impacted by ripping depth however, at this site protein was less effected. Protein was lowest at the 60 cm depth and only made APW (10.5% to 11.5%) compared to H2 for the 0, 20 cm and 40 cm treatments.

Depth of ripping (cm)	NDVI Aug 3	Grain yield (t/ha)	Grain yield % of untreated control	Test weight (kg/hL)	Screenings (%)	Protein (%)
0	0.303 b	3.14 b	100 b	76.3	4%	12.3 a
20	0.323 b	3.54 b	113 b	76.0	4%	12.6 a
40	0.468 a	4.69 a	149 a	77.5	3%	11.7 ab
60	0.420 a	5.21 a	166 a	78.1	3%	10.6 b
Pr (>F)	0.001	0.006	0.01	0.119	0.203	0.025
LSD (0.05)	0.054	0.98	31%	ns	ns	1.2

Table 10. *Greenseeker NDVI, grain yield and grain quality for depth of ripping trial South mid-slope, 2022.*

Summary and conclusions

From the topsoil and amendment inclusion trials it is evident that all three sandy soil sites responded differently to the physical and CL treatments (Figure 4). As a general overview:

- at the North hill top site it was responsive to both physical interventions and CL addition, and the combined physical plus CL treatments were the highest yielding. It did not matter what method of incorporation was used as long as the CL was mixed, ripped with inclusion plates or placed at depth in the soil profile.
- at the North mid slope site, the response to physical interventions ranged from 0.47 to 1.16t/ha. There was nil or negative response to CL treatments in grain yield, despite large increases in NDVI measured during the growing season.
- at the historically least productive South mid-slope site grain yields were improved from all physical treatments. Response to CL additions was not significant in the first season.

Depth of ripping trials were consistent with previous research where yield responses to ripping depths of less than 40 cm have proven unreliable. At two out of three sandy sites, deep ripping to depth of 40 cm was sufficient to achieve maximum grain yield improvement (Figure 5). At the third North mid slope site, higher grain yields were achieved from deeper ripping to 60 cm.

Overall, the initial results from year one highlights the importance of understanding your soil type and identifying the target soil constraint and depth. The longevity of treatments in these trials will be assessed in 2023 where the sites will be sown to Commodus CL barley.

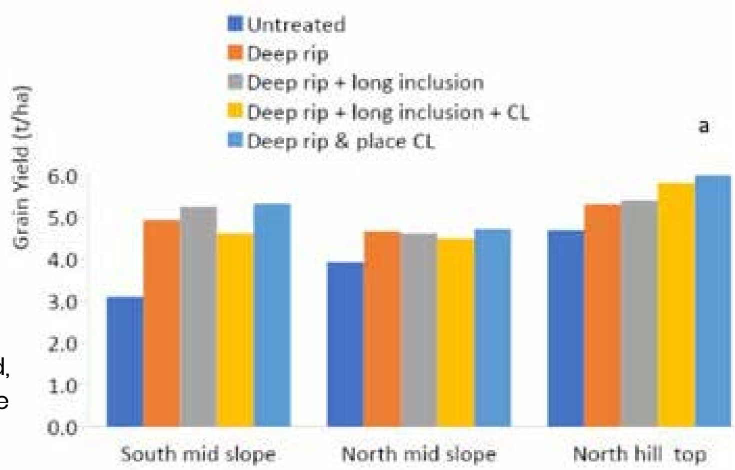

Figure 4. *Grain yield (t/ha) response to amelioration technique on all three sandy soil sites near Bute, SA 2022.*

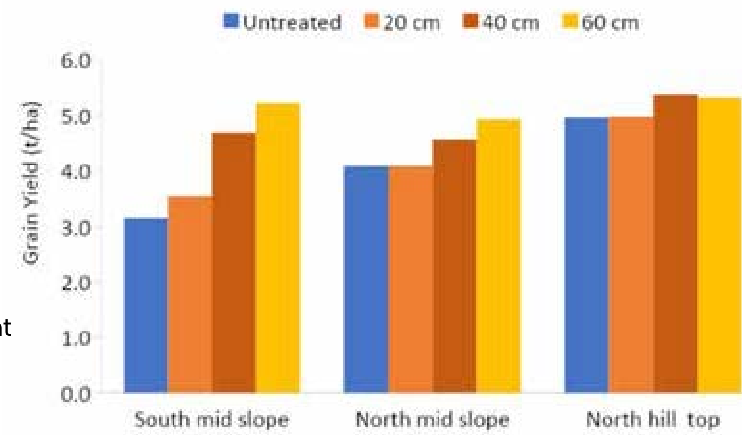

Figure 5. *Grain yield (t/ha) response to ripping depth at all three sandy soil sites near Bute, SA 2022.*

Acknowledgements

This program received funding from the Australian Government's Future Drought Fund project title 'Building drought resilience by scaling out farming practices that will enhance the productive capacity of sandy soil landscapes'. Thank you to our project partners AIR EP. We also acknowledge the support of local grower James Venning for hosting the trials.

Australian Government

Future Drought Fund

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LIVESTOCK & MIXED FARMING SYSTEMS

SHEEP TECHNOLOGY PROJECT *Extension*

Author: *Rachel Trengove, Project Officer, UNFS*
Funded By: *SA Red Meat and Wool Growth Program* | ***Project Title:*** *Sheep Technology Group – Extension*
Project Duration: *September 2022 – March 2023 (completed)* | ***Project Delivery Organisations:*** *PIRSA, UNFS*

Aim:

- Explore and share experiences and knowledge on ways that precision livestock management technologies can be used in red meat and wool production.
- Learn from experts on how technologies could assist you to improve productivity, efficiency and profitability in your business.
- Support producer members to implement and apply technology to improve productivity and profitability.

Background

Producer Technology Groups were funded through the SA Red Meat and Wool Growth Program, which is an initiative of the Government of South Australia, supported by Meat & Livestock Australia, SA Sheep and Cattle Industry Funds and SheepConnect SA. The original UNFS Sheep Technology Group program ran from July 2020 until May 2022 and was organised by UNFS Project Officer Rachel Trengove. The group met 5 times over a 2 year period, with the format, content and delivery of the group's activities tailored to suit group members' knowledge and skills.

Following the success of the project, UNFS had an opportunity for an extension until March 2023 which provided further funding to deliver two additional workshops in the region. UNFS Members and Operations Committee assisted in designing the 2 workshops. With the announcement in 2022 of mandatory eID's for the SA sheep industry by 2025, the main focus of these workshops was implementation of eID's on farm. A summary of extension activities is listed in Table 1.

Key Outcomes

The greatest achievement for our group was the engagement and commitment of our group members which was shown in attendance of workshops and willingness to share knowledge and experiences at those workshops. There was a high level of interest generated in precision livestock technologies and we have seen uptake of new technology and systems by the group members throughout the duration of the project.

Feedback suggested that group members really valued the opportunity through funding to come together locally with like-minded people and learn from each other and experts in the industry. We had some farmers share their experiences with the group on adoption of technologies on their farm which generated good levels of discussion and provided a valuable peer-to-peer learning opportunity.

Image 1. *Tom Kuerschner (Orroroo Hub Rep), Jonathan Byerlee, Wyndhurst Merino Stud, Tim Johnsson, BreedELITE.*

Activity	Date & Location	Workshop Objective	Activity Description
Workshop 1: BreedElite Smartdrafter demonstration	21st October 2022 Orroroo Footy Clubrooms & Oval	To provide information and demonstrations of EID technology and how it can be implemented and utilised in sheep enterprises.	**Tim Johnsson: BreedElite founder & owner** • Uploading and downloading data • Using data to make informed decisions on farm. • Implementing technology on farm **Jonathon Byerlee (Wyndhurst Merino Stud)** • Demonstration of his BreedElite smartdrafter, fleece weighing equipment and software • Discussion on eID's and the benefits for Jonathan's farm
Workshop 2: Implementing eID's on farm and Improving Reproductive Success	23rd February 2023 Caleb Girdham's farm, Melrose	To provide a hands on demonstration by presenter and farmer on how to incorporate technology into containment yard design as well as implementation of eID's on farm for efficiency and productivity outcomes	**NATHAN SCOTT (Achieve AG Solutions) – eID – what's in it for me?** The what, how, and why (or why not) of applying it practically on your farm. • Equipment options • How the technology works • What data to collect • Understanding the implications of applying selection pressure • How to collect data & tips on managing data **DEB SCAMMELL (Talking Livestock) – Improving Reproductive Success** • Pregnancy requirements & this season's feed • The fit of containment this year • Containment costs $$ - benefits and feed on offer – the data FREE FEED TEST WAS AVAILABLE FOR ALL PARTICIPANTS STICKY BEAK AT GIRDHAM'S AUTODRAFTER, YARDS AND CONTAINMENT FEEDING SET UP

Table 1. *Summary of the activities undertaken during the extension of UNFS Sheep Technology Group*

PDS: LOTSA LAMBS – *Improving Reproduction Success - 2022 update*

Author: *Rachel Trengove, Project Officer, UNFS*
Funded By: *Meat & Livestock Australia (MLA)* | **Project Title:** *PDS: LOTSA LAMBS - Improving Reproduction Success*
Project Duration: *Feb 2022 - Feb 2025* | **Project Delivery Organisations:** *UNFS, Talking Livestock*

Background

As a result of the impact of drought, ewe numbers are low both locally and nationally. To facilitate the rebuild of the flock, it is necessary to produce more from the existing ewe base through maximising reproductive efficiency and minimising mortality. Seasonal conditions have led to many producers aiming for an autumn lambing to utilise feed available to lambs due to shorter springs and extended low feed on offer due to extended summer conditions. Producers are aware of the research that indicates higher lamb survival from twin bearing ewe flocks run as smaller groups at lambing. Most are unsure how to best implement this strategy, particularly in a mixed farming system with a focus on cropping. On the ground solutions and demonstrations are required for producers to be able to see how this strategy could possibly work in their sheep flock.

Many producers have adopted the strategy of feeding ewes in containment over summer and early autumn, often through much of their pregnancy. Common practice for a Nov-Dec joining is a 7-8 week joining period, and a lack of pregnancy scanning resulting in significant variation in nutritional requirements of the ewes at any one time. The adoption of early pregnancy scanning, scanning for multiples and condition scoring should allow targeted feeding of mobs while held in containment, and reduce problems such as dystocia due to over feeding of later lambing single bearers.

Part of this project will look at improved genetic selection in commercial flocks, incorporating data collection and analysis on reproduction success, understanding ram genetics and Merino Flock Profiling (MFP). The aim being to refine breeding objectives and plan for future breeding decisions with fertility in mind, including an understanding of the traits to focus on to breed robust animals for UNFS production systems.

Methodology

Review and demonstrate:

1. At two sites demonstrate the value of;

   i. reduced joining period to 5-6 weeks

   ii. correct ewe to ram ratios

   iii. managing and feeding mobs separately based on condition score, foetus number and foetus age.

   iv. matching nutrition needs to rations

Measure feed consumption, lamb survival and ewe condition score. Analyse gross margins and cost of production ($/kg lamb produced). Record other observations of variations in animal health and condition. (2 lambing cycles).

2. Establish two demonstration sites for improved pregnant ewe management incorporating:

   i. Development of a clear breeding objective including improved genetic data and decision making

   ii. Pregnancy scanning

   iii. Splitting twin bearing ewes into smaller groups for lambing.

   iv. Ewe condition scoring and segregation within single bearing ewes based on condition.

Measure lamb survival and assess the cost:benefit of the practices. Record other observations of variations in animal health and condition. (3 lambing cycles)

Run 5 extension activities for UNFS members. The workshops will be delivered by recognised industry experts in condition scoring, feed budgeting, impact of mob size, effective confinement feeding, using ASBVs and the RamSelect app, breeding objective development and interpreting Merino Flock Profile results. Principles will be based on the AWI Life Time Ewe Management Course content.

Results and Discussion

Alison Henderson and Andrew Kitto are providing demonstration sites to implement the practice of pregnancy scanning and lambing multiples in smaller mobs. The demonstration sites strive to have twin-bearing ewe mobs of 100 or fewer during lambing to reduce the risks of mismothering, ewe-lamb separations, and lamb mortality. 2022 presented challenging lambing conditions at Henderson and Kitto's demonstration properties due to a late break in the season, lack of feed on offer for pregnant ewes and harsh cold conditions during lambing. Lamb marking data for 3 lambing cycles will be measured at these sites.

Lachie Smart is also providing a demonstration site from 2023 onwards, focussing on confinement feeding pregnant ewes as well as lambing in small mobs. Lamb marking for 2 seasons will be recorded.

The project has enabled demonstration site landholders to have individual sessions and ongoing support with Deb Scammell from Talking Livestock. These sessions plan for selective management of twin-bearing ewes, including ewe nutrition, condition scoring, feed budgeting, the impact of mob size, and effective confinement feeding based on the principles of Life Time Ewe Management.

Image 1. *Workshop 1 – Alison Henderson's property – lambing ewes in smaller mobs*

Image 2. *Workshop 2 – Understanding and interpreting DNA flock profiling results*

Image 3. *Workshop 3 - BreedELITE smartdrafter demonstration – Nathan Scott & Caleb Girdham*

Image 4. *Workshop 3 - Girdham's containment feeding demonstration site*

Image 5. *Caleb Gurdham, Deb Scammell, Nathan Scott in containment feeding yards*

