Eyre Peninsula Farming Systems Summary 2021

SARDI - Minnipa Agricultural Centre

Government of South Australia
Department of Primary Industries and Regions

SARDI
South Australian Research and Development Institute

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Eyre Peninsula Farming Systems Summary 2021

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All article submissions are reviewed by the Editorial Team prior to publication for scientific merit and to improve readability, if necessary, for a farmer audience.

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Front Cover: Amanda Cook - MAC. 2021 MAC Canola trials and Yarwondutta rock

Inside Back Cover (Top Left): AIR EP photo taken by Bec Smart Photography

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SARDI Foreword

It is my pleasure, on behalf of the Department of Primary Industries and Regions (PIRSA) research division South Australian Research and Development Institute (SARDI), to present the 2021 Eyre Peninsula Farming Systems Summary. This annual publication is highly anticipated and well-used by Eyre Peninsula (EP) growers and advisors, compiling the latest research development and extension activities relevant to EP. The Farming Systems Summary is a valuable resource to assist growers to access the latest research results and incorporate them into their on-farm decisions.

Good, applied research draws on the investment of time, expertise and ideas of all participants as it is a true collaboration between growers, advisors and research scientists. The research results presented here are a result of investment by research organisations including PIRSA-SARDI, the Grains Research and Development Corporation (GRDC), the South Australian Grains Industry Trust (SAGIT), the Future Drought Fund (FDF), the Australian Government (National Landcare Program, Rural R&D for Profit and Soils CRC), the EP Landscapes Board, The University of Adelaide and the CSIRO. Thank you to SAGIT for thier investment toward the printing of the EP Farming Systems Summary.

The 2021 season presented promising with good winter rainfall despite a later than ideal seeding opportunity, however the predicted 'wetter than average' spring did not eventuate until too late for many regions. Growing season rainfall varied from above average in lower Eyre Peninsula to average in Upper and Eastern EP. Large late rainfall events during November proved challenging, not only disrupting harvest for most growers but also causing downgraded grain quality for earlier maturing crops. Grain yields were generally average to above average for most regions on EP although grain quality was generally reduced in many areas.

SARDI delivers applied science that grows South Australia's primary industries. It works closely with industry to provide tangible and practical assistance to growers by holding extension activities throughout the year including Farmer Meetings, Sticky Beak Days and The Minnipa Agricultural Centre Field Day. The annual MAC Field Day is an excellent event that brings growers, advisors and researchers together to share our latest research development and upcoming extension activities. The 2021 MAC Field Day was successfully held in September with over 140 attendees.

The Future Drought Fund National investment to establish a South Australian Drought Hub is an exciting opportunity for the Minnipa Agricultural Centre to be on the front line for increasing drought resilience of farming systems. The newly appointed Drought Node coordinator based at MAC, will soon be officially announced.

Congratulations to the SARDI team at the Minnipa Agricultural Centre for continuing to put together the EP Farming Systems Summary. It is an important record of our shared research and I hope you find it both interesting and useful. SARDI staff across the state will continue to work closely with primary producers to develop relevant research programs and ensure excellence in our policy and program delivery, industry and regional engagement.

Best wishes for everyone for the 2022 growing season,

Kathy Ophel Keller

Dr Kathy Ophel Keller

Acting Executive Director, SARDI

Government of South Australia

Department of Primary Industries and Regions

SARDI

SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE

SAGIT Foreward

The South Australian Grain Industry Trust (SAGIT) is proud to be associated with this EP Farming Systems Summary.

This publication is an important resource for the region's grain growers who constantly strive for sustainable improvement within their enterprises.

The summary contains information on research outcomes that is of direct relevance to EP growers, thereby enhancing their knowledge and understanding of local cropping constraints and opportunities to address these.

Included in this year's summary are outcomes and updates on EP projects funded by SAGIT which annually invests more than $2 million state-wide to support research crucial to advancing the SA grain industry.

EP growers are challenged by issues that are unique to their environments, as well as constraints that are experienced more broadly across the State.

In 2021-22 SAGIT is funding 47 active projects, many of which will generate valuable insights, recommendations and new resources for EP growers.

In terms of projects with on-the-ground activity on EP, SAGIT is funding several initiatives.

These include a three-year project focused on improving the management of Group A resistant barley grass in current farming systems. This work is being led by Amanda Cook on behalf of SARDI, Minnipa Agricultural Centre and the University of Adelaide.

Amanda also leads the 'Improving the early management of dry sown cereal crops' project which is assessing the impact of fertiliser treatments, soil residual herbicides and seed dressings on establishment, growth and grain yield of wheat sown dry in early to mid-April at three sites with contrasting soil types.

SAGIT is supporting a Soils Cooperative Research Centre-Grains Research and Development Corporation investigation into innovative solutions for low crop performance on highly calcareous soils which severely limit crop yields and grower profitability on EP, led by Nigel Wilhelm and Brian Dzoma. This three-year research effort also involves PIRSA, New South Wales Department of Primary Industries and CSIRO.

The successful formation of AIR EP has been commendable and SAGIT is pleased to support this organisation's activities, including the maximising performance of post-emergent herbicides workshops on upper EP. AIR EP also received funding for a 'EP internship in applied grains research' and intern Rhaquelle Meiklejohn has applied herself wholeheartedly to research undertakings on EP.

Of course, there are many more SAGIT-funded projects that have application to EP farming systems, and outcomes from these will be extended to the region's growers as they are made available.

More information about current projects is available in the SAGIT Snapshot which can be viewed and downloaded via https://sagit.com.au/2021-sagit-snapshot-booklet/.

In the meantime, SAGIT remains committed to helping EP grain growers with their research needs and resource requirements.

The EP Farming Systems Summary is one of many resources and publications funded by SAGIT, the management and Trustees of which commend all those involved in its preparation and production.

On behalf of SAGIT, I hope you gain enormous value from this summary and wish you all the very best for season 2022.

Yours sincerely,

Max Young

Chairman

SAGIT

GRDC Foreword

Season 2021 on the Eyre Peninsula was again one of mixed fortunes and various challenges.

Among those challenges and constraints were a delayed break, a wet winter and spring frosts which caused major damage to some crops. Fortunately, high grain prices helped offset those losses to an extent, and those growers who managed to produce a respectable yield were well rewarded.

Season 2022 is already off to a challenging start for growers in parts of the EP where summer storms and record rainfall have caused significant damage to soils and infrastructure. While severe in places, the erosion damage was not widespread, and would have been much worse were it not for no-till and stubble retention.

The Grains Research and Development Corporation (GRDC) quickly responded to this situation by organising a series of post-storm workshops to discuss the immediate impact and to assist with the recovery effort. It is a situation we will monitor closely over the course of the coming cropping season.

EP growers are accustomed to difficult circumstances, which is why it is so important that we - GRDC and the broader industry - must continue to inject effort and investment in research, development and extension (RD&E) to build better resilience within local farming systems.

Resilience comes from sound decision making. And sound decisions are often based on consideration of a mix of facts, recommendations, observations, conversations, experience, and 'gut feel'.

The contents of this 2021 EP Farming Systems Summary are a resource for growers to factor into their decision making process. It consolidates RD&E activities, providing information and insights to inform and underpin their analysis of their farm performance and areas for potential improvements.

The local RD&E findings presented over the following pages are the result of significant individual or collaborative investment by GRDC; the South Australian Research and Development Institute (the research division of the Department of Primary Industries and Regions; the University of Adelaide; the South Australian Grain Industry Trust; Commonwealth Scientific and Industrial Research Organisation; Ag Innovation and Research EP; EP Natural Resources Management Board; and others. These organisations rely heavily on the collaboration with local farm advisers and agribusinesses to deliver enhanced farm management practices for producers.

The information contained in this publication is of direct regional relevance and value to local primary producers and advisers, assisting with their endeavours to achieve sustainable profitability. I encourage you to take the time to review the content of this summary, identify opportunities for change (no matter how big or small) and apply and implement those learnings for potential positive impact.

In addition to the detailed reports from many stakeholders in this publication, you will find a summary of some current GRDC investments of local relevance, including links to resources that may be of interest.

On behalf of GRDC, I congratulate all those involved in preparation and production of this comprehensive summary.

Best wishes for the year ahead.

Stephen Loss

GRDC Manager Soils & Nutrition - South

Contents

Minnipa Agricultural Centre update

Amanda Cook
SARDI, Minnipa Agricultural Centre

Welcome to the twenty third edition of the Eyre Peninsula Farming Systems Summary, providing detailed reports on the outcomes of RD&E carried out on Eyre Peninsula and related environments across Australia.

We would like to thank project funders GRDC, SAGIT, the Australian Government (National Landcare Program, Rural R&D for Profit, CRC for High Performance Soils) and collaborators AIR EP, University of Adelaide, SA Drought Hub and CSIRO for their contribution to the Eyre Peninsula for research, development and extension and for enabling us to extend our results to all farm businesses on the EP and beyond in other low rainfall areas. Current projects and contracted research conducted by SARDI Minnipa Agricultural Centre (MAC) are listed in Table 1. Thank you to SAGIT for their investment towards the publication of the Eyre Peninsula Farming Sytems Summary 2021.

Staff

We have welcomed John Kelsh into the role of MAC Farm Manager, as Jake Hull finished in August 2021. Thank you to Wade Shepperd who acted as interim Farm Manager in 2021. We welcomed Kym Zeppel and Craig Standley as a Senior Agricultural Officers, Zakirra Simpson as the Agricultural Officer on the MAC Farm and Nicole Baty as the Project Management Support Officer. We have welcomed Jessica Gunn back part-time as Morgan McCallum moved to the Upper North Farming Systems group in July 2021.

Projects

An exciting development in 2020 was PIRSA's AgTech Program, which aims to enhance the uptake of farm technology to increase the productivity, growth and sustainability across the South Australian primary industries sectors. The Minnipa Agricultural Centre was chosen as one of the AgTech demonstration sites, giving AgTech companies and providers the opportunity to demonstrate their capabilities and providing farmers with demonstration of technology solutions.

The recent 2021 Future Drought Fund National investment to establish the SA Drought Hub is another exciting opportunity for the Minnipa Agricultural Centre being in the front line for increasing drought resilience of farming systems, and with Fiona Tomney being announced as the Minnipa Node Co-ordinator role.

In 2021 we have also made an investment into our research infrastructure with a new Plot Harvester arriving for harvest in 2022.

Visitors

COVID19 provided challenges for MAC extension activities in 2021 but the SARDI Farmer Meetings and the Annual MAC Field Day went ahead and were very well supported by growers and industry. A range of events which were held or attended by MAC staff, with details is listed below in Table 2.

The Minister of Agriculture, David Basham visited Minnipa during June on his tour of the region to gain an insight into the research and activities which SARDI MAC provides to the region. In August the Low Rainfall committee, AIR EP representatives and GRDC's Stephen Loss visited the Calcareous soils site at MAC, and DLPS and Mixed Legume Pastures trial sites.

Members of the SAGIT Board also visited MAC and a number of project trial sites on their EP tour in August. This was a valuable exercise to gain insight into current research in our farming systems and experience first-hand some of the issues and opportunities for the region.

It was great to host the MAC Field Day event on the 15 September 2021, with over 140 growers and industry representatives attending to visit field trials and learn about the latest SARDI research.

Thank you all for your continued support at farmer meetings, field days, agricultural events and sticky beak days. Without strong farmer involvement and support, we lose our relevance to you and to the industries that provide the funding supporting our research. SARDI staff across the state will continue to work closely with primary producers to develop relevant research programs and ensure excellence in our policy and program delivery, industry and regional engagement.