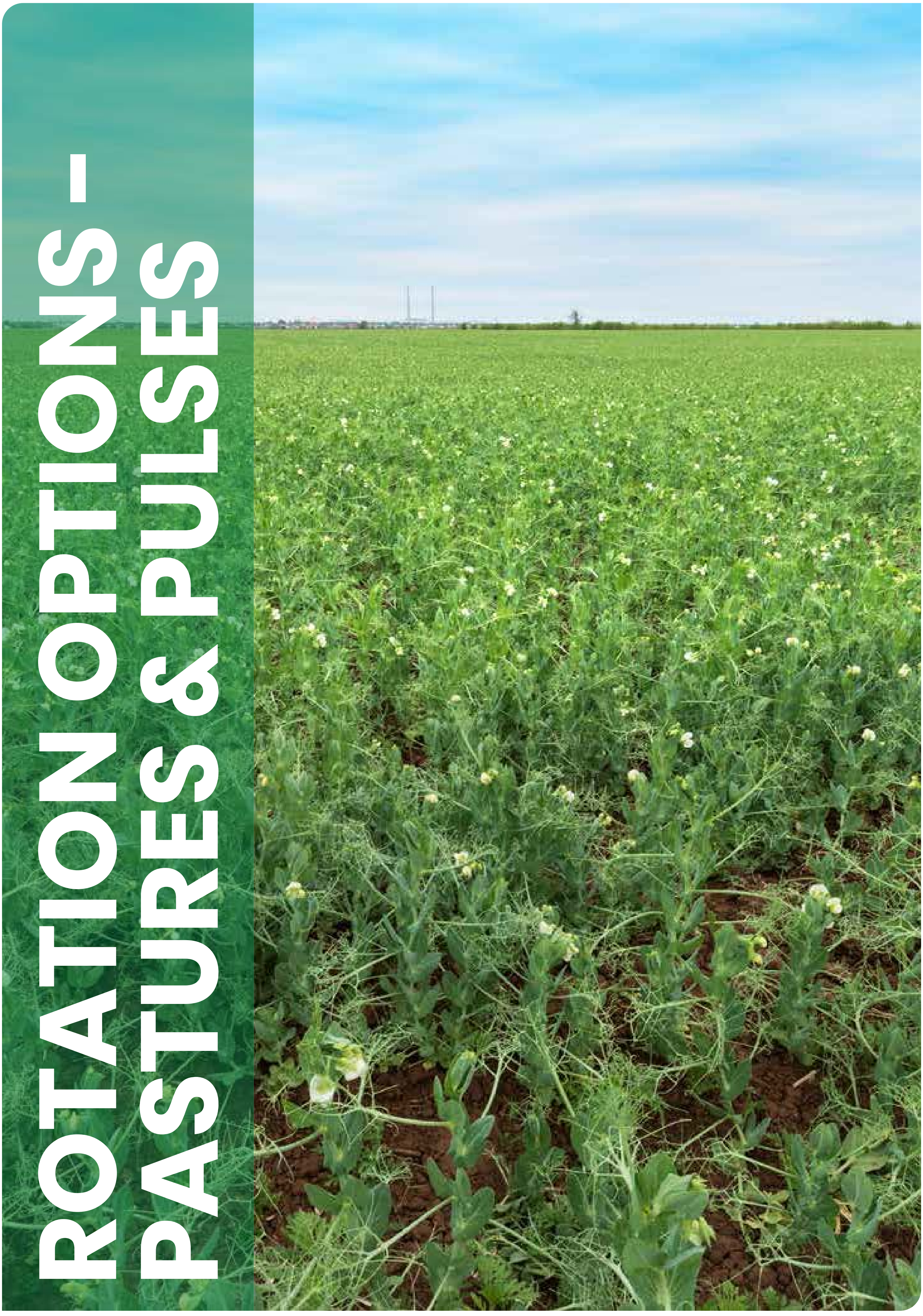
Activity	Date & Location	Workshop Objective	Activity Description
Workshop 1: **LOTSA LAMBS** Producer Demonstration Site Workshop 1	28th June 2022 Don Bottrall's Shearing Shed and Alison Henderson's farm	To provide and introduction to LOTSA LAMBS PDS project and information on topics associated with the PDS.	**Guest Speakers Michelle Cousins, Merino Services and Andrew Michael, Leachim Stud:** • Defining a breeding objective • Merino Flock Profiling—understanding test results & how to use the information • Understanding Australian Sheep Breeding Values (ASBVs) and Indexes • Why use ASBVs when buying rams • Using the RamSelect app • Pregnancy scanning ewes, splitting twins & singles, and managing smaller mob sizes **Producer Case Study: Alison Henderson gave an insight into their sheep enterprise, including sharing her experiences and a visit to their farm.**
Workshop 2: **LOTSA LAMBS** Flock Profiling & Improving Genetics	19th September 2022 Don Bottrall's Shearing Shed	Understanding and interpretation of flock profiling results	**Andrew Michael, Leahcim Stud** **Small Workshop with 12 producers who did flock profiling on their sheep** • Defining a breeding objective • Merino Flock Profiling—understanding test results & how to use the information • Understanding Australian Sheep Breeding Values (ASBVs) and Indexes • Why use ASBVs when buying rams • Using the RamSelect app • Farmers had DNA testing results on the day and had the opportunity to interpret results on an individual basis

Activity	Date & Location	Workshop Objective	Activity Description
Workshop 2: **Implementing eID's on farm and Improving Reproductive Success**	23rd February 2023 Caleb Girdham's farm, Melrose	To provide a hands on demonstration by presenter and farmer on how to incorporate technology into containment yard design as well as implementation of eID's on farm for efficiency and productivity outcomes.	**The what, how, and why (or why not) of applying it practically on your farm.** • Equipment options • How the technology works • What data to collect • Understanding the implications of applying selection pressure • How to collect data & tips on managing data **DEB SCAMMELL (Talking Livestock) – Improving Reproductive Success** • Pregnancy requirements & this season's feed • The fit of containment this year • Containment costs $$ - benefits and feed on offer – the data FREE FEED TEST WAS AVAILABLE FOR ALL PARTICIPANTS STICKY BEAK AT GIRDHAM'S AUTODRAFTER, YARDS AND CONTAINMENT FEEDING SET UP

Acknowledgements:

Thank you to the demonstration site landholders for sharing data and hosting workshops – Alison Henderson, Andrew Kitto & Nathan May and Lachie Smart

ROTATION OPTIONS – PASTURES & PULSES



IDENTIFYING SUITABLE LEGUME SPECIES *for* DRYLAND, MARGINAL RAINFALL FARMING LAND – CANOWIE BELT *Extension*

Author: *Beth Humphris*

Funded By: *SARDI* | **Project Title:** *Southern Pulse Extension Project #226* | **Project Duration:** *2020 - 2022*

Project Delivery Organisations: *UNFS, Elders Jamestown*

Key Points

- Vetch had the highest dry matter in the first year of the trial.
- No significant differences in cash crop (wheat) yield between treatments in 2021 (appendix A).
- Best re-establishment in 2022 was from medics and clovers, with vetch showing the worst re-establishment.
- Differences within cultivars was observed throughout the three replications as a result of pH change across the site, indicating the importance of cultivar selection to pasture success.

Background

The aim of this study was to investigate the suitability of various legume species in a dryland, marginal rainfall environment, that are suited to regeneration. Typical annual break crops such as faba beans, field peas or canola are not always economically viable or suited in the marginal cropping areas of the Upper North. Therefore, this project aimed to highlight other options with the ability to regenerate from a seed bank, following a rotation of a cereal cash crop where the legume species were chemically control. This attempts to achieve the well-known benefits of a break crop, such as nitrogen fixation, herbicide mode of action rotation and cereal disease break in addition to complementing livestock grazing requirements. Species were assessed to ensure they are suited to our modern mixed farming systems across the Upper North, where focus has shifted toward continuous cropping. A common break pasture was also added to the trial, Vetch to compare against.

This site was run over three growing seasons, beginning in 2020 and ending in 2022, with several factors assessed throughout the trial predominantly including how a pasture legume can fit into the modern rotation of farming in the Low Rainfall Zone (LRZ) regions of South Australia.

Methodology

This trial was located in the Canowie Belt region, approximately 20 km's North-East of Jamestown and 10 km's South of Yongala. Long term annual rainfall is ~350 mm with soil and atmospheric temperatures typically declining quickly at the beginning of the season due to frost events. This presents a challenge for early growth, resulting in a feed gap at the beginning of the season which a self-regenerating pasture may be able to address.

The trial was originally sown to legumes on the 5th of May 2020 with 40 kg/ha starting fertilizer (MAP), after species were inoculated. Pasture cultivar and species, seeding depth and rates are shown in table 1. The trial utilised a randomised trail design, with 3 replications. Plots run North, South with the trial site located on a slight incline. Soil type across the trail is a red, brown earth with clay content increasing down the profile. No major soil constraints were identified in the initial soil sampling. The site pH increases as you move up the slope, meaning the third replication has alkaline conditions, whilst replication one is closer to neutral.

The trial ran over three years (2020 – 2022), with each phase highlighted in table 2. In year one establishment counts, peak biomass, nodulation, feed quality and N fixation were evaluated. Year two assessments include weed pressure, NDVI, grain protein and cereal yield, with year three considering pasture regeneration counts.

The trial was originally sown to legumes on the 5th of May 2020 with 40 kg/ha starting fertilizer (MAP), after species were inoculated. Pasture cultivar and species, seeding depth and rates are shown in table 1. The trial utilised a randomised trail design, with 3 replications. Plots run North, South with the trial site located on a slight incline. Soil type across the trail is a red, brown earth with clay content increasing down the profile. No major soil constraints were identified in the initial soil sampling. The site pH increases as you move up the slope, meaning the third replication has alkaline conditions, whilst replication one is closer to neutral.

The trial ran over three years (2020 – 2022), with each phase highlighted in table 2. In year one establishment counts, peak biomass, nodulation, feed quality and N fixation were evaluated. Year two assessments include weed pressure, NDVI, grain protein and cereal yield, with year three considering pasture regeneration counts.

Cultivar	Species	Sowing Rate (kg/ha)	Sowing Depth (cm)
*Casbah	Biserrula	5	1
PM250	Strand Medic	7.5	1
*Scimitar	Burr Medic	10	1
SARDI Rose	Rose Clover	7.5	1
SARDI Rose + Bartolp	Rose Clover Bladder Clover	3.7 3.7	1
Margarita	Serradella	7.5	1
Saltan	Barrel Medic	7.5	1
Studencia	Vetch	40	2
*Volga + Saltan	Vetch Barrel Medic	15 7.5	2
*Volga	Vetch	40	2
Lanza	Tedera	10	2
*Mawson	Sub Clover	10	1

** Identifies cultivars where we used old seed. Germination tests were undertaken, with the Casbah (Biserrula) seed being identified as not viable seed and therefore is disregarded in this trial.*

Table 1. *Cultivar and species used in this trial, which employed a randomised trial design across 3 replications, using plots of 1.75 m by 15 m. Sowing rate and depth used in the trial is also shown below.*

Year 1	Pasture legumes sown and let to set seed
Year 2	Wheat sown and pasture legumes sprayed out
Year 3	Re-generation of pasture legumes
*Mawson	Sub Clover

Table 2. *Trial timeline, beginning in 2020 and concluding in 2023.*

Results

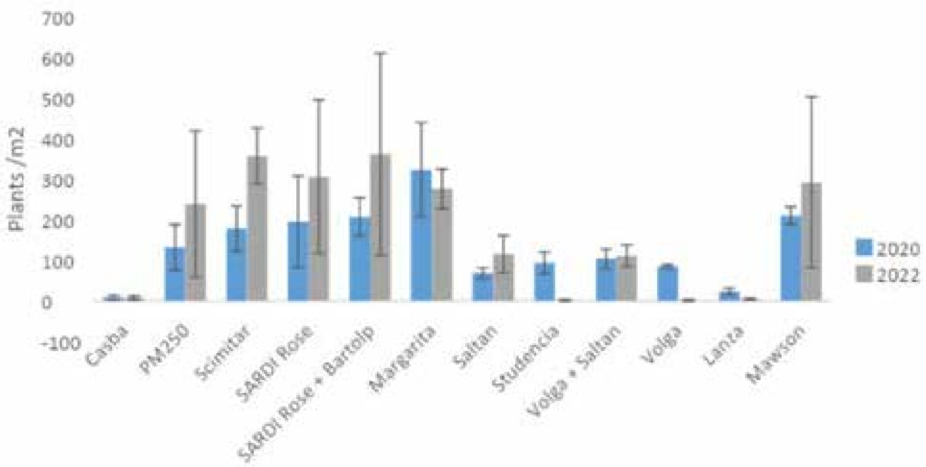


Figure 1. *Average pasture plant counts taken after sowing on the 19th of June 2020 and then again on the 20th of July 2022 after re-establishment, showing the average number of plants per square meter from the replicated trial.*

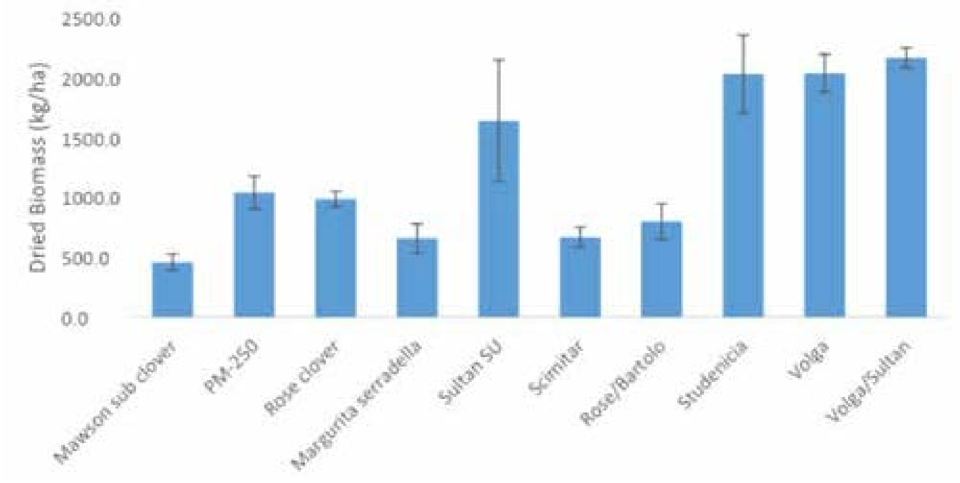


Figure 2. *Averaged shoot biomass from replicated trial as recorded from plant biomass collected on the 11th of September, capturing peak biomass. Results show averaged weights from the replicated trial. Error bars highlight variation between the three replicates for each species. Casbah (Biserrula) and Lanza (Tedera) were not included due to low plant populations present at the time of collection.*

Discussion

All vetch cultivars showed fewer plants in the regeneration year, compared to the first year, when they were initially sown. It is reasonable to conclude that vetch is a poor choice when looking for a pasture legume where regeneration, between cash crops is desired. If using vetch in the rotation, the cost and time required to re-sowing at the beginning of each pasture phase must be considered as a trade-off for the increased biomass.

Comparatively, all medic and clover species showed an increase to plant numbers in the regeneration year. Having established the trial in a year with a mild, wet spring allowed for good seed set in the first year of the trial. The first years seed set is critical for the longevity of a self-regenerating pasture. Weed and insect control is critical in the first year to achieve a good seed bank. When comparing clover and medic cultivars used in this trial, Scimitar and the SARDI Rose / Bartolo mix had the highest regeneration counts. However, when considering biomass production, these cultivars showed less biomass compared to Sultan.

The standard deviation, as shown by error bars in figure 1 and 2, shows the large variation between replicates of the same cultivar in this trial. This reflects the change to soil type across the trial site and highlights the importance of matching cultivar to soil type. This may mean more than one cultivar is required to match all soil types in a paddock. For example, the PM250 treatment varied from 84 plants/m^2 up to 439 plants/m^2 in the regeneration counts taken on the 20th of July. This cultivar performed well in the neutral, lighter soil type on the lower slope, however poorly on the alkaline, heavier soil type on the upper slope. Therefore, PM250 would need to be paired with a cultivar such as Scimitar to ensure good pasture growth across all soil types in this trial paddock.

The Bisurulla (Casba) and Tedera (Lanza) showed low plant numbers for the duration of the trial. This indicates that these species are poorly suited to our growing environment. They are typically used in saline / sodic areas and on light soil types. Seredella (Margarita) showed good potential for our environment when referring to plant numbers, however when looking at total biomass, this was low compared to other options.

The aim of this trial was to identify regenerative pasture options for the low rainfall zone of the upper north farming region. Results gained show that medic and clover species showed the most potential for regeneration compared to vetch, bisurilla, tedera and serredella. While these species produce less biomass in comparison to vetch, the requirement of sowing at the beginning of each pasture phase is removed. Considerations when choosing a pasture legume includes soil type, hard seededness and biomass production.

Acknowledgements

- Craig, Lyn and Damon Humphris, for providing the site and contributing to project management throughout the year
- SARDI for providing their cone seeder, plot harvester and staff to sow / harvest the trial
- S & W Seeds, Heritage Seeds and SARDI for providing seed and inoculant

DRYLAND LEGUME PASTURE SYSTEMS: *Harvesting annual medic pods*

Authors: *David Peck [1,2], James Webb [1], Jeff Hill [1], Trevor Rowe [1], Eric Watzke [1]*
Project Delivery Organisations: *[1] SARDI, [2] University of Adelaide*

Key Points

- With early desiccation, 350-620 kg/ha of medic pods were harvested at Palmer and 1000-2500 kg/ha at Kingsford.
- Preliminary minimum sowing rate recommendations for pods harvested on-farm are 76, 38 and 25 kg/ha for pods sown the first, second and third summer after harvest respectively.
- This is preliminary research and we recommend waiting for further research results to confirm findings before adopting

Background

This project is investigating if: 1) early desiccation of annual medic plants enables a useful amount of medic pods to be harvested with a conventional crop harvester and 2) medic pods can be broadcast to provide a relatively cheap way of establishing medic pastures. It follows on from preliminary work in the Dryland Legume Pastures Systems (DLPS) project that found medic pods may be able to be harvested (EPFS 2021 P 220-222) and sown in summer to successfully establish medic pastures (EPFS p 189-192). The cost of seed and low growth of pastures in the establishment year is regularly reported as a constraint to pasture adoption. A cheaper source of medic seeds and ability to broadcast seed early prior to season break to increase early dry matter may encourage more sowing of medics and thus benefits to subsequent grain crops. In farming systems trials in the DLPS project, medics increased subsequent grain yields by 0.7-2.9 t/ha (EPFS 2020 p 205, EPFS 2020 p 213). Recent work in Western Australia has found that a single year of a legume dominant pasture, provides sufficient organic N in the soil to grow at least one subsequent grain crop (Loi et al. 2022).

Methodology

A medic pod harvesting trial was established at Palmer and at SARDI's Kingsford Research farm near Gawler, South Australia in 2022. After the break and regeneration of medic plants, a knockdown herbicide was applied to control background medics. The strand medic cultivar Seraph and the barrel medic cultivar Sultan-SU were at sown at rates of 5, 10, 15 kg/ha in six replicates. At Palmer a strip of medics was sown at 50 kg/ha to mimic a regenerating medic pasture, which was mowed until early flowering to simulate grazing. Adjacent to the pod harvesting trial an equivalent trial with four replicates, which was allowed to naturally senesce to determine total seed yield.

Basic science reports (Gallardo et al. 2003) that medic pods require 400 growing degree days (GDD; sum of average daily temperature) for seeds to be viable and 900 GDD for pods to begin falling from the plant. Our targeted desiccation day is when the majority of pods are between 400-900 GDD. We observed when the first flowers appeared and when peak flowering finished. On a weekly basis observed daily temperature, forecast daily temperature and climate data was used to predict the desiccation time. Actual desiccation day was then chosen on observation of medic pods and a weather forecast of four fine days with light winds. Medic pods typically turn from green to grey (the burr medic cultivar Cavalier turns white) when they are fully ripe and dehisce soon afterwards. When pods start to fall, the targeted earliest desiccation time is a week later as limited flowers occur in the first week of flowering and hence limited pod fall occurs in the first week of falling. Delaying the earliest desiccation by a week also allows for plants to senesce more and less drying required after desiccation and before harvest. A week of wet weather with high winds was predicted (and occurred) at our preferred desiccation date at Palmer and desiccation was delayed by a week. Due to the large amount of late spring rainfall in 2022 we desiccated medic plants at Kingsford as soon as first pods were falling. Plots were desiccated with 2 l/ha of paraquat. Medic pods were harvested with a small plot harvester four days after desiccating. The naturally senesced area had pods sucked up from two 0.1 m^2 areas.

Pods from Palmer harvest trial have been fully processed. However, for Kingsford a clean pod sample weight has been measured but seed to pod ratio is still pending and yields have been unable to be corrected by pods with non-viable seed at this stage. The suction harvested samples from naturally senesced plots have yet to be processed and hence the percent of pods harvested is unable to be reported here.

What happened?

Widespread late spring rainfall delayed desiccation and harvest at Palmer. However, pods were still attached four days after desiccation (Fig. 1) and were able to harvest 620 kg/ha of Seraph and 350 kg/ha of Sultan-SU pods. For the simulated regenerating strips 700 kg/ha of Seraph pods and 220 kg/ha of Sultan-SU pods was harvested. Sowing rate did not affect the amount of pod harvested. At Kingsford wet weather did not delay the harvest and pod yield of 1000-2500 kg/ha was obtained (Fig. 2). For Sultan-SU, pod yield increased with sowing rate while for Seraph, 5 kg/ha had the lowest yield. At Kingsford with the relatively early harvest some pods are white and they do not contain seeds. The white pods are the late set pods. Expected seed to pod ratio is 0.33 for barrel and strand medic (0.5 for burr medic) and we need to measure this to determine percent of pod with viable seeds.


Figure 1. Medic pods were still attached to the plant four days after desiccation (left image) and were harvested with a small plot grain harvester (right image).

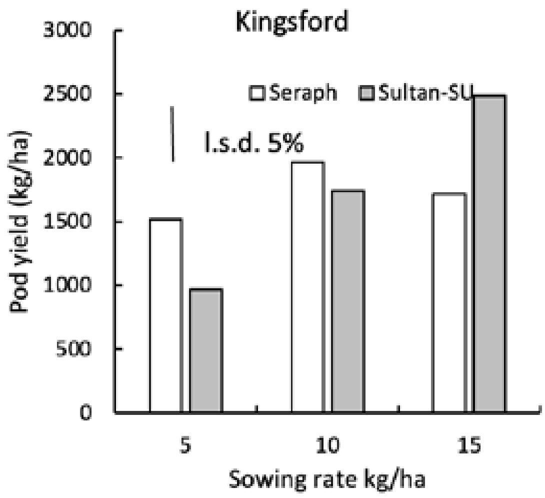


Figure 2. Pod yield at Kingsford 2023.

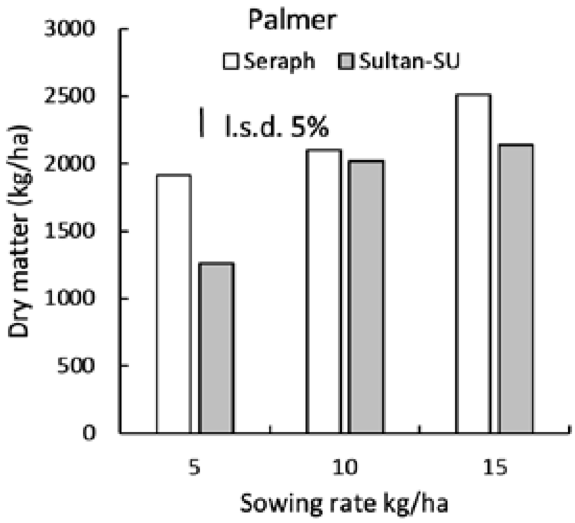


Figure 3. September dry matter at Palmer 2023

Higher sowing rates provided higher dry matter. Figure 3 shows the September dry matter at Palmer. Seraph had higher yield than Sultan-SU at sowing rate of 5 and 15 kg/ha, indicating that the soil type is better suited to a strand medic. With the wet spring powdery mildew was widespread across the state. However it was not an issue at either site with neither site being located close to a regenerating medic pasture.

What does it mean?

Harvesting pods

We successfully harvested medic pods at both sites in 2022 which means we have now been successful in 3 of 4 attempts. We also received a report of a farmer reading last year's article (EPFS P 220-222) and obtaining 20t of medic pods. Medic pods fall much more readily than pulses and to be successful you need to give harvesting medic a high priority and regularly inspect the senescence and pod fall of the medics. We suggest desiccation be done one week after the first pods fall and when a forecast of four fine days with light winds exist. At Palmer desiccation was delayed by a week of wet weather and we still managed to obtain 620 kg/ha of Seraph pods and 350 kg/ha of Sultan-SU.

For this work our focus was on planting a nursery paddock with a new cultivar. To minimise old cultivars contribution to the pod harvest we waited until background medics germinated and sprayed them out with a knockdown herbicide. However if you are happy with your current medic cultivars you can harvest medic pods from a regenerating pasture. For our stimulated regenerating pasture at Palmer 700 kg/ha of Seraph and 220 kg/ha of Sultan-SU was harvested. If harvesting regenerating medics we suggest grazing until first flower to prevent excessive dry matter and conserve water for seed set. Every week delay in removing stock after first flower will decrease pod yield potential. This may be an activity to consider in wetter years when you have excess medic pastures to feed stock.

At Kingsford increasing the sowing rate from 5 kg/ha to 10 kg/ha increased pod harvest by 1.8x, thus indicating the higher sowing rate should be used. We recommend sowing medics at 10 kg/ha but realise many farmers sow at 5 kg/ha or even lower. The September dry matter cut showed that 10 kg/ha had up to 760 kg/ha higher dry matter and an estimated increase 19 kg /ha of nitrogen fixed. The higher DM also means that the medics are better able to compete with weeds. When determining sowing rates we suggest you look at the total costs of sowing (labour and machinery, herbicides, fertiliser, insecticides, seed) and not just the seed cost.

Broadcasting pods

The next stage of the project is to conduct pod broadcasting experiments along with seed softening studies to develop recommended pod application rates. The rates we will test will be based on our understanding of hardseed breakdown patterns. Freshly harvested medic pods contain hardseed which soften in a two-stage process: 1) preconditioning stage whereby seeds progressively dry out due to high temperature and/or length of time stored; 2) softening stage with fluctuating temperature in autumn. In the DLPS project, fresh medic pods were found to have 20% soft seed by the end of the first autumn. Taylor and Ewing (1992) similarly report for annual medics in the field, ~ 20% of seeds soften per year. Assuming harvested pods behave in a similar way as the field and seed to pod ratio of 0.33, for a minimum sowing rate of 5 kg soft seed per hectare the minimum sowing rate is 76, 38, 25 kg pods/ha for pods sown in the first, second and third summer after harvest respectively.

The DLPS project studied sowing of medic pods and alternative pasture legume species French Serradella and bladder clover in February. Sowing was used as French Serradella and bladder clover have an unusual seed softening process whereby light inhibits softening. Which means that they soften much quicker when sown at 1-2 cm. By contrast medics seeds softening is maximised when they are at the soil surface as they experience greater heat and greater temperature fluctuations and are not affected by light. This suggests that medic pods can be broadcast and provide a cheap establishment method that does not leave the soil vulnerable to wind erosion. As well as establishing a medic pasture, pods can be used to top up a run-down medic paddock or a portion of a medic paddock.

Conclusions

With attention to detail and early desiccation, medic pods can be harvested from nursery paddocks or regenerating paddocks grazed up till first flower. Medic pod broadcasting trials have yet to be conducted and we have provided theoretical broadcasting rates. For this reason we suggest caution if interested in this concept and that you only trial small areas in the first instance. Storage of pods for 2-3 years is expected to reduce the broadcasting rates required and increase the multiplication factor of a nursery paddock. If you are prepared to store pods for two years and sow at 40 kg/ha a ten-hectare paddock at Palmer would be able to establish 87-150 hectares and at Kingsford 240-620 hectares.

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Taylor GB, Ewing MA 1992 Long-term pattens of seed softening in some annual pasture legumes in a low rainfall environment. Australian Journal of Experimental Agriculture 32, 331-7

Ackowledgements

This project is supported by funding SAGIT. We wish to acknowledge and thank Craig Paech (Palmer) and Gary Grigson (Turretfield Research Centre) for hosting the trials, and Murray Plains Farmers for assisting us to find a trial site and in organising a visit in spring.

Trial Details

Location	Murray Plains, Palmer
Rainfall	Av. Annual: 394mm Av. GSR: 227mm 2022 Total: 389mm 2021 GSR: 259mm
Plot size	10m
Location	Mid North, Rosedale
Rainfall	Av. Annual: 469mm Av. GSR: 358mm 2022 Total: 496mm 2021 GSR: 370mm
Plot size	10m

USE *of* LEY LEGUME PASTURES *in a* CHANGING CLIMATE

Authors: *David Peck [1], Dane Thomas [1], Peter Hayman [1], Bronya Cooper [1], Jeff Hill [1], Trevor Rowe [1], James Webb [1], Eric Watkze [1]*
Project Delivery Organisation: *[1] SARDI*

Key Points

- Climate change predictions agree for a warming climate but vary on how much drying will occur.
- Annual medic and clover accessions with increased dry matter production have been identified.
- It is hopeful that new medic cultivars with increased ability to perform under a changing climate can be developed.
- Options for pasture management under dry and wet years is discussed in detail.

Background

The low rainfall mixed farming zone of South Australia is expected to be impacted by a changing climate. Ley legume pastures systems are widely used and provide feed to livestock and fix nitrogen for the benefit of following grain crops (e.g. 0.7-2.9 t/ha EPFSS 2020. P. 205, EPFSS 2020, p. 213). Legume pastures reduce input costs and risk in low rainfall areas. This aim of this project is to better understand the impact of a changing climate on legume pastures and to develop ways to mitigate the risk in the short and long term. This work is a collaboration of SARDI's Climate Applications team and the SARDI Pasture team.

Methodology

The SARDI Pasture team tested a wide range of genetic material for future pastures in the low rainfall zone with experiments at Palmer and Orroroo. The material was sourced from the Australian Pastures Genebank (APG) which is managed by SARDI. Climate data from low rainfall regions of South Australia was matched to the origin of the accessions using the online data base Genesys. Climate analysis in Genesys was used to identify a short list of accessions. The selection was biased to include accessions from key species that have been grown commercially in Australia. Species that have shown potential to become commercial species were also used. Species from the *Medicago* (annual medics) and *Trifolium* (clovers) genera were most represented.

We utilised a large data set of annual medics from the APG which included winter and spring dry matter (DM) production scores, days to flowering and length of spines (only accessions with short spines were included). Accessions with high DM scores and early flowering not on our original short list were added to our short list. More accessions were short listed than could be grown. Our final list was obtained by: 1) removing accessions with low DM scores; 2) choosing one accession at random when multiple accessions were collected in close proximity to each other. 327 accessions made the final list and 26 species were included.

Species were grouped into six cohorts: 1) barrel medic with control of cv. Sultan-SU; 2) Strand and Disc medic with control of cv. Seraph; 3) burr medic with control of cv. Scimitar; 4) Minor species with control of cv. Sultan-SU; 5) large-seeded medic with control of cv. Sava; 6) clovers with control of SARDI Rose. Sultan-SU was included in each cohort. Accessions were sown as 100 seeds in single 1.5m row with 1.5m gap between rows. The trial was planted at Orroroo on 2 June 2022 and at Palmer on 30 May 2022.

Climate analysis was organised around four key questions: 1) What are the climate risks for low rainfall pasture production in the current climate; 2) How does this year compare with the historical climate record; 3) What are the trends in the climate indices in recent decades; 4) What are the projected changes in climate indices and how confident are we in these projections. Climate outlook was also considered in terms of pasture management decisions that farmers could make.

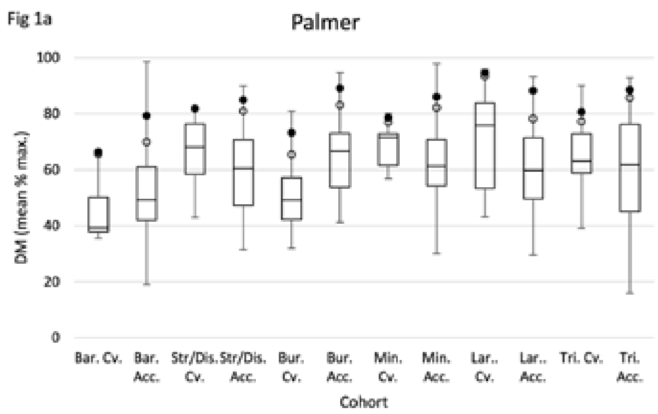
Site	Years	Ann.	Apr-Oct	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Dec
Orroroo	1900-2019	333	227	13	11	8	15	28	30	33	36	29	22	17
	2022	389	259	30	14	8	8	30	19	4	33	86	79	71
Palmer	1900-2019	394	290	12	11	9	23	32	43	45	49	41	31	20
	2022	336	316	42	9	4	27	52	35	12	51	56	82	77

Table 1. *Average (1900-2019) and 2022 annual, growing season (Apr-Oct) and monthly rainfall (mm) for Orroroo and Palmer, South Australia.*

What happened?