We look forward to seeing you all at farming system events throughout 2022 and wish you all the best for a productive and profitable season.

To contact us at the Minnipa Agricultural Centre, please call 8680 6200.

MAC Staff and Roles 2021

Amanda Cook	MAC Research Leader (Agronomy)
John Kelsh	AgTech Extension Officer/ Farm Manager 2022
Wade Shepperd	Acting Farm Manager 2021
Fiona Tomney	Research Officer (Pastures) / Minnipa Node Co-ordinator for SA Dought Hub
Jessica Gunn	Research Officer (Livestock)
Nicole Baty	Project Management Support Officer (Agronomy)
Kym Zeppel	Senior Agricultural Officer (NVT)
Ian Richter	Senior Agricultural Officer (Agronomy)
Craig Standley	Agricultural Officer (Agronomy)
Zakirra Simpson	Agricultural Officer (MAC Farm)
Leala Hoffmann	Administration Officer
Dr Rhiannon Schilling	Program Leader of Agronomy
Dr Nigel Wilhelm	Leader (Sustainable Farming Systems)
Brian Dzoma	Research Officer (Calcareous Soils)
Katrina Brands	Casual Field Assistant
Sue Budarick	Casual Field Assistant
Marina Mudge	Casual Field Assistant
Rebbecca Tomney	Casual Field Assistant
Kysen Shepperd	Casual Field Assistant

Table 1. Research projects delivered by SARDI Minnipa Agricultural Centre in 2021.

Project name	Funder	Summary
SARDI Projects		
SA Drought Hub	Future Drought Fund	The South Australian Drought Resilience Adoption and Innovation Hub ('SA Drought Hub') aims to enhance adoption of drought resilient practices. The SA Drought Hub will develop an innovation and adoption 'infrastructure' consisting of a network of grower groups, universities, government agencies, indigenous partners, agribusinesses, RD&E partners and industry organisations. The initial focus will be to co-design and deliver demand driven activities across regional nodes of pastoral, low, medium and high rainfall mixed farming to demonstrate and increase adoption of drought resilience practices, implement social resilient and wellbeing strategies and leverage future investments for drought innovation and adoption initiatives. The SA Drought Hub will increase preparedness and transition mixed farming towards a future climate with less rainfall. The SA Drought Hub will link to all industry sectors to provide broad resilience and innovation support across the state. End: June 2024
AgTech	PIRSA/SARDI	The AgTech Program aims to improve on-farm productivity through promotion and awareness raising of readily available AgTech. In 2021 the AgTech demonstrations were enhanced with the addition of AgTech start-up hubs, giving AgTech companies an opportunity to have a presence at MAC, and an AgTech testbed service to enable the validation and development of solutions not yet ready to go to market. All these elements work hand-in-hand with the AgTech Growth Fund to help grow and promote our AgTech industry and new innovations in local agricultural systems.
Soil Microbial Indicators	High Performance Soils CRC project	The overall purpose of this project is evaluating a broad suite of microbial indicator tests as used both in Australia and Internationally (e.g., USDA) for their usefulness in i) informing on-farm decision making to overcome a constraint/issue, ii) tracking changes to soil health over time and/or iii) demonstrating stewardship to the public or other stakeholders. From this the project intends to raise awareness and facilitate commercialisation of priority indicators to increase adoption and use of these indicators for improving soil biological performance and agricultural productivity. End: Sept 2024
Improving management of Group A resistant barley grass in current farming systems	SAGIT S/UA121	This research project will: Assess the impact of new herbicide and management options in both cereals and break crops for improving barley grass control. Assess current barley grass genotypes on upper Eyre Peninsula for the length of seed dormancy (2 years or greater) and germination patterns. Monitor 5 farmer paddocks per season where barley grass escapes or suspected resistance is occurring to identify environmental factors and management strategies which affect the efficacy of current herbicides. End: June 2024

Eyre Peninsula Farming Systems Summary	SAGIT S/UA121	This project will support the printing of the Eyre Peninsula Farming Systems Summaries 2021, 2022 and 2023, enabling continued distribution of this important summary to all growers, industry representatives, researchers and consultants on Eyre Peninsula and other regions. End: June 2024
A new paradigm for resilient and profitable dryland farming on the Eyre Peninsula using data to improve on-farm decision making (Resilient EP)	Aust Govt NLP2	A Regional Innovators group of farmers and advisers will engage researchers and link with the region's farmers to develop techniques to integrate information generated from the probe network, satellite imagery, climate and yield models. Farmers will be able to make more informed, timely decisions underpinned by innovations in agronomy and livestock management in order to optimise the region's productive potential whilst protecting soil and water resources in a changing climate. SARDI delivery of soil moisture probe measurements three times per season, full soil characterisations at soil moisture probe sites and yield prophet reports for focus paddock sites. End: 30 Nov 2023
Mixed Annual Legume Pastures	NLP 4-BA9KBX5	This project will demonstrate the capacity of mixed legume pastures to increase soil cover and reduce wind erosion whilst extending the growing season for farmers on the upper Eyre Peninsula. The aim is to grow pasture species that will extend the available feed on offer beyond that currently offered by the commonly grown medics (*Medicago* spp.) End: September 2023
More profitable crops on highly calcareous soils by improving early vigour and overcoming soil constraints.	High Performance Soils CRC project: 4.2.003. GRDC project: CSP2009-003RTX	This project will develop integrated solutions to reduce the impact of multiple constraints to cropping in highly calcareous soils. The importance of rapid soil drying, fertiliser availability and rhizoctonia to establishment and early vigour of crops will be investigated by a linked project delivered by CSIRO Ag & Food and supported by GRDC. A demonstration trial was conducted at Poochera in 2020. End: March 2023
Improving production on sandy soils in low and medium rainfall areas	GRDC CSP00203	There are opportunities to increase production on deep sands by developing cost effective techniques to diagnose and overcome the primary constraints to poor crop water-use or by reducing the impact of constraints with modified practices. Commonly recognised constraints that limit root growth and water extraction on sands include compaction (high penetration resistance), poor nutrient supply and low levels of biological cycling and poor crop establishment. The project has set up trials at Murlong and Brooker to investigate both low cost modified agronomy (e.g. use of wetters) and high cost interventions (e.g. spading incorporation of OM). End: March 2023
Improving the early management of dry sown cereal crops	SAGIT S419	This research project will assess the impact of management on seed germination and establishment on three different soil types in field trials and pot experiments which are kept very low in moisture; a red loam, a grey calcareous soil and a sand for: impact of fertiliser type [P and N] and fertiliser placement, impact of herbicides, impact of seed dressings. End: June 2022
Boosting profit and reducing risk of mixed farms in low and medium rainfall areas with newly discovered legume pastures enabled by innovative management methods	Rural R&D for Profit RnD4Profit-16-03-010	Dryland Legume Pasture Systems (DLPS) Develop recently discovered pasture legumes together with innovative management techniques that benefit animal and crop production and farm logistics, and promote their adoption on mixed farms over one million hectares in the low and medium rainfall areas of WA, SA, Victoria and southern NSW. At MAC, a large scale grazing trial and several small plot species evaluation trials will be conducted. End: June 2022
Updated nutrient response curves in the northern and southern regions	GRDC UQ00082	This project is developing critical levels for commercial soil tests of N, P, K and S for the major break crops. Three trial sites have been conducted on the EP. One was at Minnipa to calibrate Colwell P for canola on a red sandy loam. Another was at Mt Hope on a gravelly sand over limestone and calibrated the deep mineral N test for canola. The third site on a brown loam was at Yeelanna and also calibrated the deep mineral N test for canola. End: June 2022

Project Delivery for Air EP		
National Variety Trials	GRDC	Yield performance of cereal & break crop varieties at various locations across upper EP. End: Ongoing
Crop Improvement Trials	Various	Various trials including; Ryegrass trials - University of Adelaide (B Fleet and G Gill). Heat Tolerant Barley - University of Adelaide (A Pham). SARDI Nodulation (L Farquharson) GM Canola AGT - Cereal Trials
Soilborne Pathogens of Winter Cereals: Extension of Identification and Management Strategies	GRDC FLR1912-003RTX	Demonstration of Rhizoctonia management strategies at Buckleboo (vetch, wheat & barley +/-seed dressed). SARDI soil sampling. End: June 2022 for SARDI
Developing knowledge and tools to better manage herbicide residues in soil	Soils CRC 4.2.001	Development of tools to enable in-field assessment of risk of herbicide carry-over to the crop. A replicated field trial at MAC N7 and in season soil sampling of five growers paddocks to monitor the breakdown of clopyralid in EP farming systems. End: June 2022
Demonstration sites - Dryland Legume Pasture Systems (DLPS)	MSF 9175959	Delivery of upper EP demonstration sites for DLPS project, local awareness raising activities, host a technical pastures workshop on EP, entry and exit surveys, publish 3 x local awareness articles in local media, case studies produced on demo sites. End: March 2022
Demonstrating and validating the implementation of integrated weed management strategies to control barley grass in the low rainfall zone farming systems	GRDC 9176981	Demonstrating and validating the implementation of integrated weed management strategies to control barley grass in the low rainfall zone farming systems. Research into the ecology and control tactics of barley grass has occurred and now this needs to be transferred into the development and testing of localised IWM strategies. This investment will test localised IWM strategies against barley grass utilising large plot replicated demonstration sites and delivered within key areas of the low rainfall zone. End: March 2022
Complete project delivery		
Adapting cropping systems through improving crop competitiveness	NLP 4-BA9KBX5	The project will demonstrate the benefits of improving crop competitiveness with weeds by increasing the distribution of seed per m2 using innovative farmer equipment. Two demonstration sites will be monitored to measure ground cover, water use, erosion risk and weed numbers. The sites will be a focus for farmer discussion groups to discuss ways of incorporating the practices into their farming systems. AIR EP will promote the outcomes of the project to the broader farming community. End: September 2021
Perennial pasture systems for the upper Eyre Peninsula and other dryland farming areas	NLP 4-BA96C6H	This project will demonstrate perennial pastures as an option for improving the productivity of low productive cropping land on the upper Eyre Peninsula. The aim will be to turn this land into productive livestock pasture, with only minimal inputs of fertiliser, and without the need for herbicide and tillage. Two demonstration sites will be established; one on a grey calcareous soil and the other on a red sandy loam/typical Mallee soil. A mixture of species including grasses and legumes will be sown based on their suitability for local soil and rainfall conditions. End: September 2021
Using soil and plant testing data to better inform nutrient management and optimise fertiliser investments for grain growers	GRDC 9176604	Work with 5 EP growers x 6 paddocks = 30 paddocks on EP. Soil testing of 2 sites per paddock, with fertiliser test strips in 3/6 paddocks sampled on their property. In-season tissue testing (GS30) in the paddocks where test fertiliser strips are located and biomass cut. Field day/workshop to be held at one of the test strip sites in-season. Discussion of soil testing, nutrition and determining fertiliser rates. At the end of the season need to obtain the yield map data from the growers. End: June 2021

Table 2. Minnipa Agricultural Centre events in 2021.