Accessions

Both sites established well and experienced low rainfall (decile 1) in July and a wet spring (Table 1). The plants at Orroroo were particularly stressed through July due to very low rainfall which was accompanied by cold nights. The plants survived and recovered in August and benefited from the wet spring. All accessions set reasonable number of seeds which will allow them to regenerate in subsequent years. Dry matter (DM) production was regularly scored throughout the growing season and converted to percent of maximum score within a cohort. Figure 1 shows a boxplot for the cultivars and accessions for each cohort. For each cohort accessions with increased DM were readily found, with barrel and burr medics having the highest proportion of accessions with higher DM than the commercial cultivars that were included within the trial.



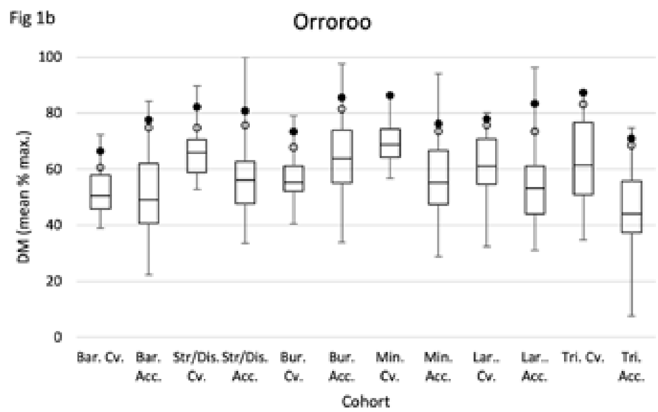


Figure 1. *Box plot (minimum, 25%, 50%, 75%, maximum, 95% is indicated by solid circle and 90% by open circle) of dry matter (DM) (up to early Oct 2022) of cultivars (Cv.) and accessions (Acc.) for the different cohorts, namely barrel medics (Bar.), strand and disc (Str/disc), burr medic (bur), minor species (Min.), large seeded (Lar.) and clovers (Tri.) for Palmer (Fig. 1a) and Orroroo (Fig. 1b) in 2022.*

Figure 2. *is the DM at Orroroo plotted against DM at Palmer for the barrel medic cohort. Accessions within the dotted area green square and circle are those accession lines identified as having high DM in both locations and which have been short-listed as worthy of further research. Accession were short-listed from the other cohorts by the same method. The number of accessions shortlisted for the major species were barrel medic 14, strand medic 5, burr medic 10, and for the minor species disc 3, button 2, sphere 2, murex 1, snail medic 7, and clovers 9. Short-listed accessions come from the following countries: Australia 5, Chile 4, Cyprus 1, Greece 3, Israel 5, Italy 4, Jordan 8, Libya 7, Malta 1, Morocco 13, Spain 2 and Tunisa 4.*

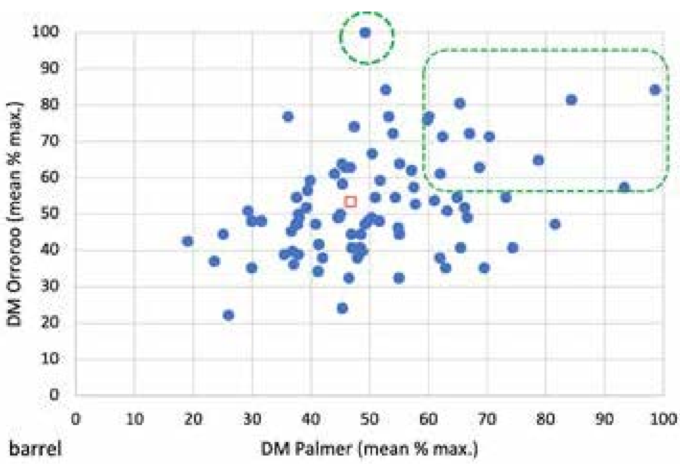


Figure 2a. *Barrel medic DM at Orroroo plotted against DM at Palmer. The square is the cultivar Sultan-SU and accessions inside dotted area have been shortlisted.*

Climate Analysis

We have compared climate change projections from the National Drought Fund, Climate Services for Agriculture website and the DEW (Nov 2022) document on projections for planning. We found consistent messages and very high confidence of increasing temperature. Projections consistently show drying in winter and spring in southern Australia, but the rate of drying ranges between severe drying (>20%) which would precipitate transformational change and moderate drying which is more likely to be managed by incremental and systemic change. Communicating the different level of confidence on warming vs drying is important in discussion with the people who are managing low rainfall farming systems. An important message is that there are maps of the future not a single map.

Management decisions

Ley legume pastures increase yields of subsequent grain crops and lift overall farm profitability. Farmers regularly report that they find establishing pastures a costly exercise with little or no income in the establishment year and are concerned about failure to achieve high seed set. Sown pastures are more likely to be successful in wetter years (decile 4-10) than dry years. Farmers may have more success if they sow pastures in years with wet autumn (e.g. upper EP 2022) or years with optimistic seasonal outlook. If a wetter year eventuates, sowing the pasture and achieving high seed set will contribute to long term profit. In wetter years, sheep will have plenty of feed on offer in spring. In these years farmers may want to remove stock in early spring from paddocks with poorer pastures to allow for greater seed set.

What does it mean?

We have short listed accessions with higher DM production at both sites and the assumption is that they will be better adapted to a changing climate. Regeneration in autumn will be assessed before making the final shortlist for future work. Short listed accessions have the potential to be included in future cultivar development work and may be suitable for direct release or as agronomic parents. As well as potentially increasing production they can increase the genetic diversity and reduce risk. For example, early season barrel medics are directly derived from the 1959 released cultivar Cyprus with new traits backcrossed into Cyprus to overcome major constraints (Caliph, Cheetah, Sultan-SU, Penfield). This was similar with early season strand medics effectively being Harbinger genotype with new traits (Herald, Jaguar, Angel), until Seraph was developed by crossing Angel with an accession with powdery mildew resistance and high DM accession achieving a 15% increase.

The world faces many challenges from current and future climate change and need to reduce greenhouse gas emissions. Methane has a greater global warming effect than CO2 (about 23 times more). *Medicago* species contain plant secondary compounds called saponins that are antimethanogenic (EPFSS 2021 p 208-2011). It is possible that some of the accessions can not only perform better in a changing climate, but also contribute to lessening climate change effects by reducing methane emissions and less CO2 emissions from the production and transport of nitrogen fertilisers.

The unifying theme of this work is managing climate risk to pastures in low rainfall regions of South Australia. Drought, especially terminal drought with hot, dry springs is the common focus of low rainfall regions. However, wet years are essential to understanding profit and risk in low rainfall regions. Low rainfall farmers are quick to point out that they manage both downside risk and upside opportunity. We have progressed a decision framework that enables growers and agronomists to put down what they know about both good seasons and poor seasons and discuss the balance between risk and opportunity. We have shown that this can be applied to pasture decisions. Decisions are complex and multifaceted, but it helps the discussion about risk when there is clarity on the choices available, the risky climate events and the outcomes.

Acknowledgements

This is a SARDI funded project. We wish to acknowledge and thank Tom Kuerschner (Orroroo) and Craig Paech (Palmer) for hosting the trials, and the Upper North Farming Systems and Murray Plains Farmers for assisting us to find famers to host trials and in organising visits in spring.

Location: Murray Plains

Town or District: Palmer

Farmer Name: Craig Paech

Rainfall

Av. Annual: 394mm

Av. GSR: 227mm

2022 Total: 389mm

2021 GSR: 259mm

Plot size 1.5m single spaced rows

Location: Upper Mid North

Town or District: Black Rock near Orroroo

Farmer Name: Tom Kuerschner

Rainfall

Av. Annual: 333mm

Av. GSR: 227mm

2022 Total: 389mm

2021 GSR: 259mm

Plot size 1.5m single spaced rows

ANNUAL MEDICS *in a* CHANGING CLIMATE

Authors: *David Peck, Dane Thomas, Peter Hayman*
Project Delivery Organisation: *SARDI*

Key Points

- Climate analysis of low rainfall areas of South Australia show a consistent trend of higher temperature but variation in the amount of drying that will occur
- An optimistic seasonal outlook (decile 4-10) favours the establishment of medic pastures
- We have shortlisted medic germplasm with higher dry-matter production than existing cultivars

Annual medics are widely grown in the low rainfall areas of South Australia. They provide high quality and high protein feed to livestock and fix nitrogen for the benefit of the following grain crops. In the recent DLPS project they lifted following wheat crops by an average of 0.7 t/ha. Climate change projections are that low rainfall areas face a transition to a warmer and drier climate. This project focuses on climate risk in low rainfall areas and the search for new pasture germplasm for a changing climate.

We have compared climate change projections from the National Drought Fund, Climate Services for Agriculture website and the DEW (Nov 2022) document on projections for planning. We found consistent messages of increasing temperature, but some projections predicted more severe drying than others. However, wet years are essential to understanding profit and risk in low rainfall regions. Farming systems work, and economic modelling consistently show benefits of legume pastures to subsequent grain crops. However pasture planting and renovations remain at low levels. The cost of sowing pastures, their low production in the establishment year, and risk of low seed set in a dry year is a concern to farmers. A year with decile 4-10 rainfall results in high seed set and hence sets the pasture up for long term persistence and greater benefits to the faming system. Farmers in a low rainfall area balance risk and opportunity in good and poor seasons. Productive medic pastures provide an opportunity to fix more nitrogen and increase overall profitability. An optimistic seasonal outlook (decile 4-10) increases the chances of a high seed set and the establishment of long term productive and persistent pastures.

The aim of the pasture trial at Blackrock is to search for new germplasm with increased agronomic performance in a low rainfall site. The Australian Pastures Genebank (APG) holds many accessions of pasture species important to Australia. Climate analysis was done, and we used a set of climatic conditions to search Genesys PGR (an online platform that allows you to search Plant Genetic Resources) to shortlist annual medic and annual clover accession held by the APG. Our list was then finalised based on dry-matter production and short spines. We grouped accessions into barrel medics, strand & disc medics, spineless burr medics, minor medic species, large-seeded medics (e.g. snail medic) and clovers. 100 seeds of each accessions were planted (2/6/202) at Black Rock as short, spaced rows. For each group we had a repeated control of an existing cultivar.

The site established well in early June, which was followed by a decile 1 July and decile 10 September, October, and November. Plants suffered during the dry July but survived and grew and set seed in the wet spring. Dry matter (DM) production was regularly scored throughout the growing season. For each DM score, we determined the maximum score of each cohort and figure 1 shows a boxplot for the cultivars and accessions for each cohort. For each cohort we were able to readily find accessions with increased DM, with barrel and burr medics having the highest proportion of accessions with higher DM than cultivars. We shortlisted lines in the top 10% and they come from a range of countries including Australia, Chile, Cyprus, Greece, Israel, Italy, Jordan, Libya, Malta, Morocco, Spain and Tunisa.

Flowering time was recorded, and accessions varied from one week earlier to 2-3 weeks later than the cultivar controls (Fig. 2). Historically early flowering cultivars have been recommended for low rainfall sites. However when collecting accessions, a range of flowering time often occurs at a site. In a wet spring, late season lines are likely to be beneficial. Later lines with high DM may also have a role to play in medium rainfall areas.

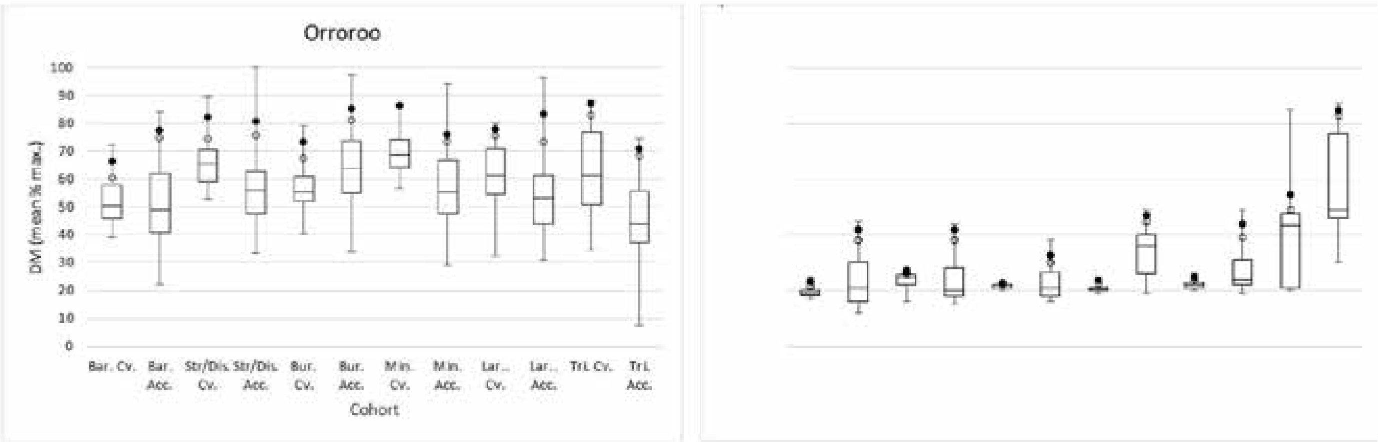


Figure 1. *Box plot of DM (up to early Oct) and days to flowering of cultivars (Cv.) and accessions (Acc.) for the different cohorts, namely barrel medics (Bar.), strand and disc (Str/disc), burr medic (bur), minor species (Min.), large seeded (Lar.) and clovers (Tri.). 95% is indicated by solid circle and 90% by open circle; bottom of line is the accession with the lowest DM, the bottom of the rectangle is 25%, mid-line is 50%, top of rectangle is 75% and top line is 100%.*

A sister site was established at Palmer and regeneration in 2023 will be assessed before making the final shortlist. Short-listed accessions have the potential to be suitable for direct release or as agronomic parents. As well as potentially increasing production they can increase the genetic diversity and reduce risk. The work was dependant on obtaining germplasm from the APG and relied on climate and agronomic information linked to each accessions. It also relied on climate analysis done by SARDI's climate team. In the long term, the identification of new germplasm is expected to increase DM and reduce risk under a changing climate. Annual medics fix nitrogen and increase profitability of farming in low rainfall areas.

Acknowledgments

This work is a SARDI funded project. We thank Tom Kuerschner for hosting the trial at Blackrock and the UNFS for putting us in contact with Tom and organising a spring walk.

Government of South Australia

SARDI

SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE

FIELD PEA *and* LENTIL VARIETY PERFORMANCE *in the* UPPER NORTH *in* 2022

Authors: *Sarah Day, Penny Roberts* | *Funded By: GRDC (UOA2105-013RTX)*
Project Title: *Development and extension to close the economic yield gap and maximise farming system benefits from grain legume production in South Australia* | ***Project Duration:*** *2021-2025* | ***Project Delivery Organisations:*** *University of Adelaide*

Key Points

- Pulse variety selection should be based on herbicide tolerance characteristics and disease resistance, to reduce the risk of a grain yield penalty from weed competition and disease infection.

Background

Lentil production area has increased by 6300 ha over the last decade in the Upper North region of South Australia (PIRSA, 2022). This increase in production area has coincided with a reduction in area sown to field pea, as well as recent high grain prices for lentil and developments in breeding, particularly the release of varieties with improved herbicide tolerance characteristics and varieties better adapted to low rainfall environments. The aim of this project (UOA2105-013RTX) is to deliver local grain legume development and extension to close the economic yield gap and maximise farming system benefits from grain legume production in South Australia.

Methodology

Two field experiments comparing pulse varieties and seeding rates were established near Melrose in 2022. The first field experiment tested six varieties of field pea (Figure 1) sown at three different seeding rates (Table 1). The second field experiment tested six varieties of lentil (Figure 2) sown at three different seeding rates (Table 2). Both field experiments were designed as randomised block designs with three replicates and were sown on 20 May 2022. Plots were sown with six rows spaced nine inches apart. Plant establishment, biomass dry matter, grain yield and grain quality were assessed for both field experiments. Crop dry matter biomass production was measured by taking biomass cuts and drying samples as each variety reached 50% flowering. Field peas were harvested on 17 November and lentils were harvest on 5 December 2022. Data was statistically analysed using an ANOVA model in Genstat 21st Edition.

Table 1. *Field pea target plant density (plants/m²) and seeding rate (kg/ha) sown at Melrose, 2022.*

Seeding rate	Plants/m²	kg/ha*
High	60	130-160
Recommended#	50	110-130
Low	40	80-110

**A range is given for seeding rate per hectare as this will vary depending on seed size and seed weight.*

#Average of the recommend plant density for conventional (45 plants/m²) and semi-leafless (55 plants/m²) field pea varieties.

Table 2. *Lentil target plant density (plants/m²) and seeding rate (kg/ha) sown at Melrose, 2022.*

Seeding rate	Plants/m²	kg/ha*
Recommended	120	50-70
Three-quarter	90	35-50
Half	60	25-35

**A range is given for seeding rate per hectare as this will vary depending on seed size and seed weight*

Results and Discussion

Field pea variety selection

There were differences in biomass production measured at 50% flowering (Figure 1), as field pea varieties vary in phenology and flowering time (Table 3). The two earliest flowering varieties, PBA Percy and GIA Ourstar, had the lowest crop biomass at flowering (1.43 and 1.34 t/ha, respectively). The mid to late flowering variety, PBA Butler, had the highest production of biomass at flowering (4.4 DM t/ha). Despite this difference in biomass production between varieties, there were no differences in grain yield production at Melrose 2022 (P>0.05) (Figure 1). Average grain yield was 2.89 t/ha.

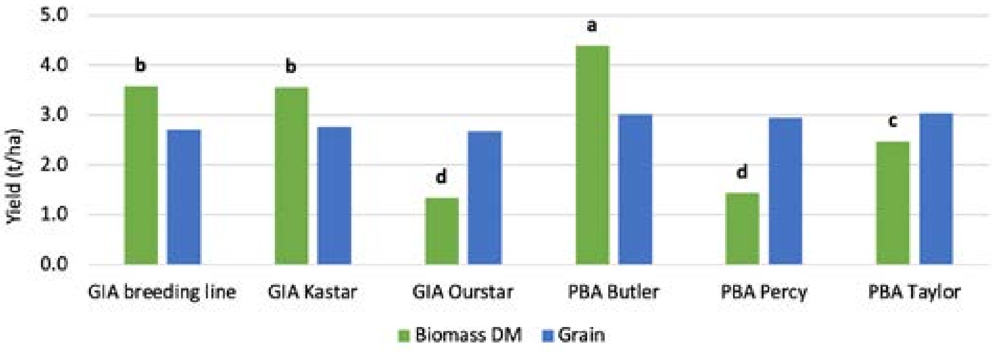


Figure 1. *Crop biomass measured at 50% flowering (DM t/ha) and grain yield (t/ha) of six field pea varieties averaged for the different sowing densities sown near Melrose, 2022. For each biomass and grain yield, columns labelled with the same letter are not significantly different (P<0.05). Columns within the same series with no labels indicates no significant difference (P>0.05).*

Lentil variety selection

There is less variation in lentil variety flowering characteristics than in field pea varieties, with most lentil varieties either early or mid-flowering (Table 3). However, there are some recent variety releases and varieties still in development with mid to late flowering characteristics. The later flowering varieties, GIA Lightning and CIPAL2122, had the highest biomass at mid flowering (Figure 2). The early to mid-flowering varieties had low and similar levels of dry matter production at mid flowering (0.53 - 1.06 DM t/ha), with only PBA Highland XT producing less biomass than PBA Jumbo2 (Figure 2). Despite these differences observed in flowering and biomass, there were no differences in grain yield between lentil varieties near Melrose, 2022 (Figure 2).

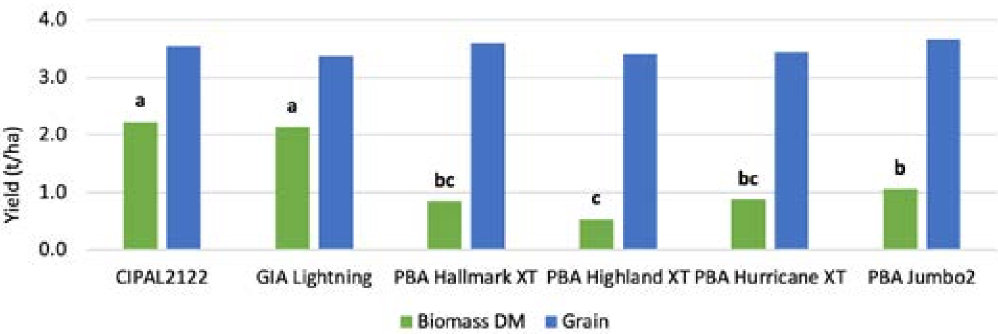


Figure 2. *Crop biomass measured at 50% flowering (DM t/ha) and grain yield (t/ha) of six lentil varieties averaged for the different sowing densities sown near Melrose, 2022. For each biomass and grain yield, columns labelled with the same letter are not significantly different (P<0.05). Columns within in the same series with no labels indicates no significant difference (P>0.05).*

Crop	Variety	Flowering Characteristic	Biomass dry matter cut date (50% flowering)
Field pea	GIA breeding line	-	14 September
	GIA Kastar	Mid	14 September
	GIA Ourstar	Early-Mid	8 September
	PBA Butler	Early-Mid	14 September
	PBA Percy	Early	2 September
	PBA Taylor	Mid	14 September
Lentil	CIPAL2122	-	14 September
	GIA Lightning	Mid-Late	14 September
	PBA Hallmark XT	Mid	8 September
	PBA Highland XT	Early	2 September
	PBA Hurricane XT	Mid	14 September
	PBA Jumbo2	MId	14 September

Table 3. *Lentil and field pea varieties and their flowering characteristic, and the date the biomass dry matter cuts were taken as each variety reached 50% flowering, near Melrose 2022.*

Seeding rates

Changing the field pea seeding rate to higher or lower than the recommended seeding rate did not impact crop biomass measured at mid-flowering (P>0.05) or grain yield (P>0.05, data not shown). Reducing the seeding rate of lentil from the recommended rate of 120 plants/m^2 did not affect biomass dry matter at mid flowering (P>0.05) or grain yield (P>0.05, data not shown). This is similar to previous findings from lentil seeding rate field experiments in low rainfall environments (Day & Keeley, 2022; Day & Roberts, 2021, 2022).

Conclusion

2022 was a high disease risk season in most regions of South Australia (Blake et al., 2023). While the field experiments at Melrose were not infected with botrytis grey mould, this was not the case for many other field experiment sites and cropping regions. Selecting varieties with improved disease resistance is important in all regions and seasons to reduce the risk of disease infection and reduce the need for multiple foliar fungicide sprays.

Acknowledgements

The research undertaken as part of this project is made possible by the significant contributions of growers through both trial cooperation and the support of the GRDC (UOA2105-013RTX – Development and extension to close the economic yield gap and maximise farming system benefits from grain legume production in South Australia), and the authors would like to thank them for their continued support. The continued assistance in trial management from SARDI Agronomy groups at Clare, Pt Lincoln and Minnipa is gratefully acknowledged and appreciated.

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HERBICIDE CONTROL OPTIONS *for* EMEX SPINOSA *in* XT

Authors: Stefan Schmitt, Agricultural Consulting and Research

Key Points

- Broadstrike applied either IBS or PSPE at 50g/ha provided good control of spiny emex in XT Tolerant lentils. This use rate and timing is not registered, further research is needed to explore crop safety.
- Sentry herbicide applied IBS provided good control of spiny emex in XT Tolerant lentils. This product in not registered in XT lentils.
- District practice pre-emergent mixes involving Diuron and Brodal applied either pre and in a post sowing pre-emergent split did not offer commercially acceptable control of spiny emex.
- Broadstrike 50g/ha applied pre flowering on large emex plants caused mild stunting, yet the plant still set seed.
- The trial site was sprayed with Intervix at 600mls/ha 6-8 WAS due to high medic numbers, this did not control Emex Spinosa around or in the trial.
- Reflex herbicide caused suppression of spiny emex plants early, plants recovered with the final assessment no different to district practice treatments.

Background

The aim of this trial was to explore new and existing chemical options to control emex australis (three corner jack) in XT lentils. Emex australis and emex spinosa (lesser jack) are problem weeds for lentil production in the lower Broughton region. Spatial spread of emex in paddocks is usually confined to patches on non-wetting sand, deep sand or the sides of paddock rises. Though these patches are often small, they can cause issues with marketability of lentils if harvested. Emex is classified as type 1 foreign seed contaminant at receival with a maximum tolerance of two seeds per 100g sample.

Emex populations in the district have a wide germination window, with a large portion of the seed bank germinating mid-late in the season based on anecdotal observations. At this point, most pre-emergent products that have activity on species have run out of residual control. All emex species are naturally quite tolerant to group B 'imi' herbicides that are commonly used for broadleaf weed control in XT lentils. Growers are therefore left with limited options to manage late germinations of emex in lentils.

This trial aims to explore alternative chemical options and application strategies for the management of emex in XT lentils in the district.

Methodology

Sowing Date	3/5/2022
Location & Soil Type	Nurom (Port Pirie) red sandy loam – neutral pH
Pre Emergent & Sowing Conditions	No pre-emergent or knockdown applied, marginal soil moisture
Conditions following sowing	~ 11.6mm rainfall received two days after sowing.
Crop Type	Highland XT Lentils @ 40kg/ha
Sowing Details	Sown with plot seeder using Atom Jet points. Sowing speed 8.5 km/hr, tine spacing 10 inches. Sowing depth 4cm. Sown with 60kg/ha of MAP.
Spray Application Details	Hand boom – 100L/ha at 4km/hr – 2 bar pressure with Agrotop Airmix 110-01 nozzles. PSPE herbicides applied ~ 3 hours post sowing. IBS herbicides applied ~ 2 hours pre sowing EPE broad strike applied on a warm sunny day – mid afternoon ~ 27 degrees.

Treatments

Table 1. *herbicide treatments, use rates and application timing. Note Diuron formulation was 900 a.i.*

Treatment Number	IBS Herbicides & Rates	PSPE Herbicides & Rates	Post Em Herbicide and Rate	Post Emergent Timing
1	Reflex 1L/ha			
2	Sentry 40g/ha + Diuron 400g/ha			
3	Broadstrike 50g/ha			
4	Diuron 400g/ha			
5	Diuron 300g/ha	Diuron 200g/ha		
6	Reflex 500mls/ha + Diuron 400g/ha			
7	Diuron 400g/ha + Brodal 70mls/ha	Brodal 40mls/ha		
8	Diuron 400g/ha + Brodal 70mls/ha			
9	Diuron 400g/ha + Brodal 70mls/ha		Broadstrike 50g/ha + 0.5% Oil	Pre Flowering
10	Diuron 400g/ha			
11	Diuron 400g/ha	Broadstrike 50g/ha		
12	Voraxor 100mls/ha + Diuron 400g/ha			
13	Nil			

Results

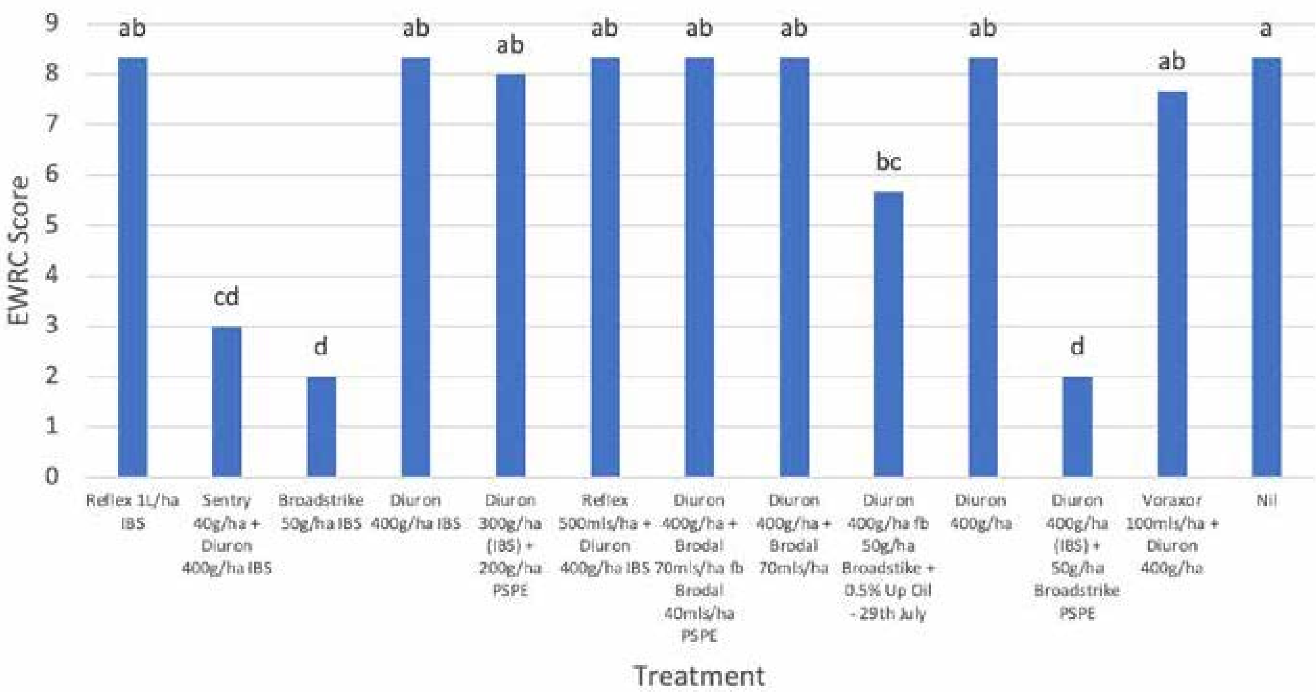

Figure 1. *Figure 1. Emex Spinosa control in lentils scored at desiccation timing. EWRC Weed Control Scores: 1 = 100% weed control and 9 = no control, 4 = commercially acceptable. An analysis of variance (ANOVA) was conducted on the data using R statistical software. Treatment means were separated using Tukey's HSD Post Hoc at the 95% level of probability. Treatments with letters in common are not significantly different from one another.*