Event	Topic	Attendance
2021 EP SARDI Harvest Report Farmer meetings Wirrulla, Ceduna, Elliston, Warramboo, Rudall, Cowell, Buckleboo, Minnipa 9-12 March	Presenters (in person): Amanda Cook - Barley Grass Resistance, GRDC Low rainfall Barley grass Trial, NLP Crop competition, SAGIT Dry sowing, Herbicide Residues. Brian Dzoma - Calcareous soils Nigel Wilhelm/Amanda Cook - Sandy soils, NPKS Fiona Tomney - DLPS Legume Species Adaptation Trial, DLPS Spineless burr medic trial John Kelsh - AgTech Morgan McCallum - DLPS Grazing Trial, DLPS Demo sites SA Drought Hub - Rhiannon Schilling	133 people attended (114 growers, 12 advisors, 4 research staff, 3 others)
Eyre Peninsula Farming Systems Summary March 2021	Compiling and printing 1100 copies of the annual Eyre Peninsula Farming Systems Summary for distribution to all EP growers, industry representatives, researchers and consultants on Eyre Peninsula and other regions.	SARDI staff
Calcareous Soils site visit Minnipa 5 March	GRDC Stephen Loss, Low Rainfall RD&E Committee, AIR EP representatives visited the Calcareous soils site at MAC. Trial information presented by Nigel Wilhelm, Brian Dzoma and Brett Masters. Fiona Tomney presented at the DLPS and Mixed Legume Pastures trials.	MAC SARDI staff, Low Rainfall RD&E Committee
Minister of Agriculture David Basham and Sam Telfer Minnipa 30 June	Presentation of MAC farm, current research program and MAC Farm Tour - Amanda Cook, John Kelsh and Wade Shepperd.	MAC SARDI staff
DLPS Team Visit 4-5 August	Ross Ballard and David Peck visited MAC for an update on trials. The Wirrulla and Mount Cooper demonstration sites were also visited.	3 staff and grower demonstration host.
SAGIT Board Tour 9 September	The SAGIT Board visited project trial sites and MAC. This was a valuable exercise to gain insight into our local farming systems, talk to growers and experience first-hand some of the issues and opportunities for the region. Current research projects at MAC were presented by Amanda Cook, Fiona Tomney, John Kelsh and Brian Dzoma.	3 SAGIT Board members and 1 Extension officer, 12 SARDI staff
MAC Field Day Minnipa Agricultural Centre 15 September	Herbicide resistance in barley grass populations from the low rainfall zones - Ben Fleet (on-line) Pre-sowing testing for herbicide residues in soil - Mick Rose (on-line) More profitable crops on highly calcareous soils by improving early vigour and overcoming soil constraints – Brian Dzoma Improving crop productivity on sands - what is the latest? - Brett Masters Canola system demonstration - Amanda Cook and Natasha O'Brien Resilient EP Soil moisture probes, soil characterisations and focus paddocks - Amanda Cook and Jake Giles Improving management of Group A resistant barley grass in current farming systems - Amanda Cook NVT Variety Trials - Rhiannon Schilling, Kym Zeppel and plant breeders. SA Drought Hub - Rhiannon Schilling AgTech - John Kelsh Melatonin livestock trial - Tom Flinn (on-line) Improving the early management of dry sown cereal crops - Amanda Cook Utilising novel genetic diversity to increase barley yields nationally - Anh Pham Mixed Legume Pastures for the Upper Eyre Peninsula and Other Dryland Farming Systems - Fiona Tomney Dryland Legume Pasture Systems: Overview and grazing trial summary - Ross Ballard	143 growers, plant breeders and industry representatives

	NVT Pulses and Canola - Amy Keeley and plant breeders Vetch Update - Stuart Nagel Demonstrating and validating the implementation of integrated weed management strategies to control barley grass in low rainfall zone farming systems - Amanda Cook NLP2 - Demonstrating adaptive cropping systems to improve crop competition - Amanda Cook, Bruce Heddle and Andrew Polkinghorne The effect of combinations of crop row spacing, seedbed utilisation and pre-emergence herbicides on ryegrass management in wheat - Ben Fleet (article only)	
Sticky Beak Days - Upper Eyre Peninsula 8 September to 15 October	A series of 15 grower crop walks organised by local Agriculture Bureau Groups across the Eyre Peninsula.	Over 300 people: mostly growers
Resilient EP RIG Meeting Port Lincoln 18 March Minnipa 20 September	Presentation by SARDI Amanda Cook and John Kelsh RIG Meeting attended on 2021 and soil characterisation information presented. On-line monthly research meetings.	AIR EP, Regional Innovators Group (RIG), SARDI, EPAG, CSIRO.
SA Drought Hub Meetings Wudinna 26 August On-line 25 November	Planning meetings for SA Drought Hub.	SARDI staff Amanda Cook, Rhiannon Schilling, Fiona Tomney, AIR EP
AIR EP Resilient EP/ SA Drought Hub Climate change workshop Wudinna 13 December	Presentation by SARDI, Peter Hayman.	SARDI staff Amanda Cook, Rhiannon Schilling, Fiona Tomney, Nigel Wilhelm, Brian Dzoma (on-line)

DATES TO REMEMBER

Upper Eyre Peninsula Farmer Meetings 28 February - 4 March 2022

MAC Annual Field Day: Wednesday 7 September 2022

Amanda Cook presenting at the SARDI Farmer Meeting, Kimba 2021

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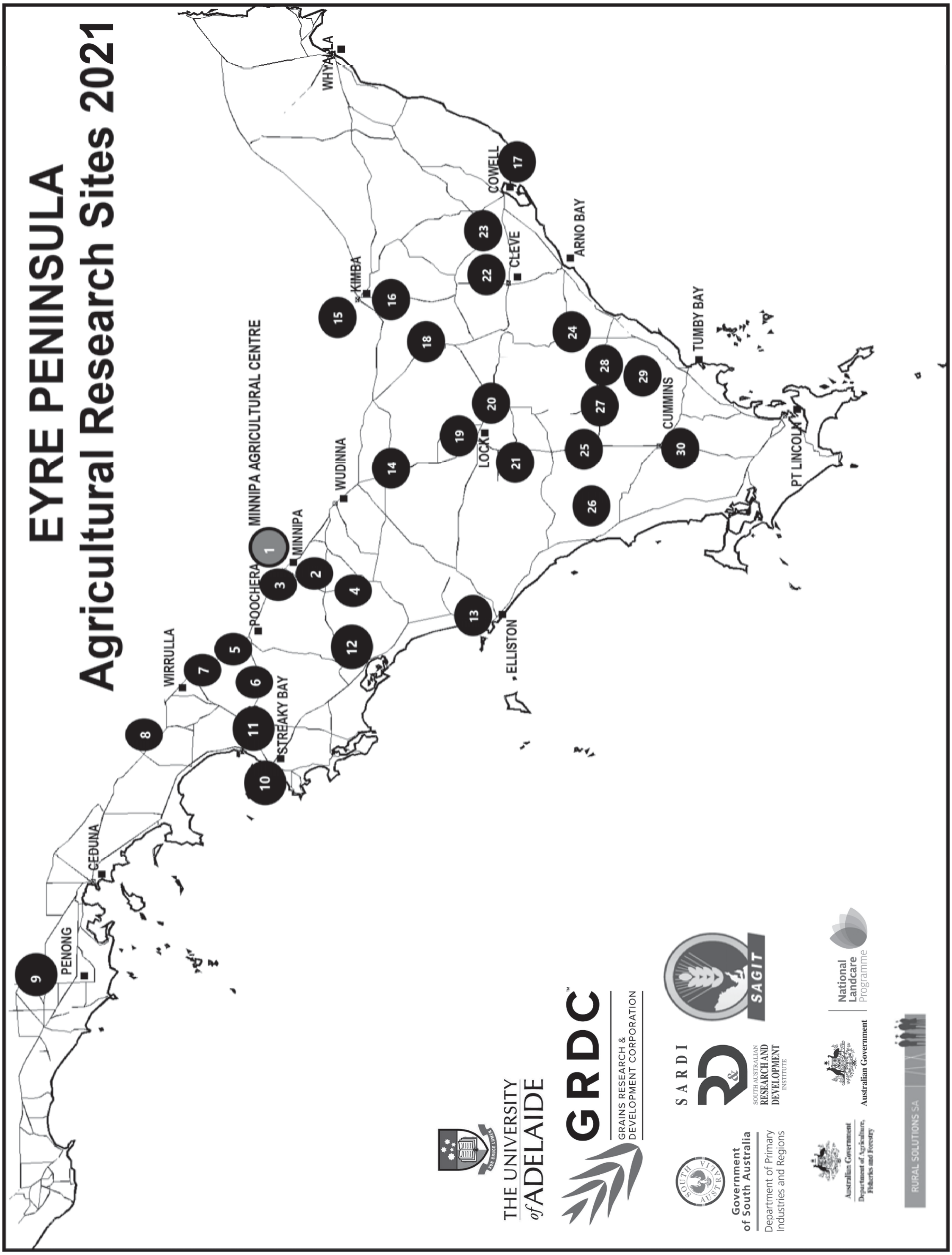
EYRE PENINSULA
Agricultural Research Sites 2021
MINNIPA AGRICULTURAL CENTRE
WHYALLA
COWELL
ARNO BAY
CLEVE
KIMBA
TUMBY BAY
CUMMINS
PT LINCOLN
LOCK
WUDINNA
MINNIPA
POOCHERA
WIRRULLA
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Eyre Peninsula agricultural research sites 2021 map references.

Map reference	Location	Trials	Host farm / business
1	Minnipa	NVT wheat and early wheat, barley, peas and canola. NVT Field pea & Canola - TT, IMI. Blackspot peas. Time of sowing beans and lentils. Low rainfall zone pulses. Lentil herbicides. Vetch breeding. Intergrain wheat and barley. AGT wheat. Large scale annual pasture legume grazing trial. Annual pasture legume species evaluation. Nitrogen fixation annual pasture legumes. Mixed annual legume pastures. Barley grass management strategies. Herbicide residues. Soil Characterisation. Heat tolerant barley. Saline tolerant varieties. GM Canola. Herbicide resistance in barley grass. AGT seeding depth and herbicide. Dry sowing red loam. Calcareous soils. AgTech demonstrations.	SARDI Minnipa Agricultural Centre
2	Minnipa	Ryegrass management trials, soil characterisation, crop competition demonstration.	Bruce Heddle
2	Minnipa	Herbicide residues, perennials.	Jerel Fromm
2	Minnipa	Sandy soils.	Nigel Oswald
3	Minnipa	Nodulation in pulses.	Matthew Cook
4	Mt Damper	Soil characterisation.	AJ (Ashley) Michael
5	Poochera	Herbicide residue.	Paul Carey
5	Poochera	Calcareous soils.	Shard Gosling
6	Chandada	Soil characterisation.	Shaun Carey
7	Cungena	Dry sowing (grey calcareous).	Myles Tomney
8	Nunjikompita	NVT wheat and oats.	Craig Rule
9	Penong	NVT wheat, SARDI wheat and barley trial.	Cade Drummond
10	Streaky Bay	Dry sowing (grey calcareous).	Luke Kelsh
11	Piednippie	NVT wheat & barley.	Ian Montgomerie
11	Piednippie	DLPS demonstration.	Dion Trezona
12	Port Kenny	Calcareous soils.	Simon Guerin
12	Calca	Herbicide resistance in barley grass.	Keiran Kelsh
12	Calca	Herbicide residue.	Craig Kelsh
13	Elliston	NVT barley, cereal pathology.	Nigel & Debbie May
14	Warramboo	NVT wheat.	Murphy Family
14	Warramboo	Perennials.	Kane & Veronica Sampson
15	Buckleboo	Soil characterisation.	Andrew Baldock
15	Buckleboo	Sandy soils.	Karinya Ag
16	Kimba	Pulse end-use in vetch & lentil, lentil variety.	Tristan Baldock
16	Kimba	NVT wheat.	Trevor Cliff
16	Kimba	AIR EP soilbourne pathogen.	Tim Larwood
16	Kimba	Herbicide residue.	Dion Harris
16	Solomon	Soil characterisation.	Shannon Mayfield
17	Cowell	NVT wheat. Soil characterisation.	Kaden family