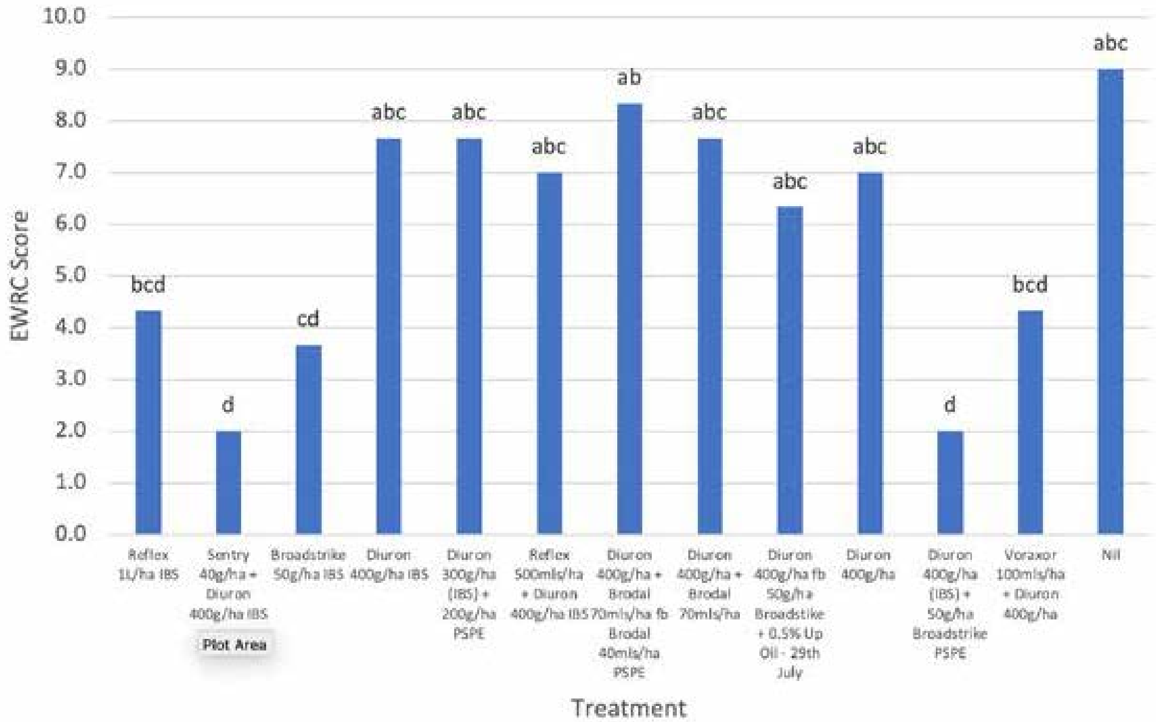

Figure 2. *Emex Spinosa control in lentils scored on the 6th of July note post emergent broadstike in treatment 11 had not yet been applied. EWRC Weed Control Scores: 1 = 100% weed control and 9 = no control, 4 = commercially acceptable. An analysis of variance (ANOVA) was conducted on the data using R statistical software. Treatment means were separated using Tukey's HSD Post Hoc at the 95% level of probability. Treatments with letters in common are not significantly different from one another.*

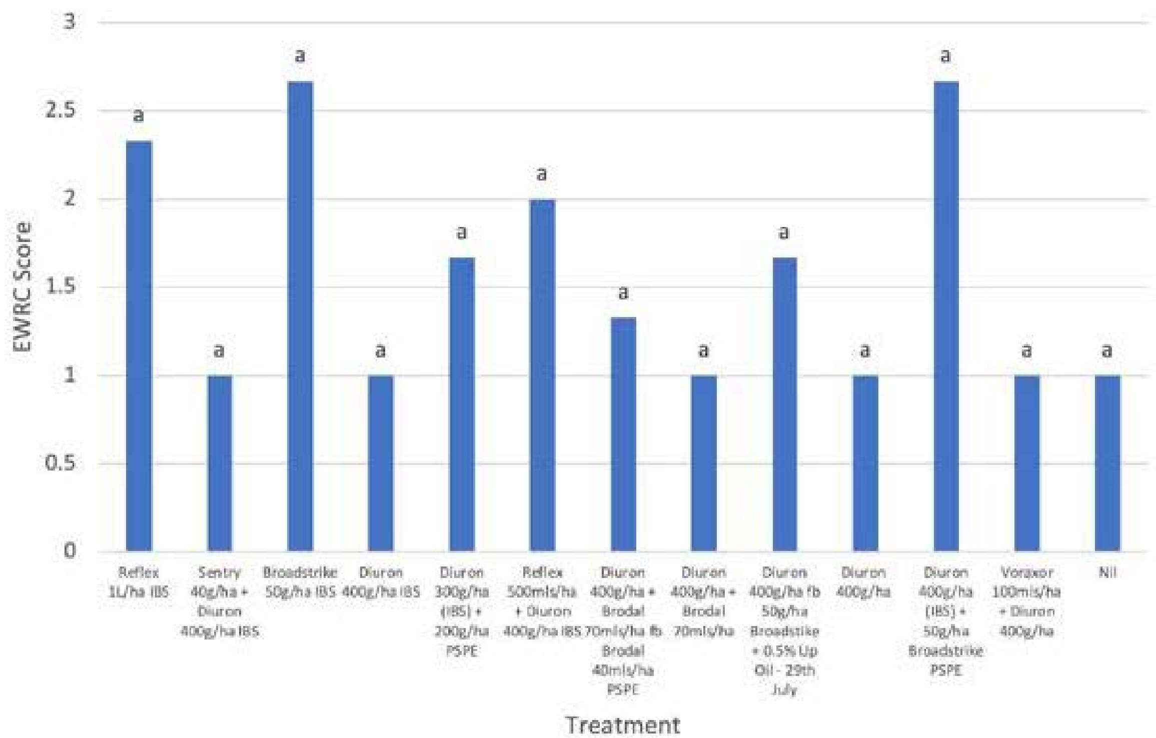

Figure 3. *Crop vigour assessment recorded 6th July ~ 8 EWRC Crop Tolerance Scores: 1 = No effect and 9 = total loss of plants and yield, 4 = Substantial chlorosis and or stunting: most effects probably reversible. An analysis of variance (ANOVA) was conducted on the data using R statistical software. Treatment means were separated using Tukey's HSD Post Hoc at the 95% level of probability. Treatments with letters in common are not significantly different from one another.*

Discussion

This trial has demonstrated that district practice pre-emergent herbicide strategies in lentils provide unacceptable control of spiny emex. This was evident where Diuron + Diuron and Brodal mixes exhibited only a suppression level of control of emex. This trial site was also sprayed with Intercept at 600mls/ha to manage medic, this application only marginally suppressed Emex indicating that other options need to be explored.

This trial has also demonstrated that emex becomes quite tolerant to group B herbicides as it develops. This was indicated where late applications of broadstrike barely suppressed emex. Early applications of group B herbicides either Sentry (imazapic + imazapyr) or Broadstrike (flumetsulam) provided good control of Emex throughout the season. These products provided residual control that lasted the majority of the season. Slight crop effect was observed early from the applications of broadstrike, therefore future work is needed to explore the crop safety of this application timing. Furthermore, Broad strike is not registered at the rate used in this trial and in the use pattern used in this trial. Sentry herbicide currently has no registration in XT lentils.

Recently released herbicide Reflex initially provided improved control of emex compared to district practice treatments, however this was not evident at the final scoring. Experimental product Voraxor (not registered in lentils in Australia) initially provided some suppression of emex however this was not evident at the end of the season.

Acknowledgments

I would like to thank the Nelshaby Agricultural Bureau for funding this research work. I would also like to thank the Johns family for hosting the trial and assisting with trial site management during the season. Special thankyou goes to Steven Johns for assisting with sowing the trial.

Broadleaf weed control and crop safety in lentils

Jordan Bruce[1], Navneet Aggarwal[2,3], Stuart Sherriff[1], Sam Trengove[1] and Penny Roberts[2,3]
[1]Trengove Consulting; [2]SARDI; [3]University of Adelaide.

Key messages

- **Reflex® when used alone did not result in any plant establishment reduction, whereas Terrain® reduced plant establishment at seven out of eight trial sites.**
- **Recovery from herbicide damage symptoms from Reflex® and Terrain® was highly dependent on seasonal weather conditions, with better recovery in 2022 due to higher spring rainfall than 2021.**
- **Reflex® herbicide damage symptoms progressed slowly through winter, whilst Terrain® symptoms began earlier and improved towards the end of winter.**
- **Crop damage with Reflex® and Terrain® on alkaline sands was cumulative when applied in combination with diuron.**
- **Control of bifora, common sowthistle, Indian hedge mustard, and marshmallow populations were achieved with Reflex® and Terrain® applied in combination with registered Group 2, 5 and 12 herbicides.**
- **New Group 14 herbicides, Reflex® and Terrain®, had associated risks of crop damage and yield loss, which emphasises the need for careful planning of weed control on acidic, alkaline and sandy soils to achieve satisfactory weed control and adequate crop safety.**

Why do the trial?

The release cf imidazolinone (IMI) herbicide tolerant lentils coupled with the availability of this technology in most other broadacre crop species has led to the over-reliance on Group 2 herbicides. Developing IMI herbicide resistance in broadleaf weeds is a major constraint to achieving yield potential in pulse crops. Reflex® (fomesafen 240 g/L) Group 14 herbicide was registered in 2021 for use in pulses and vetch and provides more opportunities for rotating modes of action. Lentil is the most sensitive pulse species to Reflex®. Terrain® (flumioxazin 500 g/kg) is another Group 14 herbicide for broadleaf weed control in lentil, newly registered in 2022.

Lentils are particularly sensitive to Group 14 herbicides; therefore, label rates are lower, and the use pattern is restricted to incorporated by sowing (IBS) when compared to other pulse crops. The SAGIT funded project TC121 is investigating crop safety and weed control of Reflex® and Terrain® and their combinations with Group 2 (previously B), Group 5 (previously C) and Group 12 (previously F) herbicides on a range of soil types varying in soil texture and pH in 2021 and 2022 on the northern Yorke Peninsula. Lentil crop safety varied significantly between acidic and alkaline sands in 2021 trials, with the use of Reflex®, diuron, metribuzin and terbuthylazine herbicides, with alkaline sand sites incurring more herbicide damage than acidic sand sites. Care needs to be taken when considering the use of Group 14 on lentils in terms of soil types, seeding system and time of rolling. These studies were continued in 2022 through the SAGIT project TC121 and GRDC Project UOA2105-013RTX. The results of 2022 including those of newly registered herbicide Terrain® are presented here.

How was it done?

A total of four trial sites were established at Alford and Bute, SA in 2021, and another four sites at Wards Hill, Paskeville and Bute, SA in 2022 to assess crop herbicide safety and weed control on IMI tolerant lentils. The herbicides used in the trials are described in Table 1. Each year included two alkaline sandy light textured sites, one acidic sandy site and one medium textured site with results in Table 2.

Trial establishment

Trials were sown using knife points and press wheels and were sown in late May or early June. All varieties grown were IMI tolerant lentils. Herbicides were applied using a hand boom delivering 100 L/ha water volume at a pressure of 200 kPa. One alkaline sand site and acidic sand site were rolled post-emergent in 2021, whilst the other alkaline sand site and medium textured site was rolled post-sowing pre-emergent (PSPE). All the sites were rolled post-emergent in 2022.

Rainfall conditions

A total of 219 mm and 295 mm growing season rainfall (June 2022 to December 2022) was received at Wards Hill (alkaline loamy sand) and Paskeville (neutral clay soil) sites, respectively in 2022. Out of this, Wards Hill and Bute sites received 39 mm and 53 mm rainfall, respectively within the first two weeks of sowing. Similarly, two major rainfall events occurred after seeding in 2021, with 28 mm and 24 mm of rainfall received within the first and second week, respectively at Bute. Wards Hill site received 119 mm and Paskeville 160 mm rainfall in spring 2022.

Table 1. Pre-emergent herbicide properties and application details for products used in the herbicide tolerance trials in 2022 (Source: GRDC pre-emergent herbicide fact sheet).

Herbicide (Group)	Active Ingredient	Solubility (mg/L @ 20°C)		Adsorption Coefficient, K_{oc} value	
Diuron (5)	900 g/kg diuron	36	Low solubility	813	Slightly mobile
Reflex® (14)	240 g/L fomesafen	50	Moderate solubility	228	Moderately mobile
Terrain® (14)	500 g/kg flumioxazin	0.8	Low solubility	889	Slightly mobile

Table 2. Soil test results. The range of pH (H_2O), organic carbon (OC) % and soil texture at 0 – 20cm for the trial sites in 2021 and 2022.

Soil type	pH (H_2O)	OC %	Soil Texture	# of sites
Alkaline sand sites	8.1–8.4	0.84–0.96	Sand–loamy sand	4
Acidic sand sites	5.8–6.8	0.76–0.87	Sand–loamy sand	2
Medium textured sites	7.4–8.1	1.33–1.96	Loam–light clay	2

Table 3. Crop safety data for all sites across 2021 and 2022. Plant establishment presented as percent of control (nil), stunting score (1 = no stunting, 9 = plant death), chlorosis score (1 = no chlorosis, 9 = plant death), spring NDVI as percent of control (nil) and grain yield as percent of control (nil).

Soil type	Herbicide treatment	Rates of commercial product used across trials (timing)	Plant establishment % of control	Herbicide damage stunting score	Herbicide damage chlorosis score	Spring NDVI*	Yield	# of sites
		g or mL/ha	Min.–max. (average)	Min.–max. (average)	Min.–max. (average)	% of control	% of control	
Alkaline sand sites	Nil	Nil	100–100 (100)	1.0–1.2 (1.1)	1.0–2.1 (1.3)	100–100 (100)	100–100 (100)	4
	Diuron (900 g/kg)	550 (PSPE), 623–830 (IBS)	84–100 (95)	1.0–3.7 (2.2)	1.2–2.7 (2.0)	67–100 (83)	80–100 (92)	4
	Reflex®	500 (IBS)	90–100 (96)	1.5–2.0 (1.7)	1.0–1.7 (1.3)	–	83–100 (94)	4
	Reflex®	1000 (IBS)	93–100 (97)	2.8–3.9 (3.2)	1.8–4.2 (2.9)	80–81 (81)	46–98 (79)	4
	Diuron (900 g/kg) + Reflex®	550–623 + 500 (both IBS)	90–100 (95)	2.3–3.3 (2.9)	1.8–3.5 (2.4)	–	61–100 (85)	3
	Diuron (900 g/kg) + Reflex®	623–830 + 1000 (both IBS)	83–93 (88)	3.2–6.1 (4.6)	3.2–4.7 (3.9)	53–84 (68)	48–93 (71)	2
	Terrain®	120 (IBS)	32–100 (60)	2.0–4.2 (3.3)	1.0–3.2 (2.8)	96–100 (98)	85–100 (95)	4
	Diuron (900 g/kg) + Terrain®	550–830 + 120 (both IBS)	27–87 (52)	3.2–5.8 (4.1)	1.5–3.3 (2.2)	82–97 (89)	79–100 (92)	4
Acidic sand sites	Nil	Nil	100–100 (100)	1.0–1.4 (1.2)	1.2–1.8 (1.5)	100–100 (100)	100–100 (100)	2
	Diuron (900 g/kg)	623–830 (IBS)	100–100 (100)	1.0–1.9 (1.4)	1.2–1.9 (1.5)	98–100 (99)	100–100 (100)	2
	Reflex®	1000 (IBS)	99–100 (100)	1.3–1.5 (1.4)	1.7–1.8 (1.7)	100–100 (100)	100–100 (100)	2
	Diuron (900 g/kg) + Reflex®	623–830 + 1000 (both IBS)	90–95 (93)	1.7–2.1 (1.9)	1.8–1.9 (1.9)	100–100 (100)	100–100 (100)	2
	Terrain®	120 (IBS)	76–84 (80)	2.7–3.3 (3.0)	1.2–2.5 (1.8)	92–100 (96)	94–100 (97)	2
	Diuron (900 g/kg) + Terrain®	623–830 + 120 (both IBS)	75–79 (77)	2.7–3.4 (3.0)	1.0–2.1 (1.5)	92–100 (96)	93–100 (97)	2
Medium textured sites	Nil	Nil	100–100 (100)	1.0–1.2 (1.1)	1.0–1.0 (1.0)	–	–	2
	Metribuzin	200 (PSPE)	87–100 (93)	1.7–2.8 (2.3)	1.0–1.7 (1.4)	–	–	2
	Reflex®	500 (IBS)	100–100 (100)	1.5–1.5 (1.5)	1.0–1.0 (1.0)	–	–	2
	Reflex®	1000 (IBS)	100–100 (100)	1.7–2.5 (2.1)	1.0–1.8 (1.4)	–	–	2
	Reflex® + Metribuzin	500 + 200 (both IBS)	81–89 (85)	2.7–3.0 (2.9)	1.0–3.0 (1.5)	–	–	2
	Terrain®	120 (IBS)	34–56 (45)	3.7–3.8 (3.8)	1.0–2.0 (1.5)	–	–	2
	Terrain® + Metribuzin	120 + 200 (both IBS)	28–47 (38)	3.5–5.3 (4.4)	1.2–2.7 (2)	–	–	2

Spring NDVI data only comes from two trial sites for all listed treatments, – indicates no data available.