Map reference	Location	Trials	Host farm business
18	Darke Peak	NVT barley.	Paul Dolling
19	Lock	Soil characterisation. Crop competition demonstration, PBA lentil, field pea.	Tim and Andrew Polkinghorne
19	Lock	DLPS demonstration.	Kerran Glover
19	Lock	NVT canola - TT, IMI & RR.	Leon & Karen Hurrell
20	Goldmine Hill	Soil characterisation.	Gus & Mel Glover
21	Murlong	Sandy soils.	Mark Siviour
22	Cleve	Soil characterisation.	Paul Bammann
23	Mangalo	Soil characterisation.	Craig James
24	Wharminda	Sandy soils.	Hunt Family
24	Wharminda	Cereal pathology.	Tim Ottens
25	Tooligie	Lentil disease management. Ryegrass management in lentil. Lentil pod shatter. Ground cover & legacies of pulses. Pulse protien in faba bean & field pea.	Bill Long
25	Karkoo	Sandy soils.	Modra Family
26	Brimpton Lake	Soil characterisation.	Luke Moroney
27	Cockaleechie	Soil characterisation.	Dan Adams
28	Brooker	Soil acidity - sowing, harvest.	Casey Carr
28	Brooker	Sandy soils.	Challinger Family
29	Stokes	Chickpea, faba bean rhizobia & nodulation.	Josh Telfer
30	Cummins	Sandy soils.	Mickan Family

SAGIT visit to MAC, Sept 2021. L-R Amanda Cook, Andy Barr, Malcolm Buckby and Jenny Davidson.

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Eyre Peninsula seasonal summary 2021

Brett Masters
SARDI, Pt Lincoln

Key messages

- **Crop yields in 2021 varied depending on early rainfall and soil type and were generally better than expected given little spring rainfall, with average to slightly above the long-term average yields in most districts.**
- **Above average winter rainfall and forecast spring rains saw a large amount of in-crop nitrogen applied during winter.**
- **Rainfall at harvest hampered harvest efforts and shot grain resulted in quality downgrades on much of the wheat from western, central and some eastern Eyre districts.**
- **Good yields and prices helped to offset the quality downgrades.**
- **Only minor pest and disease issues were reported during the season with routine insecticide applications providing adequate control.**
- **Above average October and November rainfall resulted in regrowth of crops and pastures which, whilst improving paddock surface cover, caused some issues at harvest.**

Summer 2020/21

Stubbles and summer weeds provided moderate surface cover over summer, and most farmers either supplementary fed stock in paddocks or removed them to containment feeding areas to protect vulnerable soils from wind erosion. Thunderstorms in late January/early February 2021 brought above average rainfall to Western and Lower Eyre districts but little to Eastern Eyre Peninsula. As a result, soil moisture at the end of summer varied greatly depending on where rain fell.

Summer weeds grew rapidly in districts where rain fell and required multiple herbicide applications to control successive germinations. Good soil moisture following these rains enabled deep ripping and delving work to overcome soil constraints to be undertaken on large areas of sandy soils in western and central Eyre. Whilst summer rainfall increased snail activity during this period, several years of good control meant numbers weren't high, and growers only baited a few paddocks at seeding to protect vulnerable crops.

Depending on opening rainfall, early indicators suggested that the crop area for 2021 would be similar to normal, with only a small decrease in the area sown to peas due to frost damage in recent seasons, and a corresponding increase in the area of cereals or lentils depending on the reliability of the district. Livestock producers also planned to sow an extra paddock or two of vetch or barley for early feed given low soil moisture and poor surface cover on pasture paddocks at the end of summer.

Autumn

Thunderstorms from tropical weather systems delivered above average March rainfall to the northern parts of upper Eyre Peninsula, but districts further south remained dry during this period. April was hot and very dry. Strong winds experienced across the region on April 13 resulted in significant amounts of raised dust on eastern Eyre paddocks which continued to have low surface cover due to poor crop establishment in 2020 and paddocks in western and central Eyre districts which had been ripped or delved.

Some farmers around Cummins burnt stubble residues in late April and early May to control ryegrass and manage stubble loads prior to seeding. Whilst light showers brought some rain to coastal districts on the western side of Eyre Peninsula during May these did not extend far inland, with well below average rainfall recorded in the eastern half of the region for the month. With dry conditions delaying seeding landholders continued soil management activities (soil modification operations and spreading lime/gypsum on paddocks which required them) well into May.

Although some paddocks were sown for feed during April, continued dry conditions saw many growers stagger seeding waiting for good opening rains, particularly those on more erodible soils in Western and Eastern Eyre districts. Although a large opening rain was not received regular small rainfall events (around 10 mm each), combined with good subsoil moisture, gave western and lower Eyre growers confidence to begin seeding in late May, with most finished by the middle of June. However, most of eastern Eyre Peninsula missed out on these showers, with farmers waiting until further rainfall was received in mid to late June to sow more vulnerable non-wetting sands. Despite these delays most farmers sowed their whole cropping program with only small changes to crop areas, giving consideration to drier autumn conditions and market forces. Increased demand and prices for canola saw a small increase in the area sown (perhaps 5 to 10%), with a corresponding reduction in the area of frost susceptible pulse crops.

Very strong winds on May 24 continued to cause drift on paddocks with poor surface cover, or those that were recently ripped or sown. Deep burial of seeds from drift sand and damage to newly emerged crops required small areas to be resown. Above average rainfall and mild temperatures in June saw most of these areas recover without further intervention.

Isolated pockets of increased snail and mice activity were reported during autumn, but strategic baiting in vulnerable paddocks provided effective control. Summer weed control effectively removed the "green bridge", however most farmers treated at least a portion of their seed with insecticide to protect early crops against Russian wheat aphid.

The region had good supplies of hay at the end of autumn with livestock producers only sowing a paddock or two for hay to replenish on-farm supplies. Early germination of pastures was excellent. However, dry autumn conditions checked growth with many producers needing to continue supplementary feeding throughout June to protect vulnerable soils from erosion and give pasture paddocks time to accumulate biomass. Livestock remained in excellent condition with reports of good lambing percentages despite the late opening rains. Continued dry conditions and low water levels in dams required livestock producers in the Cleve Hills to continue carting water well into winter.

Winter

Generally mild temperatures and warm soils resulted in rapid germination of crops and pastures. However, crop establishment was patchy, particularly on dry sown paddocks where crop growth varied greatly within paddocks. Whilst crops remained generally healthy, dry conditions in autumn put crop maturity about a fortnight behind normal and by the end of June only the small areas of dry sown cereals were tillering, with those sown following May rains only at the 2 to 4 leaf stage.

Good pre-emergent herbicide efficacy and dry soils prior to seeding resulted in low grass weed numbers in crop. However limited opportunities for the use of knockdown herbicides prior to seeding resulted in high broadleaf weed numbers, with many farmers applying in-crop herbicides in late June.

Temperatures cooled significantly in late June, slowing crop and pasture growth. Above average rainfall resulted in good soil moisture, and some minor waterlogging was observed on paddocks south of Edillilie toward the end of June. Despite strong winds on June 24 good crop and pasture growth provided adequate surface cover for erosion protection in most districts and there was not the same amount of raised dust as observed during windy days in April and May.

Rainfall for July and August was average to above average. Good soil moisture and warm temperatures saw good growth during this period. Whilst having generally less biomass than normal, crops remained healthy with good yield potential and even later-sown paddocks on non-wetting sands near Darke Peak, Kielpa, Arno Bay and Wharminda covered well. With forecasts of good spring rainfall large amounts of additional nitrogen were applied to maintain crop yield potential. However, it was reported that issues with supply chains made nitrogen fertiliser increasingly hard to source toward the end of winter.

Although there were reports of armyworm and cutworm damaging cereals this was not at critical crop growth stages and numbers of other insect pests were below control thresholds during this period. Isolated pockets of septoria, yellow leaf spot and powdery mildew were reported in cereals, but routine fungicide applications provided effective control. A large amount of fungicide was applied to protect pulse crops during warm humid conditions in August. Whilst some fungicide supply issues were reported at this time, dry conditions in September reduced the disease risk and need for additional sprays.

Vetch and medic pastures, as well as cereals sown for feed, responded well to winter rainfall enabling producers to reduce or stop supplementary feeding livestock. Good June rainfall also filled dams in the Cleve Hills and allowed livestock producers in this district to cease carting water. To help preserve paddock biomass most growers delayed spraying out grass weeds in pasture paddocks, instead spray-topping them in spring to manage grass weed seed set. Lambing percentages were good, probably resulting from the supplementary feeding of pregnant ewes to maintain condition during summer and autumn.

Spring

Little rain fell in September, with rainfall totals well below average across the region, and dry conditions and warm days resulted in rapid crop maturity during this period. Although average to above average rainfall was recorded in October, this rain all came during storm events in the last week of the month. Whilst this extended ripening helped fill grain in the later districts of Lower Eyre and the Cleve Hills, it was too late to benefit crops in Western and Eastern Eyre districts causing harvest delays with areas of uneven ripening and summer weed growth in crops.

Several frosts in September and early October damaged crops during critical growth stages in the Lock, Murdinga and Tooligie districts and resulted in significant crop loss, with some of the worst affected areas cut for hay. There was minor frost damage in other central and Lower Eyre districts, with some districts not often associated with frost including Ungarra and Cummins reporting frost events.

Dry conditions and hot north winds in mid-October caused significant moisture stress on heavier soils near Wirrulla, Buckleboo and Cowell. Despite these conditions, crops on other soil types remained healthy and maintained average to above average yield potential. Severe storms battered the region on October 28 generating strong winds and hail and causing significant crop damage in some districts. The worst-hit areas, from Mt Hill to east of Wharminda, suffered 50% crop loss whilst further east near Arno Bay, estimates of crop losses were between 5 and 15%. Minor damage was also reported near Mt Hope, Cummins, Tumby Bay and Poochera.

To replenish on-farm supplies depleted by extended supplementary feeding of livestock during summer and autumn some vetch and oat crops and medic pastures were cut for hay in early spring. Hay yields were less than normal due to dry conditions during peak growth periods in late winter and spring, but good curing conditions allowed most paddocks to be baled before October rains which preserved hay quality.

Grasses and summer weeds germinated rapidly following October rain, particularly caltrop, melons and heliotrope, with most growers starting to spray these whilst waiting for crops to ripen. Pastures and cereal paddocks cut for hay responded well to October rainfall, with extra growth improving paddock surface cover and providing livestock feed until stubbles became available after harvest. Low amounts of crop disease and insect pests were reported late in the season. A late flight of native budworm saw increased pest numbers in pulses and canola in October, but these were easily controlled with routine insecticide applications to avoid crop damage.

Harvest 2021/22

Windrowing of canola began in mid to late October. Some barley crops were also windrowed to facilitate even ripening and minimise head loss. Many pulse crops in Eastern and Lower Eyre districts were still flowering at the end of October with farmers applying desiccant herbicides to ensure even ripening.