What happened?

Crop safety

Crop damage in lentil was assessed using loss of plant number, chlorosis, necrosis and stunting. Lentil crop safety varied between acidic and alkaline sands with the use of Group 14 herbicides Reflex® and Terrain®, and Group 5 herbicides diuron and metribuzin and is summarised in table 3.

Plant establishment

Reflex® did not result in any plant establishment issues on any soil type when applied alone at the low and high label rate (Table 3). Terrain® reduced plant establishment at all sites regardless of soil type, except for one alkaline sand site in 2021 (individual site data not shown). Terrain® caused greater reduction in plant establishment at the alkaline sand and medium textured sites compared to the acidic sand sites. However, plant establishment was still reduced by 25% on average at the acidic sand sites. The Terrain® label states not to use on lighter soil types (sand) due to high levels of crop damage, however, the reduction in plant establishment on the medium textured sites was greater than 50% on average, which was a greater reduction than the sandy sites. This crop damage might be associated with the washing of pre-emergent herbicide into the crop row due to the large amounts of rainfall received within two weeks of sowing in both years. In terms of rolling timing, it is worth noting that in 2021 one alkaline sand site was rolled post emergent and the Terrain® treatment did not affect crop establishment at this site. However, all sites were rolled post-emergent in 2022 with plant establishment reductions for the Terrain® treatment occurring at all sites.

Diuron applied alone did not impact plant establishment at the alkaline sand sites compared to the control except at one site and did not reduce establishment at the acidic sites. Despite this, when adding diuron to Reflex® and Terrain® on either of these soils, the plant establishment reduction was more than when those products were applied alone.

Stunting

Plant stunting was one of the main Group 14 herbicide symptoms observed. Stunting caused by Reflex® was rate responsive and was generally worse on alkaline sands compared to acidic sands and medium textured soils (Table 3, Figure 1). The stunting symptom was barely present within the first six weeks post-emergence but gradually worsened into late winter and early spring (Figure 1). Recovery from this symptom was highly dependent on the amount of spring rainfall received, which influenced plant stress levels and the length of time for recovery. In the 2021 season, the late winter and spring rainfall was well below average resulting in lack of recovery from earlier herbicide damage. Conversely, the 2022 spring rainfall was average to above average, which allowed for good moisture availability and longer recovery time and resulted in better recovery from herbicide damage.

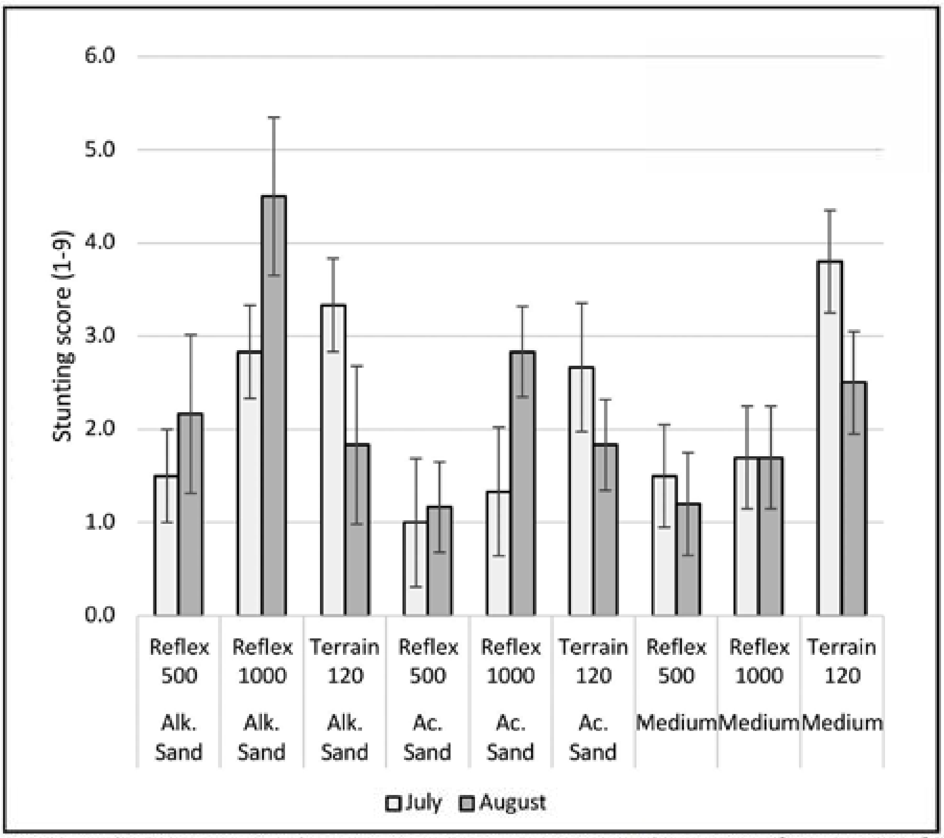

Figure 1. Stunting scores (1 = no stunting, 9 = plant death) for Reflex® and Terrain® treatments recorded on 21 July and 15 August at all sites in 2022. Error bars show LSD (P=0.05) for 21 July and 15 August are each respective site.

Similar to Reflex®, stunting severity caused by Terrain® was greater on alkaline sandy soils. Herbicide damage scoring from Terrain® in both years in July were generally consistent. In 2022, two timings of herbicide damage scoring were recorded, late July and mid August. Stunting from Terrain® improved over all soil types as the season progressed in 2022, in contrast to Reflex® where stunting increased on the sands (Figure 1).

Chlorosis

Chlorosis symptoms for Reflex® are generally visualised as "bronzing" and are well correlated with the amount of stunting present. It appears these symptoms go hand in hand; therefore, a combination of both stunting and chlorosis is likely contributing to the yield loss.

Terrain® chlorosis symptoms were independent of stunting symptoms. Chlorosis symptoms were very low at the acidic sand and medium textured sites, however, were present at low-moderate levels on the alkaline sand sites.

Springtime NDVI/biomass

There was no relationship between plant establishment and grain yield, as some herbicide treatments reduced plant establishment that ultimately reduced grain yield, whilst others such as Terrain® reduced plant establishment, but this did not influence yield. Terrain® treatments were able to recover with lower plant densities, suggesting compensation by accumulating more biomass per plant into spring allowed these treatments to match the potential yield of the untreated control. This crop recovery might be associated with the above average rainfall received in spring 2022 compared to 2021.

Previous trial work has shown that on sandy soil types or lower yielding environments, there is a strong relationship between spring NDVI (where NDVI is correlated to biomass) and yield for lentil, which was the case for the 2021 alkaline sand herbicide tolerance trial (Figure 2). Maximising biomass is important on soil types that are particularly sensitive to herbicides, such as alkaline sands.

Grain yield

Over the two seasons, the grain yield differences caused by the preceding herbicide damage was generally consistent across the two sandy sites (Table 3). Herbicides, diuron and Reflex® applied alone were more damaging at the alkaline sand sites, which aligns with recorded spring NDVI values. Reflex® yield loss is rate responsive with the 500 mL/ha rate averaging 6% yield loss compared to the control treatment, whilst the 1000 mL/ha rate averaged 21% yield loss across sites and years. When Reflex® was applied with diuron, the herbicide damage and resulting yield loss compared to the control was larger.

Terrain® averaged 95% and 97% yield of the control on average at the alkaline sand sites and acidic sand sites, despite losing 40% and 25% of plants on average, respectively. Over the two seasons and soil types in this project, Terrain® herbicide behaviour appears to be influenced less by the soil pH of sands than some other herbicides.

Rolling timing

Timing of rolling is important to keep separation of the soil that is treated with herbicide out of the crop row, where it may then be washed into the root zone by following rainfall events. In theory, post-emergent rolling of lentils allows time for the herbicide to move into the soil and even experience some level of degradation before potentially levelling some of the furrow back over the row. In contrast, PSPE rolling can potentially move the concentrated herbicide band back over the row before the crop has emerged.

The Reflex® label makes note for caution when rolling on sandy soils as they are more prone to soil movement back into the furrow. The Terrain® label states "for lentils, avoid rolling the paddock prior to crop emergence". This is to prevent pushing excessive amounts of treated soil back into the furrow and reducing crop emergence.

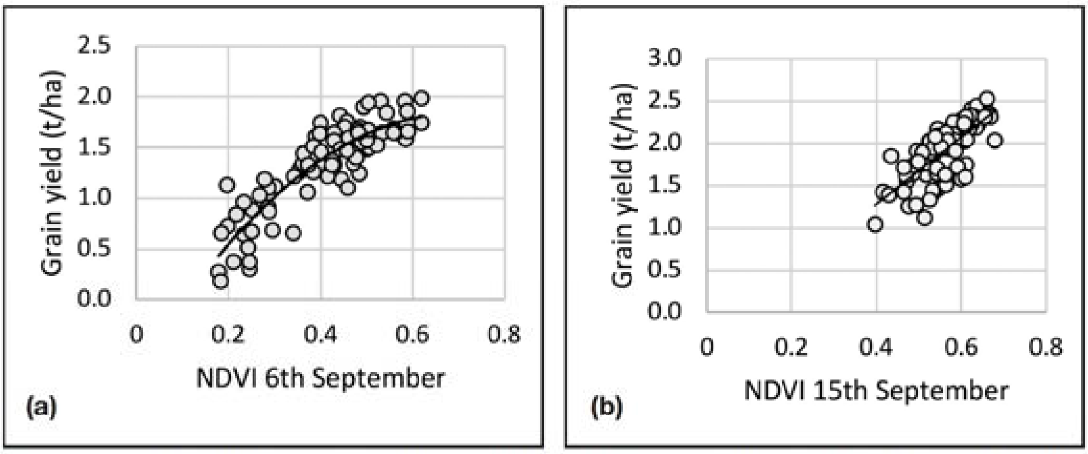

Figure 2. The relationship for Greenseeker NDVI and grain yield recorded (a) 6 September for the alkaline sand trial at Alford in 2021 (y = –5.2444x2 + 7.3026x – 0.706, R^2 = 0.77), and (b) 15 September for the alkaline sand trial at Wards Hill in 2022 (y = 3.955x – 0.2994, R^2 = 0.56).

Table 4. Effect of herbicides on Indian hedge mustard (IHM) and common sowthistle seed set on sandy alkaline soils at Wards Hill, 2022.

Herbicide treatment (commercial product rate)	Common sowthistle pods/m²	Indian hedge mustard pods/m²
Diuron 550 g/ha (PSPE) - Post-sowing, Pre-emergence	11.8 def	8.5 cde
Intercept® 600 mL/ha (POST) - Post sowing	56.9 abc	137.1 b
Metribuzin 180 g/ha (PSPE) - Post-sowing, Pre-emergence	66.1 ab	28.7 c
Reflex® 1000 mL/ha (IBS) - Incorporated by sowing	21.3 bcd	3.0 de
Reflex® 500 mL/ha (IBS)	15.5 cde	2.1 de
Reflex® 500 mL/ha (IBS) f/b* Diuron 550 g/ha (PSPE)	0.0 f	0.0 e
Reflex® 500 mL/ha (IBS) f/b Diuron 550 g/ha (PSPE) f/b Intercept® 600 mL/ha (POST)	0.3 ef	0.0 e
Reflex® 500 mL/ha (IBS) f/b Metribuzin 180 g/ha (PSPE)	21.5 bcd	0.9 de
Reflex® 500 mL/ha (IBS) f/b Metribuzin 180 g/ha (PSPE) f/b Intercept® 600 mL/ha (POST)	1.6 def	0.0 e
Reflex® 750 mL/ha (IBS)	18.1 cde	1.5 de
Terrain® 120 g/ha (IBS)	12.0 def	12.5 cde
Terrain® 120 g/ha (IBS) f/b Diuron 550 g/ha (PSPE)	8.8 def	8.6 cde
Terrain® 120 g/ha (IBS) f/b Diuron 550 g/ha (PSPE) f/b Intercept® 600 mL/ha (POST)	0.0 f	0.0 e
Terrain® 120 g/ha (IBS) f/b metribuzin 180 g/ha (PSPE)	8.8 def	0.0 e
Terrain® 120 g/ha (IBS) f/b metribuzin 180 g/ha (PSPE) f/b Intercept® 600 mL/ha (POST)	0.0 f	6.7 cde
Unweeded control	103.4 a	288.0 a

**f/b = followed by*

Table 5. Effect of herbicides on broadleaf weeds (bifora, marshmallow, Indian hedge mustard and common sowthistle) and their seed set on clay loam soils at Paskeville, 2022.

Herbicide treatment (commercial product rate)	Bifora seeds/ m²	Marshmallow pods/m²	Indian hedge mustard pods/m²	Common sowthistle pods/m²
Intercept® 600 mL/ha (POST)	4 d	0 e	12 cde	135 e
Metribuzin 200 g/ha (PSPE)	6416 b	1176 ab	924 a	581 abc
Reflex® 1000 mL/ha (IBS)	0 d	231 cd	32 bcde	467 bcd
Reflex® 500 mL/ha (IBS)	475 c	807 b	121 bc	818 a
Reflex® 500 mL/ha (IBS) f/b Intercept® 600 mL/ha (POST)	0 d	0 e	15 cde	54 efg
Reflex® 500 mL/ha (IBS) f/b Metribuzin 200 g/ha (PSPE) f/b Intercept® 600 mL/ha (POST)	0 d	0 e	0 e	20 gh
Reflex® 500 mL/ha (IBS) + Terbyne 1000 g/ha (IBS) f/b Intercept® 600 mL/ha (POST)	21 d	0 e	0 e	5 h
Reflex® 750 mL/ha (IBS)	0 d	196 d	96 bcd	428 cd
Reflex® 750 mL/ha (IBS) f/b Intercept® 600 mL/ha (POST)	0 d	0 e	0 e	35 fgh
Reflex® 750 mL/ha (IBS) f/b Metribuzin 200 g/ha (PSPE) f/b Intercept® 600 mL/ha (POST)	0 d	0 e	0 e	16 gh
Reflex® 750 mL/ha (IBS) + Terbyne 1000 g/ha (IBS) f/b Intercept® 600 mL/ha (POST)	0 d	0 e	0 e	14 gh
Terbyne 1000 g/ha (IBS)	8010 b	660 bc	190 b	104 ef
Terrain® 120 g/ha (IBS)	11664 a	286 cd	169 b	296 d
Terrain® 120 g/ha (IBS) f/b Intercept® 600 mL/ha (POST)	58 d	0 e	37 bcde	18 gh
Terrain® 120 g/ha (IBS) f/b Metribuzin 200 g/ha (PSPE) f/b Intercept® 600 mL/ha (POST)	0 d	0 e	0 e	42 efgh
Terrain® 120 g/ha (IBS) + Terbyne 1000 g/ha (IBS) f/b Intercept® 600 mL/ha (POST)	10	0 e	3 de	37 fgh
Unweeded control	6724 b	1772 a	1069 a	713 ab

Table 6. Efficacy of herbicides on Indian hedge mustard and common sowthistle plant number on sandy alkaline soils at Wards Hill, 2022 (herbicide tolerance trial).