Storms throughout the first half of the month brought well above average November rainfall to all districts with several districts including Ceduna, Minnipa and Wudinna recording their wettest November on record. Strong winds accompanied rainfall on November 11, but most paddocks contained adequate surface cover to protect vulnerable soils from erosion. Later sowing, mild conditions and spring rainfall delayed crop maturity and resulted in harvest beginning some 7 to 14 days later than usual. Damp, cool conditions at harvest meant growers found it difficult to get grain to dry below critical moisture levels for delivery. Whilst for most growers it meant waiting until late morning before being able to start reaping each day, some on Lower Eyre utilised grain driers to allow them to continue reaping. Despite these delays most farmers finished harvest before Christmas.

Crop yields varied greatly depending on soil type and rainfall distribution but were better than expected given the dry spring with most districts achieving average to above long-term average yields. Crops on the heavier soils around Chandada and Mudamuckla struggled and whilst some very poor yields <0.5 t/ha were reported, these were generally restricted to the worst soils in a paddock, which in most instances only made up a small proportion of the total paddock area. Cereal crops in other western Eyre districts yielded above the long-term average (yielding 1.3 to 2.0 t/ha, with some exceptional yields of more than 2.5 t/ha reported on better soil types in districts which received early rainfall). Pulse crops unaffected by frost had good yields ranging from 1.0 to 2.0 t/ha for peas and 0.8 to 1.5 t/ha for lentils. Canola yields ranged from 1.2 to 1.5 t/ha on the better soil types around Mt Cooper and 1 to 1.2 t/ha in other central EP districts. Well above average canola prices made this a very profitable option despite the later than optimal seeding time.

Grain quality on early maturing crops which were harvested before November rains was generally good, with high protein and low screenings. However, harvest rainfall caused significant grain quality issues, and most of the wheat delivered in Western, central and parts of Eastern Eyre was downgraded due to shot grain. Fortunately, good yields and good prices for feed wheat still made 2021 a reasonably profitable season for most growers.

Very dry spring conditions resulted in very poor yields (<1.0 t/ha) on the heavier textured soils near Kimba, Buckleboo and north of Cowell. In other Eastern Eyre districts yields were better than expected given a late start and limited spring rainfall. Cereals on loamier soils from Darke Peak to Wharminda (where not hail affected) achieved 2.0 to 3.5 t/ha, with around 1.2 to 1.5 t/ha south of Cowell.

Frost impacted crops near Tooligie yielded very poorly (<0.5 t/ha), whilst in other districts where spring frosts were reported damage seemed to be restricted to only small areas within paddocks, with good yields in the remainder of the paddock. The extended ripening period saw above average canola (1.2 to 1.5 t/ha) and pulse yields (>1.0 t/ha) in the Cleve Hills.

Cereal yields on Lower Eyre were slightly above the long-term average, despite the very dry spring, with reports of 3.5 to 4.0 t/ha common on the better soils in more reliable districts. Crops on heavier soils near Tumby Bay and Butler yielded 2.0 to 2.5 t/ha. Whilst there were isolated reports of shot grain near Karkoo and Mt Hill, wheat crops in other Lower Eyre districts ripened later and avoided grain quality issues. Canola generally performed well with many farmers reporting yields of 1.8 to 2.5 t/ha and oil content above 43%. Pulse yields were variable depending on soil type and rainfall. Lentils and peas yielded well in the range 1.5 to 2.5 t/ha, but beans yields were poorer (from 1.0 to 2.0 t/ha).

Rains at harvest saw most growers applying their first summer herbicide spray before Christmas. Rains in late spring increased snail activity at harvest, which will require farmers to undertake management activities prior to sowing in 2022. High numbers of Russian wheat aphid were also reported in pastures and volunteer crops in spring, with growers hoping that summer weed control and seed treatment prior to sowing will effectively manage them.

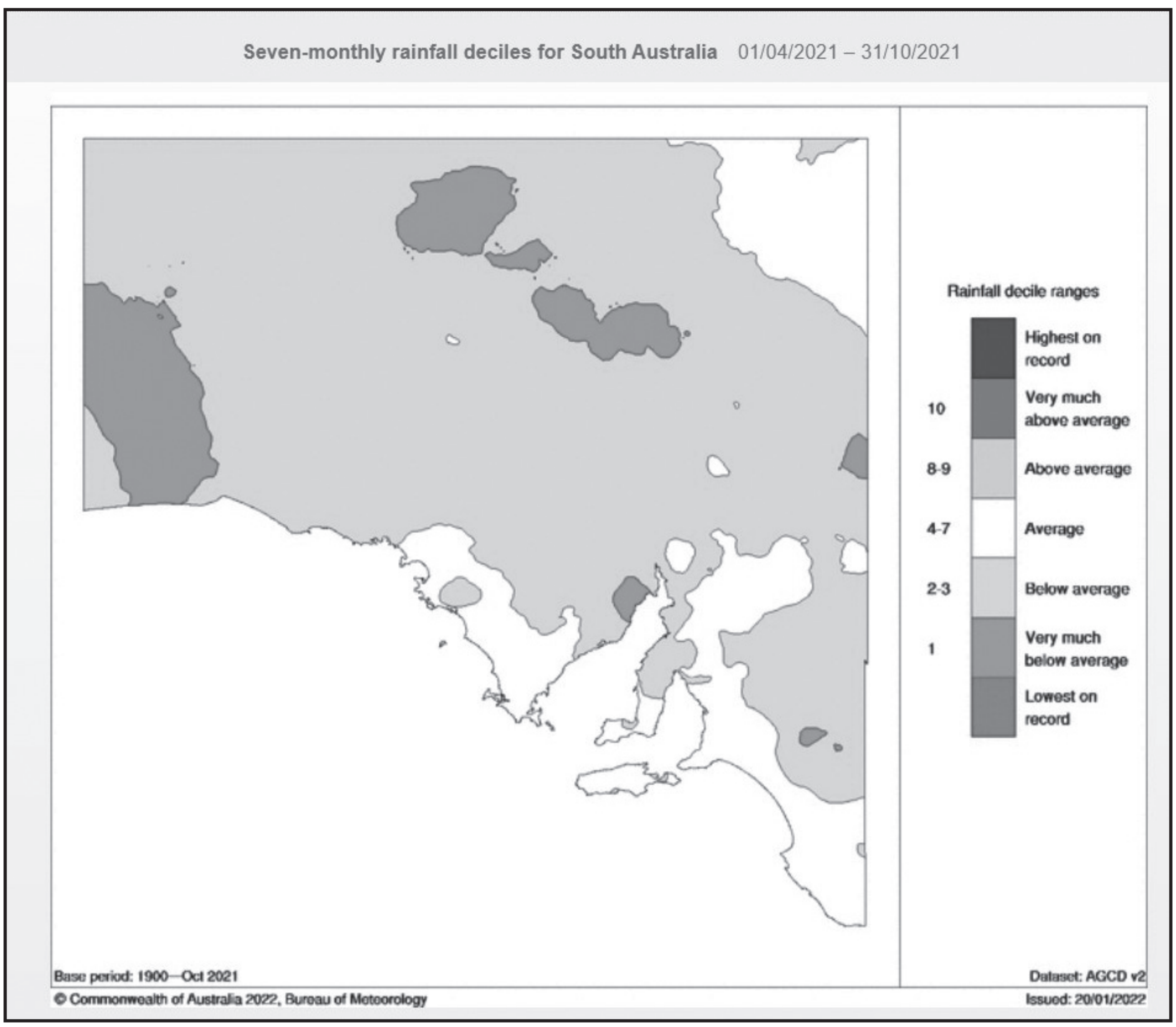

Figure 1. April to November rainfall deciles, 2021.

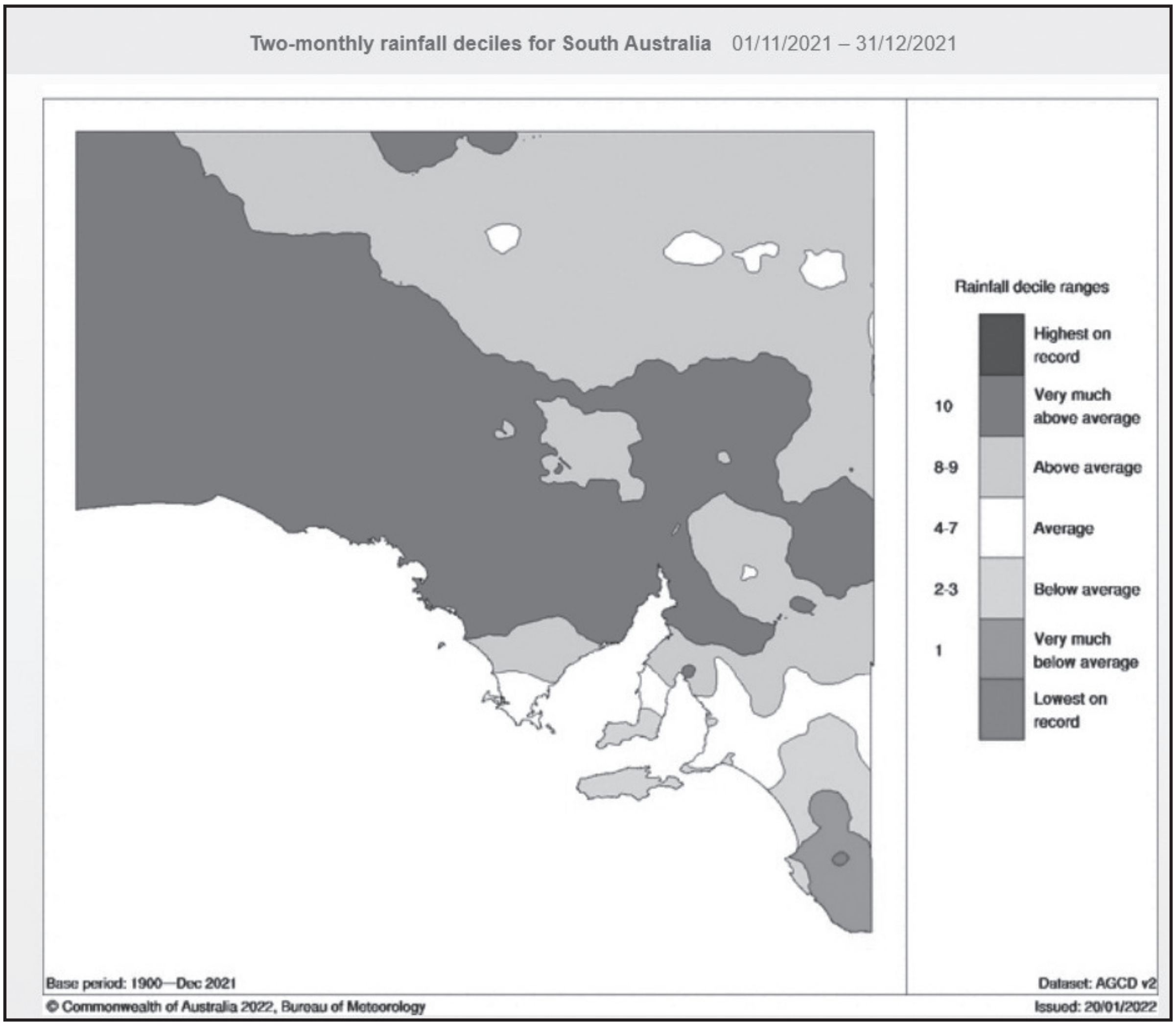

Figure 2. November to December rainfall deciles, 2021.

Acknowledgements

The author wishes to acknowledge that much of the information contained within this summary has been compiled from PIRSA's 2021 Crop and Pasture Reports.

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MAC Farm Report 2021

John Kelsh
Farm Manager, SARDI Minnipa Agricultural Centre

Location
Minnipa Agricultural Centre
Rainfall
Av. Annual: 325 mm
Av. GSR: 241 mm
2021 Total: 406 mm
2021 GSR: 248 mm

Key outcomes

- **Good cereal yields were achieved but with quality issues.**
- **Break crops also performed well.**

Background

The performance of the Minnipa Agricultural Centre (MAC) farm is an essential component in the delivery and extension of relevant research & development to Eyre Peninsula farming systems. The aim of the MAC Farm team is to showcase how the effective use of research findings, agronomic improvements, and new technologies can be applied on a broad scale and to exemplify best practice farming on Eyre Peninsula.

What happened?

Staffing Changes

Our previous Farm Manager, Jake Hull, moved on to greener pastures after the conclusion of seeding 2021. Thank you Jake for your efforts over the past years. Thanks also to Wade Shepperd, acting Farm Manager for the bulk of the season, until I re-joined the SARDI team at the start of 2022 as Farm Manager. I hope to continue to build the legacy and reputation of MAC as a centre for innovation and excellence in agriculture.

Weather

The season started out very promising with good winter rainfall, a predicted 'wetter than average' spring did not eventuate leaving our crops looking thirsty and exhibiting signs of stress during the latter half of September, with shorter season varieties seemingly impacted most. A late shower (15 mm) two weeks out from harvest seemed to have little effect, if anything perhaps accelerating senescence. Murphy's law proved true again in November, when in mid-harvest we received our wettest day of the year (41 mm) and a whopping 101 mm total for November.

Cropping

Seeding commenced on the 26 May after we received 10 mm the day before. Canola was sown first, followed by Field Peas, Wheat, Barley and finally Oats, with the program concluding on the 11 June. Granulock SS was sown below the seed, both fertilizer and seeding rates are in Table 2, below.

This resulted in the distribution of our arable areas into the following:

43% Wheat - 454 ha (Scepter⍦, Hammer⍦CL, Ballista⍦)

11% Barley - 116 ha (Maximus⍦ CL, Beast⍦)

7% Peas - 77 ha (PBA Butler⍦)

6% Canola - 62 ha (HyTTec Trident, Hyola Enforcer CT)

3% Oats - 38 ha (Mulgara⍦)

30% Pasture - 314 ha (regenerated medic)

Harvest was a bit of a mixed bag, with rain slowing us down more than breakdowns. Yields were above average (see Table 1 for details), and in total we ended up delivering more than 1,500 tonnes of grains and oilseeds through the silo system. All wheat was delivered as feed grade due to the reduction in grain quality brought on by the wet weather.

Livestock

Another successful year for the MAC Merino flock with nearly 400 ewes joined and 485 lambs marked. Although our scanning results were impressive it seems that there were many late-term abortions resulting in a marking percentage slightly above average. Full details in Table 1.

Shearing is on a 6 monthly schedule with 2021 hoggets producing an average fibre diameter of 19.2 micron, standard deviation of 2.96, and comfort factor of 99.42%. The ewe flock has consistently been producing more than 4.5 kg/hd GFW per shearing event (9 kg/hd/yr). Current flock numbers sit at: 322 Flock ewes, 121 hoggets, 260 lambs & 7 Rams.

Forward planning for 2022

With fertiliser prices so high and restricted availability we've had to budget very carefully, dropping rates back quite a bit. The cropping program will include Calibre wheat, Emu TruFlex Canola and a few other interesting varieties. We're also planning to re-sow some medic pastures that haven't had the best establishments in recent times. Other jobs on the radar include fencing improvements, infrastructure works and machinery and plant improvements.

Acknowledgements

MAC farm staff: Wade Shepperd and Zakirra Simpson

MAC research staff: Morgan McCallum and Jessica Gunn

MAC admin staff: Leala Hoffmann

Table 1. Minnipa Agricultural Centre historical Merino flock joining data summarised.

	Ewes joined	Lambs scanned	Lambs born	Lambs marked	Scanning (%)	Marking (%)	Survival at birth (%)	Survival at marking (%)
2011	338	426	414	410	126	121	97.2	96.2
2012	337	540	558	439	160	130	103.3	81.3
2013	350	534	531	448	153	128	99.4	83.9
2014	349	442	443	386	127	111	100.2	87.3
2015	424	555	534	437	131	103	96.2	78.7
2016	422	532	632	502	126	119	118.8	94.4
2017	366	428	458	361	117	99	107	84.3
2018	335	434	382	294	130	88	88	67.7
2019	342	486	485	434	142	127	99.8	89.3
2020	367	543	551	464	148	126	101	84
2021	398	625	512	485	157	122	82	78
Av.	366	504	500	410	138	105	99.3	84.1

**2011, 2014, 2015, 2016, 2017 all had 1 x sire failure*

Minnipa Agricultural Centre

Table 2. Cropping results summary table for the 2021 season, Minnipa Agricultural Centre.

Paddock	Rotation 17-18-19-20-21	Crop	Variety	Sown	Seed Rate (kg/ha)	Fert Rate (kg/ha)	Harvested	Yield (t/ha)	Test Weight (g)	Protein (%)	Screenings (%)	Moisture (%)
AP Highway	V-W-B-P-W	Wheat	Scepter	29 May	75	66	14 Dec	2.64	77.9	9.9	0.9	10.5
AP MAC	W-L-W-B	Barley	Beast	06 Jun	65	90	17 Nov	2.74	66.8	12.1	0.5	10.9
AP Town	B-C-W-W	Wheat	Scepter	29 May	75	70	14 Dec	2.77	77.2	9.8	1.1	11.0
North 1	W-M-W-M-W	Wheat	Ballista	03 Jun	75	70	06 Dec	2.54	77.5	10.9	1.0	11.4
North 3/9	V-W-B-W-P	Field Peas	PBA Butler	27 May	120	55	31 Oct	0.90	40.0	-	-	11.9
North 6	B-M-O/V/C-B-W	Wheat	Hammer CL	04 Jun	75	90	03 Dec	2.33	77.4	11.0	1.4	11.3
North 7	C-W-B-M-W	Wheat	Scepter	31 May	75	70	29 Nov	2.63	78.5	11.0	0.7	10.9
North 8	C-W-W-M-W	Wheat	Scepter	01 Jun	75	70	01 Dec	2.87	78.3	9.7	0.9	9.1
North 10/11	M-B-V-W-B	Barley	Maximus CL	09 Jun	65	85	09 Nov	3.44	-	-	-	-
North 12	C-W-M-B-P	Field Peas	PBA Butler	27 May	120	55	31 Oct	1.12	-	-	-	11.5
South 1	B-V/B/O-W-M-W	Wheat	Scepter	30 May	75	65	10 Dec	2.71	77.5	10.1	1.1	11.2
South 3	V-W-B-C-W	Wheat	Scepter	03 Jun	75	90	08 Dec	1.97	77.5	10.5	0.9	12.1
South 4	B-V-W-B-O	Oats Vetch	Mulgara Volga	11 Jun	70 10	85	Cut for hay					
South 5	B-M-W-B-C	Canola	Trident	26 May	2.4	75	02 Nov	1.25	65.1	23.7	0.8	7.3
South 9	W-B-M-W-B	Barley	Maximus CL	07 Jun	65	85	08 Nov	2.64	-	-	-	-

M = Medic, P = field pea, W = wheat, B = barley, O = oats, C = canola, V = vetch

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 "$P \leq 0.05$". 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	$P \leq 0.05$
LSD (P=0.05)	*0.33*

Statistical analysis indicates that there is a fertiliser treatment effect on yields. $P \leq 0.05$ 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 m^2 (square 100 m by 100 m)

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 equivalent 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)

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

Yield Approximations

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

Section Editor:
Amanda Cook
SARDI, Minnipa Agricultural Centre

Section 1

Industry

Agricultural Innovation & Research Eyre Peninsula update 2021

Bryan Smith and Naomi Scholz
Agricultural Innovation & Research Eyre Peninsula

Vision

A professional, farmer driven organisation that leads RD&E of agricultural technologies and innovations for farmers on the Eyre Peninsula.

Key activities

AIR EP was very fortunate to host, deliver and support a range of activities across Eyre Peninsula in 2021, despite facing COVID-19 challenges.

- Acid soils workshops Cummins and Cleve in February and June for the EP Landscape Board's Sustainable Agriculture program.
- Hosted GRDC Precision Ag workshops 16 February and follow up workshop 7 September at Cleve delivered by Pinion Advisory.
- AIR EP Lower EP Ag Expo held 2 March, topics included: social benchmarking survey results; grazing crops, autumn/winter feed gap; soil biology and soil amendments; cultural and chemical control of annual ryegrass; SAGIT powdery mildew and soil amelioration research; herbicide residues; intercropping and early sown pulses; SAGIT canola project update, Resilient EP project update.
- Soil CRC soil health information session at Minnipa on 3 March, guest speakers Lukas Van Zwieten and David Davenport.
- Supported the EP SARDI Harvest Report Farmer meetings 9-12 March.
- Hosted GRDC Frost workshops at Lock 16 March and Cummins 17 March.
- Participated in student field day at Cleve on 7 May, presented information on soil testing.
- The first AIR EP Strategic plan was adopted in June 2021.
- Regen Ag Forum (keynote speaker Dr Christine Jones) at Cleve 8 June for the EP Landscape Board's Sustainable Agriculture program.
- AIR EP Member Days (Mark Congreve, post-emergent herbicides) held at Ungarra and Wudinna 21 & 22 June.
- Resilient EP project discussion group sessions held via zoom and then in the focus site paddocks across EP throughout the season.
- AIR EP inaugural AGM held 23 August.
- Provided registration services for GRDC Farm Business Update in Port Lincoln on 19 August.
- GRDC Farmer Update delivered online 3 August due to COVID-19
- AIR EP Lower EP Crop Walk 2 September.
- MLA survey sessions at Cleve, Ceduna, Wangary and Tumby Bay 27-30 September.
- AIR EP/GRDC/SARDI Pulse Field Day at Tooligie 5 October.
- Supported the sticky beak days across EP in September and October (featuring Mallee seeps, Sustainable Agriculture small grants, Eastern EP soil management, rhizoctonia demo site, Resilient EP and various other local projects being hosted by AIR EP).
- AIR EP Resilient EP/SA Drought Hub Climate change workshop 13 December.

Structure

The AIR EP Board provides governance oversight and sets the strategic direction for the organisation. The Board is supported by two RD&E Committees, one with a focus on the medium rainfall zone (lower EP) and one on the low rainfall zone (upper EP). These committees focus on setting priorities for RD&E investment in the region, reviewing projects and providing input into events for farmers.

Board Members: Bryan Smith (Chair), Andrew Polkinghorne, Bill Long, Ken Webber, Greg Scholz (LR RD&E rep), John Richardson (MR RD&E rep), Greg Arthur, Mark Stanley (special skills).

Low Rainfall RD&E Committee Members: Symon Allen (Chair), Andy Bates, Rhiannon Schilling, Amanda Cook, Greg Scholz, Daniel Bergmann, Matthew Cook, Rhys Tomney, Andrew Ware, Leigh Scholz, Kevin Dart.

Medium Rainfall RD&E Committee Members: John Richardson (Chair), Daniel Adams, David Davenport, Dustin Parker, Billy Pedler, George Pedler, Jacob Giles, Denis Pedler, Lochie Siegert, Brett Masters, Daniel Puckridge.