Herbicide treatment (commercial product rate)	Common sowthistle control (%)	Indian hedge mustard control (%)
Unsprayed control	0 a	0 a
Diuron 623 g/ha (IBS)	64 bc	23 ab
Reflex® 500 mL/ha (IBS)	73 bcde	94 defg
Reflex® 750 mL/ha (IBS)	80 defg	98 fg
Reflex® 1000 mL/ha (IBS)	94 i	95 defg
Terrain® 120 g/ha (IBS)	69 bcd	70 bc
Reflex® 500 mL/ha (IBS) f/b Diuron 623 g/ha (PSPE)	63 b	82 bcd
Reflex® 500 mL/ha (IBS) f/b Intercept® 500 mL/ha (POST)	95 i	95 efg
Reflex® 500 mL/ha (IBS) f/b diflufenican 150 mL/ha (POST)	76 cde	100 g
Reflex® 500 mL/ha (IBS) f/b diflufenican 150 mL/ha (POST) f/b Intercept® 500 mL/ha (POST)	97 i	100 g
Reflex® 500 mL/ha (IBS) f/b Diuron 623 g/ha (PSPE) f/b diflufenican 150 mL/ha (POST) f/b Intercept® 500 mL/ha (POST)	90 fghi	100 g
Reflex® 500 mL/ha (IBS) f/b Diuron 623 g/ha (PSPE) f/b diflufenican 150 mL/ha (POST)	92 ghi	100 g
Reflex® 500 mL/ha (IBS) f/b Diuron 623 g/ha (PSPE) f/b Intercept® 500 mL/ha (POST)	94 i	91 defg
Reflex® 1000 mL/ha (IBS) f/b Diuron 623 g/ha (PSPE)	80 def	89 cdef
Reflex® 1000 mL/ha (IBS) f/b Intercept® 500 mL/ha (POST)	96 i	91 cdef
Reflex® 1000 mL/ha (IBS) f/b diflufenican 150 mL/ha (POST)	93 hi	100 g
Reflex® 1000 mL/ha (IBS) f/b diflufenican 150 mL/ha (POST) f/b Intercept® 500 mL/ha (POST)	97 i	98 fg
Reflex® 1000 mL/ha (IBS) f/b Diuron 623 g/ha (PSPE) f/b diflufenican 150 mL/ha (POST) f/b Intercept® 500 mL/ha (POST)	99 i	100 g
Reflex® 1000 mL/ha (IBS) f/b Diuron 623 g/ha (PSPE) f/b diflufenican 150 mL/ha (POST)	94 hi	100 g
Reflex® 1000 mL/ha (IBS) f/b diflufenican 150 mL/ha (POST) f/b Intercept® 500 mL/ha (POST)	95 i	95 defg
Reflex® 750 mL/ha (IBS) f/b Diuron 623 g/ha (PSPE)	89 fghi	83 bcde
Terrain® 120 g/ha (IBS) f/b Diuron 623 g/ha (PSPE)	71 bcde	62 b
Terrain® 120 g/ha (IBS) f/b Diuron 623 g/ha (PSPE) f/b Intercept® 500 mL/ha (POST)	96 i	91 defg
Weeds/plot in unsprayed control	52	22

Broadleaf weed control

IMI herbicide Intercept®, did not provide adequate control of Indian hedge mustard (IHM) at the alkaline loamy sand site (Wards Hill), and was not significantly different to the untreated control (Table 4). Similar results for poor IHM control with Intercept® were also reported at 2021 trial sites in lentil growing areas of Yorke Peninsula (Bruce *et al*. 2022), that might be due to an increase of IHM populations resistant to IMI herbicides. However, IHM was effectively controlled with Intercept® at the Paskeville light clay site. These results suggest the strategic use of IMI herbicides is important to ensure longevity of the chemistry. This will require rotating modes of action that is now possible with the availability of new Group 14 herbicides Reflex® and Terrain®. Reflex® applied at 500 - 1000 mL/ha and Terrain® at 120 g/ha as incorporated by sowing (IBS) were effective at controlling IMI resistant IHM populations at all the sites except at Wards Hill, where Reflex® proved to be slightly stronger than Terrain® (Tables 4, 5, 6 and 7).

Common sowthistle control improved with increasing Reflex® rates from 500 mL/ha to 1000 mL/ha (Tables 5 and 7). Terrain® proved as effective as Reflex® applied at 750 mL/ha or at higher rates. Reflex® treated plots at alkaline sandy soil at Wards Hill had up to 0.3 surviving common sowthistle plants/m^2 compared with up to 4 plants/m^2 in the neutral light clay soil of Paskeville (data not shown).

Table 7. Efficacy of herbicides on common sowthistle and medic plant number on sandy acidic soil at Bute, 2022 (herbicide tolerance trial).

Herbicide treatment (commercial product rate)	Common sowthistle control (%)	Medic control (%)
Unsprayed control	0 a	0 a
Diuron 623 g/ha (IBS)	74 cde	21 ab
Reflex® 500 mL/ha (IBS)	38 ab	74 bcde
Reflex® 750 mL/ha (IBS)	62 bcd	58 bcde
Reflex® 1000 mL/ha (IBS)	77 def	63 bcde
Terrain® 120 g/ha (IBS)	82 defg	53 abcd
Reflex® 500 mL/ha (IBS) + Diuron 623 g/ha (IBS)	74 cde	84 cdef
Reflex® 500 mL/ha (IBS) f/b Intercept® 500 mL/ha (POST)	85 defg	95 ef
Reflex® 500 mL/ha (IBS) f/b diflufenican 150 mL/ha (POST)	44 abc	53 abc
Reflex® 500 mL/ha (IBS) f/b diflufenican 150 mL/ha (POST) f/b Intercept® 500 mL/ha (POST)	95 ij	89 def
Reflex® 500 mL/ha (IBS) f/b Diuron 623 g/ha (IBS) f/b diflufenican 150 mL/ha (POST) f/b Intercept® 500 mL/ha (POST)	94 hij	95 ef
Reflex® 500 mL/ha (IBS) + Diuron 623 g/ha (IBS) f/b diflufenican 150 mL/ha (POST)	80 defg	79 cde
Reflex® 500 mL/ha (IBS) + Diuron 623 g/ha (IBS) f/b Intercept® 500 mL/ha (POST)	91 fghi	95 ef
Reflex® 1000 mL/ha (IBS) + Diuron 623 g/ha (IBS)	89 fghi	74 bcde
Reflex® 1000 mL/ha (IBS) f/b Intercept® 500 mL/ha (POST)	95 hij	100 f
Reflex® 1000 mL/ha (IBS) f/b diflufenican 150 mL/ha (POST)	86 efgh	53 abc
Reflex® 1000 mL/ha (IBS) f/b diflufenican 150 mL/ha (POST) f/b Intercept® 500mL/ha (POST)	97 ij	89 def
Reflex® 1000 mL/ha (IBS) + Diuron 623 g/ha (IBS) f/b diflufenican 150 mL/ha (POST) f/b Intercept® 500 mL/ha (POST)	95 hij	100 f
Reflex® 1000 mL/ha (IBS) + Diuron 623 g/ha (IBS) f/b diflufenican 150 mL/ha (POST)	91 fghi	74 cdef
Reflex® 1000 mL/ha (IBS) f/b diflufenican 150 mL/ha (POST) f/b Intercept® 500 mL/ha (POST)	97 ij	100 f
Reflex® 750 mL/ha (IBS) + Diuron 623 g/ha (IBS)	91 ghi	42 abc
Reflex® 500 mL/ha + Diuron 312 g/ha (IBS)	71 cde	47 abc
Terrain® 120 g/ha (IBS) + Diuron 623 g/ha (IBS)	91 fghi	79 cdef
Terrain® 120 g/ha (IBS) + Diuron 623 g/ha (IBS) f/b Intercept® 500 mL/ha (POST)	97 ij	100 f
Weeds/plot in unsprayed control	22	6.3

Higher weed density at Paskeville in Reflex® treated plots coupled with moist conditions in medium textured soil due to spring rainfall resulted in surviving common sowthistle plants producing 428–818 pods/m² compared to 16–21 pods/m² at Wards Hill (Tables 4 and 5). Similarly, Terrain® treated plots recorded higher common sowthistle pods at Paskeville site. Most of the surviving plants of both common sowthistle and IHM in Reflex® and Terrain® treated plots were found in the in-row spaces, from where the applied herbicide was likely moved out by the seeding operation. Where Reflex® and Terrain® was applied IBS and were followed by a Group 5 herbicide metribuzin, as a post-sowing pre-emergence (PSPE) application, the surviving weeds in the in-row area were mostly controlled. Similarly, the combinations of Reflex® + Intercept® and Terrain® + Intercept® provided effective control of common sowthistle control at all sites where it was present. Importantly, the paddocks where common sowthistle is IMI-resistant, will still have this weed surviving in the intra-row spaces even after applying Group 14 IBS herbicide followed by Intercept®.

Further, Reflex® was effective in controlling bifora by reducing its seed set from 6724 seeds/m² in unsprayed control plots to 475 seeds/m² when applied at 500 mL/ha, and to <1 seed/m² at 750 and 1000 mL/ha (Table 5). Similarly, Reflex® reduced bifora seed set by 94–98% in 2021 trials (Bruce *et al.* 2022). Application of Intercept®, on its own or in combination with Reflex®, provided excellent control of bifora, reducing seed set to 0–4 bifora seed/m² compared to existing pre-emergent herbicide options metribuzin and Terbyne recording 6416 and 8010 bifora seeds/m2, respectively. Terrain® did not prove effective for bifora control (11664 seeds/m²), and a subsequent post-emergent application of Intercept® was needed to achieve improved control with weed seed set reducing to 58 plants/m².

The Paskeville site had a background population of marshmallow. The level of marshmallow control improved with increasing Reflex® rates from 500 mL/ha (807 pods/m²) to 1000 mL/ha (231 pods/m²) (Table 5). Terrain® proved as effective (286 pods/m²) as Reflex® applied at 750 mL/ha (196 pods/m²) or 1000 mL/ha for controlling marshmallow and was better than Reflex® at 500 mL/ha. Both Group 14 herbicides proved superior to Group 5 herbicides metribuzin (1176 pods/m²) and Terbyne (660 pods/m²) for marshmallow control. A follow up application of Intercept® was needed after Reflex®/Terrain® IBS to achieve effective control of marshmallow (<1 pod/m²). Intercept® also achieved effective control of marshmallow without an upfront herbicide. But the IBS herbicides will be reducing selection pressure on Intercept®. Similarly, Intercept® was the standalone treatment for controlling medic up to 100% in lentil, likewise in 2021 research trials (Bruce *et al.* 2022), with the next best herbicide treatment Terrain® + diuron reducing weed population by 79% (Table 7).

What does this mean?

Group 2 IMI herbicides will continue to be a valuable tool for broadleaf weed control in lentil for weeds that have not evolved resistance to this mode of action, and for weeds such as medic that are not effectively controlled with other herbicides. Rotating with other effective modes of action will reduce resistance selection pressure on this vulnerable herbicide group and sustain its efficacy on important weeds further into the future. However, for some weed species in some locations, IMI resistance is already well developed. The availability of the new Group 14 herbicides Reflex® and Terrain® applied in combination with other registered Group 2, 5 and 12 herbicides has increased the options for broadleaf weed control in lentil, including weeds resistant to IMI herbicides. However, consideration should be given to the associated risks of crop damage and a yield loss with new herbicides when applied alone or with Group 5 herbicides, depending on the soil type and herbicide rates. Background information on likely weed types, their population, and resistance status will be crucial for deciding herbicides and rates to achieve balance between satisfactory weed control and adequate crop safety on high-risk soils such as alkaline sandy textured soils.

Acknowledgements

The research undertaken as part of this project is made possible by the significant contributions of growers through both trial cooperation and the support of the GRDC, the authors would like to thank them for their continued support. Similarly, the authors thank SAGIT for their continued support (project codes: TC121, TC116, TC119). The help received from SARDI Agronomy Clare team in the field work is greatly appreciated. Authors also thank David Keetch and Jason Sabeeney for making available the new Group 14 herbicides for the current research studies.

Project codes: SAGIT funded TC121 and GRDC funded UOA2105-013RTX

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Mr	Nicholas	McCallum	Carly	Melrose
Mr	Ras	McCallum		Flinders Machinery
Mr	Richard	McCallum	Michelle	Booleroo Centre
Mr	Warren	McCallum	Jennifer	Booleroo Centre
Ms	Krystal	McMahon	Bradley	Ag Ex Alliance
Mr	Stewart	McMillan		Topcon
Mr	Larn	McMurray		Global Grain Genetics
Ms	Taryn	Mangelsdorf		Landscape SA Northern & Yorke
Mr	Robert	Mills		Booleroo Centre
Mr	David	Moore	Bec	Jamestown
Ms	Millie	Moore		S & W Seed Co.
Ms	Tanja	Morgan		Mallee Sustainable Farming
Mr	Tom	Moten		Pekina
Mr	Barry	Mudge	Kristina	Port Germein
Mr	Jonathon	Mudge		Port Germein

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Mr	Matthew	Nottle	Alice	Booleroo Centre
Mr	Len	Nutt	Carolyn	Orroroo
Mr	Morgan	Nutt	Joy	Orroroo
Mr	Stuart	Ockerby		Tatton NSW
Ms	Kim	Oldfield		Carrieton
Mr	Mitch	Orrock		Murray Town
Mr	Todd	Orrock	Brooke	Orrock Farming
Ms	Kate	Pearce		Landscape SA Northern & Yorke
Mr	Darren	Pech		Elders
Mr	Marcus	Perry		Perrys Fuels
Mr	Nicholas	Piggott	Emily	Booleroo Centre
Mr	John	Polden		Booleroo Centre
Mr	Thomas	Porter		Washpool
Ms	Courtney	Ramsey		GRDC
Mr	Patrick	Redden		Clare
Mr	Thomas	Reichstein		CentreState Exports
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Ms	Penny	Roberts		SARDI
Mr	Quinton	Rodda		Alford
Mr	Paul	Rodgers		Quorn
Mr	Joe	Ross	Lauren	Emu Downs
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Mr	Stephen	Sanders	Elishia	Melrose
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Mr	Daniel	Vater		AGT
Ms	Krisite	Vater		SA Arid Lands Landscape Board
Mr	Henry	Voigt		CentreState Exports
Mr	Andrew	Walter	Lydia	Melrose
Mr	Ken	Walter	Denise	Melrose
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Mr	Nigel	Wilhelm		SARDI
Mr	Lachie	Williams		Booleroo Centre
Mr	Andrew	Woodroffe		Greening Australia

Mr	Craig	Woolford		Wirrabara
Mr	Samuel	Young		Port Pirie
Mr	Wayne	Young		Port Pirie
Mr	Andrew	Zanker		Laura
Mr	Bryan	Zanker		Booleroo Centre
Mr	Eric	Zanker	Raelene	Booleroo Centre
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Mr	Jason	Zohs	Kim	Crystal Brook
Mrs	Kim	Zohs	Jason	Crystal Brook
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Collation and editing of this report was undertaken by
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