Staff: Executive Officer - Naomi Scholz, Finance Officer - Alanna Barns, Regional Agricultural Landcare Facilitator - Amy Wright, Sustainable Agriculture Officer - Josh Telfer.

Contact us: Executive Officer Naomi Scholz 0428 540 670 eo@airep.com.au

For more information or to find out about coming events, visit our website www.airep.com.au, follow us on Twitter **@ag_eyre**, join us on Facebook **@aginnovationep**, subscribe to our newsletter and **become a member** via the AIR EP website.

Table 1. Projects in 2021.

Project title	Funder	Delivery organisation	Project summary
AIR EP hosted projects			
A new paradigm for resilient and profitable dryland farming on the Eyre Peninsula using data to improve on-farm decision making (Resilient EP) 4-CS70YDN	Aust Govt NLP2	EPAG Research SARDI CSIRO Regional Connections	A Regional Innovators group of farmers and advisers will engage researchers and link with the region's farmers to develop techniques to integrate information generated from the probe network, satellite imagery, climate and yield models. Farmers will be able to make more informed, timely decisions underpinned by innovations in agronomy and livestock management in order to optimise the region's productive potential whilst protecting soil and water resources in a changing climate.
Warm and cool season mixed cover cropping - upper & lower EP 4-60A5VY4	Aust Govt NLP2	SARDI/AIR EP	Identify and demonstrate suitable cover crops across south eastern Australia. The impacts of cover cropping on soil health, nutrient cycling, organic carbon, and soil moisture will be measured, and the optimum timing and method to terminate the cover crops will be determined.
Regional Agricultural Landcare Facilitator (RALF) services DEW-1648	Aust Govt NLP2 (EPLB)	AIR EP	Delivery of the EPLB's RALF services (see EPLB article for more detail).
Sustainable Agriculture Program DEW-1604	Aust Govt NLP2 (EPLB)	AIR EP/RSSA	Delivery of the EPLB's sustainable agriculture program (see EPLB article for more detail).
Barley grass management strategies 9176981	GRDC	SARDI	Test localised integrated weed management strategies against barley grass utilising large plot replicated demonstration sites within key areas of the low rainfall zone.
Increasing production on sandy soils in low and medium rainfall areas CSP00203	GRDC	PIRSA	Investigating the physical, chemical impediments and the biological constraints in sandy soils and crop establishment on non-wetting soils.
Delivery of DLPS Demo Sites on upper & lower EP 9175959	Rural R&D4P/ GRDC/ MLA/ AWI	SARDI/EPAG Research	Delivery of upper and lower EP demonstration sites for the Dryland Legume Pasture Systems project and local awareness raising activities.
Intern Research Officer EP120	SAGIT	EPAG Research	Annually engage a recent graduate to work as an intern/ trainee in applied grains RD&E, located on EP. In 2021, the Research Officer was Rhaquelle Meiklejohn, from Esperance, WA. In 2022, the Research Officer will be Rebekah Fatchen, Ungarra SA.

Taking canola profitability to the next level LEA120	SAGIT	EPAG Research	Determining the maximum achievable water limited yield of canola on Lower EP.
1.2.004: Surveying on farm practices	Soil CRC	AIR EP	Surveying land managers across EP to improve understanding of current practices, including farmer aspirations; motivations and their perceptions of existing and proposed R&D initiatives.
4.2.001 Herbicide residues in soil	Soil CRC	SARDI	Develop new knowledge and tools to better understand the factors regulating herbicide persistence and bioavailability, giving farmers increased confidence in crop choice, timing of sowing and herbicide management to ensure soil and crop performance is not limited by herbicide residues.
Building Drought Resilience in Agriculture-Dependent Communities through Mapping Young Farmer Information and Support Networks	FRRR	Southern Cross University/ AIR EP	This project will map young farmer and AIR EP's information and support networks, and through two interactive co-design workshops, deliver a young farmer network-strengthening action plan.
1.2.006 Knowledge-Sharing for Good Soil Stewardship	Soil CRC	AIR EP	In order to support knowledge-sharing efforts for grower-groups across four case-study regions, this project will co-develop and test a range of knowledge-sharing modes and processes, from digital strategies to field days, drawing on the skills of a cross-institutional, cross-disciplinary research team.
MSF2007-001SAX Applying current knowledge to inform grower decision making to mitigate the impact of frost, now and in the future.	GRDC	AIR EP/ EPAG Research	To extend and apply the outcomes of previous R&D investments relating to frost to build knowledge that will inform grower and advisor decisions relating to pre-season planning, in-season management, and post-frost event responses. Demo site at Tooligie Hill.
UOA2105-013RTX Legume Extension project	GRDC	AIR EP	Delivery of extension activities around 4 pulse sites on EP (Tooligie, Kimba, Yeelanna, Mt Hope).
FLR1912-003RTX Soilborne Pathogens of Winter Cereals: Extension of Identification and Management Strategies	GRDC	AIR EP/ SARDI	Demonstration of Rhizoctonia management strategies at Buckleboo (vetch, wheat & barley +/-seed dressed).
Partnerships in other projects			
4.2.003 More profitable crops on highly calcareous soils by improving early vigour and overcoming soil constraints.	Soil CRC/ GRDC	PIRSA/SARDI	Outcomes will be modified agronomic practices and improved soil conditions which increase WUE of crops and farm profitability as well as improved knowledge of the impact of high carbonate on crop performance.

Completed projects in 2021			
1.2.002: Understanding adoptability of techniques and practices for improved soil management	Soil CRC	AIR EP	"Adoptability framework" developed, a set of questions to guide thinking to maximise the value of the interventions for improving relative advantage and therefore adoptability of soil improvement innovations.
1.4.002: Building farmer innovation capability	Soil CRC	EPAG Research	Innovation strategy developed to capture ideas from farmers, advisors and researchers in different formats (meetings, events, bus tours to exchange ideas) to address farming challenges.
Southern Pulse Extension - Pulse Check Groups upper & lower EP BWD9175825	GRDC	George Pedler Ag/ Bates Ag Consulting	'Pulse Check Discussion groups' based around Wudinna, Kimba and Cummins, facilitated by Andy Bates and George Pedler, learnt about improving pulse production via a group learning approach and practical in-field learning at local demonstration sites and on bus trips.
Soil & plant testing 9176604	GRDC	SARDI	There are opportunities for farmers in the Southern region to further utilise soil test information to increase crop gross margins. Improved nutrient management through zoning by soil type is likely to be economically worthwhile. Managing two or three zones per paddock is likely to be optimum. Paddock data layers (NDVI, yield and pH maps) can be used to identify soil x production zones to improve soil sampling programs.
Eastern EP Soil Management G2021-5	EPLB	Davenport Soil Consulting	Remediation of 430 ha of eroded areas (levelling, ripping, delving), increased vegetative cover in pasture systems over 420 ha (mixed species planting, cell grazing), and monitoring of 130 ha of summer crops to improve determine impacts for the following crop on Eastern EP.
Crop Competition 4-BA9KBX5	Aust Govt NLP2	SARDI	This project demonstrated and encouraged low rainfall broad acre farmers to trial reduced row spacing seeding systems for increased crop competition with grass weeds within their current farming practice. The demonstrations of the benefits of reducing row spacing were shown to growers by establishing two demonstration sites at Minnipa and Lock in 2020 and 2021, to compare conventional sowing systems with reduced or no-row spacing sowing systems.
Perennial Pastures 4-BA96C6H	Aust Govt NLP2	SARDI	This project showed that perennial pasture species can grow in the low rainfall environment of the upper EP however establishing them in sufficient numbers to be a productive pasture option is challenging. Weed control must be implemented in the season prior to establishment, and pre-seeding, as there are limited options in mixed species perennial pastures. With rainfall predominantly in winter with cold temperatures, annual species may still provide a more productive pasture option even on poorer soils. Trial sites were located at Warramboo and Minnipa.

AIR EP
Ag Innovation & Research
Eyre Peninsula

Deep ripping 4-BA163YG	Aust Govt NLP2	Davenport Soil Consulting	Incorporating organic material and topsoil has mainly been used in sandy soils with compacted A2 horizons. This project has extended the technology to other soil types including calcareous soils that do not have a physical constraint. Gains observed in crop growth on these soils have created considerable interest and led to several landholders conducting larger paddock scale demonstrations in 2021.

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GRDC Investment Snapshot

The 2021 season on the Eyre Peninsula was one of mixed blessings and various challenges, with spring frosts causing major damage to some crops. Fortunately, high grain prices helped offset losses, and for those that managed to produce a respectable yield, profits were reasonable.

The Grains Research and Development Corporation (GRDC) continues to invest in research, development and extension on the Eyre Peninsula to ensure growers in the region can remain profitable, productive and sustainable. GRDC recognises the geographical and agroecological breadth of the region and hence the varied farming systems, constraints and opportunities that exist within it.

GRDC ensured its investments are regionally relevant through feedback and insights from local Southern Region Panel members Michael Treloar and Andrew Ware, as well as National Grower Network members and local research partners such as AIR EP and the South Australian Research and Development Institute's* (SARDI) Minnipa Ag Centre (MAC). GRDC's recent investments on the EP fall into a number of broad categories, including soil-based yield limitations, diseases, weeds and pests, through to crop nutrition, varietal testing and rotations. Trial results from many of these investments are reported in this publication.

One immediate issue which GRDC has been quick to act upon is the heavy rains in January 2022 and the ensuing **flooding** and damage to roads, farm infrastructure and soils. Extension activities such as workshops will commence in February, with more information to be provided in due course. Additionally, the challenge provided by the resultant summer weed growth will be addressed through a webinar by Independent Consultants Australia Network (ICAN).

Another soils-related investment is the collaborative research initiative focused on **calcareous soils**, which limit crop yields and grower profitability across large parts of the southern cropping region, and in particular, the EP. These soils occur across 60 per cent of the cropping area in the southern region, mainly in low rainfall zones. Calcareous soils are strongly alkaline, contain free lime (calcium carbonate) and are particularly common in subsoils on the upper EP, among other areas.

Last year was the second of the three-year investment collaboration with the Cooperative Research Centre for High Performance Soils (the Soil CRC), which builds on previous research into calcareous soils. Research partners involved in this project include the Department of Primary Industries and Regions (PIRSA), New South Wales Department of Primary Industries (DPI) and the Commonwealth Scientific and Industrial Research Organisation (CSIRO). The SA Grain Industry Trust (SAGIT) is also supporting the initiative through the Soil CRC. The research is being undertaken by SARDI MAC with trials located at MAC, Poochera and Port Kenny.

The CSIRO-led 'Increasing production on **sandy soils** in the low-medium rainfall areas of the southern region' investment continues to yield promising results for growers, particularly those on the EP. This investment includes 10 research experiments over five years and 18 validation experiments over three years, and is working to define which sandy environments and amelioration treatments are more likely to provide strong return on investment, and where environmental risks or short-lived effects are likely to limit potential benefits. One significant finding from this research is that physical disturbance techniques (deep ripping or spading) closed the yield gap at half of the sandy soils at the sites analysed. Soil disturbance, near row sowing and wetting agents were effective at overcoming water repellency and improving crop establishment at a trial site at Murlong.

The calcareous soils and sandy soils projects are currently planning extension activities, including regionally relevant masterclasses, to ensure these investments have maximum local impact.

'Practical tactics to **improve ground cover and ensure soil preservation** following successive low rainfall seasons' is another GRDC soils-related investment. This investment has two case study sites on the EP, one at Wharminda and the other at Cleve. The aim of this investment is to develop locally-relevant information that will help landholders make informed decisions to manage and re-establish ground cover and reduce soil loss following drought and improve soil preservation. Results from these sites, including soil cover monitoring, will be available later this year.

GRDC's 'Development and extension to close the economic yield gap and maximise farming systems benefits from grain legume production in South Australia' investment, led by the University of Adelaide and SARDI, had trials at Tooligie, Kimba, Mount Hope and Cummins in 2021 which will repeat in 2022. This investment is operating on a hub and spoke model of delivery for grower-driven **grain legume validation and demonstration trials** across South Australian sub-regions to address these gaps. Trials undertaken as part of the investment will investigate the economic impacts of grain legumes on farm profitability; disease management and integrated weed management strategies in grain legumes; and flexible responses to emerging grower issues, primarily arising from GRDC National Grower Networks.

The **Dryland Legume Pasture Systems** (DLPS) project, which has attracted considerable interest from growers and advisers through the trial work conducted at MAC, will finish in June this year. This research has evaluated a diverse range of annual pasture legumes on mixed farms in the low to medium rainfall zone. The overall aim of the project has been to provide a critical assessment of the regional performance of existing and new pasture lines; determine if pasture legumes can be established more efficiently; and quantify the benefits provided by pasture legumes to crops and livestock. Local workshops to extend the key findings of this research are planned for March.

Frost is an ever-present challenge for growers across Australia, and as 2021 showed, the EP is no different. GRDC is working to ensure EP growers have access to the most relevant information when it comes to mitigating the risk of frost, and is currently initiating frost trial sites, including monitoring sites, across the central EP. More information on this investment will be provided via GRDC's communication channels prior to the growing season.

On the crop protection front, important initiatives such as the **National Canola Pathology Program** and the **Australian Fungicide Resistance Extension Network** continue to provide growers with up-to-date and important advice regarding the management of diseases and how we can prolong the life of cost-effective chemistries.

Barley grass is a weed that EP growers are all too familiar with. GRDC's 'Demonstrating and validating the implementation of integrated weed management strategies to control barley grass in low-rainfall zone farming systems' investment, led by the University of Adelaide, has featured trials at MAC. A key output from this investment will be a booklet of case studies summarising the outcomes relevant to barley grass management in the southern region LRZ, which will be available later this year.

GRDC always aims to make information easily accessible and locally relevant to growers and a great example of that is the regional ***National Variety Trials (NVT) Harvest Reports***. These reports provide the latest independent varietal information on yield, quality, and disease ratings from the NVT program. Released in March every year, the EP Harvest Report provides information to support decisions on variety selection for the region. The publication also includes a summary of the long-term yield performance of varieties of crop species suitable for production on EP, together with their quality and disease responses. Keep an eye out for this report when it is released in March on the NVT Online website, https://nvt.grdc.com.au/harvest-reports/south.

Growers can get further information through the state-based sowing guides, published every year prior to harvest. The **SA Sowing Guide**, available at grdc.com.au/NVT-south-australian-crop-sowing-guide, is published by GRDC and compiled by SARDI in partnership with SAGIT.

Growers can receive the most recent news, information and event details by ensuring their subscription details are up-to-date on the GRDC website at grdc.com.au/grdc-subscriptions.

Should you require any additional information about any of the aforementioned investments, or should you wish to raise and discuss ideas with GRDC, please contact the Southern Office on southern@grdc.com.au or 08 9230 4600.

**SARDI is the research division of the Department of Primary Industries and Regions*

GRDC™ GRAINS RESEARCH & DEVELOPMENT CORPORATION

Update from the Eyre Peninsula Landscape Board

The Eyre Peninsula Landscape Board works with community, industry and government agencies to ensure a sustainable approach to the management, protection and restoration of our soil, water and native plants and animals. We support local communities and land managers to be directly responsible for managing their region's natural resources.

In 2021, our Eyre Peninsula Regional Landscape plan was finalised. The plan sets the vision and priorities for the region to achieve sustainable landscape management, with a focus on the priority areas of water, sustainable agriculture, pest plants and animals, biodiversity and community. The plan is on our website at www.landscape.sa.gov.au/ep/about-us/landscape-plan.

Our key functions include development of water allocation plans for prescribed water resources and operating as the relevant authority for a range of water, land protection and animal and plant control activities.

The Eyre Peninsula region that we cover extends from Whyalla in the east, along the Gawler Ranges in the north, to the edge of the Nullarbor Plain in the west. It takes in approximately 8 percent of South Australia, covering an area of 80,000 square kilometres. Our main offices are located in Port Lincoln and Ceduna with other offices including Whyalla, Tumby Bay, Wudinna, Cleve, Elliston and Streaky Bay (see map).

Water resources

Water resources on the Eyre Peninsula are precious and need to be managed sustainably, this includes watercourses, lakes, dams, wetlands and watercourse habitat, springs, soaks, and catchment landscapes. Some activities can have adverse impacts on the health and condition of water resources, the ecosystems that depend on them, as well as on downstream and other water users.

Water affecting activities are activities and works that can impact on the health and condition of water resources, water dependant ecosystems and other water users. Under the Landscape South Australia Act 2019, an approved permit is required to undertake a water affecting activity.

For more information about permits for water affecting activities, see our website: www.landscape.sa.gov.au/ep/water/water-affecting-activities.

Managing plants and animals

Pest animals and plants can pose significant threats to agriculture, the natural environment and public health and safety on the Eyre Peninsula. We work closely with land managers to find ways of reducing the number of pests, help restore native biodiversity and reduce losses in the agricultural industry. Sightings of pest animals can be reported on the Feral Scan website: www.feralscan.org.au.

If you'd like advice on control and management of pest animals and plants on your property, you can contact your local landscape officer or your nearest team leader of landscape operations.

- Team Leader Landscape Operations, Eastern (Whyalla): Tim Breuer, E: timothy.breuer@sa.gov.au, Ph: 0488 000 481
- Team Leader Landscape Operations, Southern (Port Lincoln): Ben Smith, E: benjamin.smith@sa.gov.au, Ph: 0427 188 546
- Team Leader Landscape Operations, Western (Streaky Bay): Liz McTaggart, E: liz.mctaggart@sa.gov.au, Ph: 8626 1108

Delivery of the Eyre Peninsula Landscape Board's agricultural programs

Agricultural Innovation & Research EP (AIR EP) are contracted to deliver our Regional Agricultural Landcare Facilitator services and components of the Regenerative Agriculture Program to June 2023, which are funded by the Australian Government's National Landcare Program.

The **Regenerative Agriculture Program** (RAP) aims to support farmers by increasing awareness and adoption of sustainable land management practices. The RAP provides general sustainable agriculture support to the Board. We have a project officer who works closely with local landholders with priorities including:

- Addressing soil acidification through organising workshops for farmers to identify areas of current or emerging acidification and working out a plan to address the issue.
- Mallee seeps awareness raising, identification of emerging sites and organisation of local workshops or field days for farmers.
- One-on-one site visits with farmers to identify soil-related issues and provision of reports.
- Coordinating an annual Regenerative Agriculture Forum.

We also manage a small grants program that farmers can access for mixed species / soil cover demonstrations across the EP. Aimed at improving soil health and sustainability, the sustainable agriculture grants are available to individual farmers or farmer groups for a range of activities to reduce soil erosion, increase soil biodiversity and soil health across a range of soil types, in 'farmer scale' demonstrations. Applications are open year-round for the small grants for mixed species crops. Farmers are encouraged to contact the Sustainable Agriculture Project Officer for more information.

Much of the program is being delivered by our Sustainable Agriculture Project Officer, Josh Telfer. Josh can assist farmers in any of the areas listed above, with Brett Masters, SARDI also providing soils technical expertise to support the program.

For more information, please contact Josh Telfer on susag@airep.com.au or 0460 000 290 or visit www.landscape.sa.gov.au/ep/sustainable-agriculture.

The **Regional Agricultural Landcare Facilitator** (RALF) role works with Josh and provides a central contact point for farmers, industry, and community groups; and supports agriculture related activities. Amy Wright is our RALF, assisting EP farmer groups with the organisation of agricultural events such as farmer meetings, field days, workshops and sticky beak days as a way of keeping stakeholders informed about industry issues.

Amy can also support agricultural groups to develop new projects, seek grant funding and provide feedback to the Board and the national RALF network on the needs of the agricultural community and keeps abreast of emerging challenges, issues or threats that may affect the agricultural sector in the region.

For more information, please contact Amy Wright, on ralf@airep.com.au or 0467 004 555.

Covering bare soils in eastern EP

AIR EP, on behalf of Franklin Harbour Ag Bureau, Buckleboo Farm Improvement Group and Roberts-Verran Ag Bureau, were contracted by the Board to deliver the Eastern Eyre Peninsula Soil Management project, aimed at increasing soil cover of bare soils over the 2020/21 summer. The project aimed to gain an increased understanding of summer crops and the effect of other activities on soil surface cover, erosion potential and plant growth and impact on subsequent winter crops.

Monitoring of the activities was undertaken by farmers with support from David Davenport from Davenport Soil Consulting. A number of activities have been undertaken in 2021, positively impacting more than 1,000ha.

Key activities included:

- Monitoring the impact of summer cover crops on soil moisture and mineral nitrogen.
- Ameliorating previously eroded areas through engineering techniques including levelling, ripping and clay delving.
- Improving pasture growth to increase soil cover using mixed species and cell grazing.

Photos. A sand blow out site and then the site after remediation.

Cummins Wanilla Basin drainage infrastructure

Up to 85,000 hectares of Eyre Peninsula farming land is increasingly being affected by poor drainage in the Cummins Wanilla Basin. The basin contains a vast network of surface water and groundwater drainage channel systems that have been developed over many decades to support agricultural production and address issues such as dryland salinity, waterlogging, erosion and sedimentation.

We have worked with the Cummins Wanilla Basin Streamcare Group to establish a basin management plan. A total of $250,000 in funding was secured by the Cummins Wanilla Basin Streamcare Group for priority infrastructure works as outlined in the management plan. The final round of funding for landholders within the basin is now open until mid-2023. Landholders within the basin area can apply for grants of between $2,000 and $30,000 for works that upgrade or maintain existing drainage, with works to be completed by May 19, 2023. For more information, see the Board's grant website www.landscape.sa.gov.au/ep/get-involved/grants-and-funding.

Mallee seeps

Our two-year Mallee seeps project has seen different management methods trialled at five different sites near Kimba, Rudall and Lock. Mallee seep sites are often found at the base of deep sandy rises and are driven by the formation of shallow perched water tables.

The main management strategies are to:

- stop the flow of water into these areas, often with strategic lucerne establishment to intercept the excess water flows; and
- establish living perennial soil cover on bare scalds, to help reduce evaporation (particularly over the summer months) and stop water wicking to the surface and leaving salt behind.

Demonstration sites are showing a return to health of saline scalded soils once this is achieved. Soil testing in September at two sites showed an average 70% reduction in 0-10 cm soil salinity and an average 40% reduction in 10-20 cm soil salinity after only one year since establishment. While these and other sites will continue to be measured, this trend brings hope that many of these scalded seep sites can be rehabilitated back to cropping. The project will continue in 2022 with results and resource to be released to help farmers across the region.

This project is funded by the Australian Government's National Landcare Program. Mallee seeps expert, Farming Systems Consultant Chris McDonough from Insight Extension for Agriculture is leading the trials.

Industry

Agriculture Stewardship Package

The Eyre Peninsula Landscape Board has been one of six trial regions across Australia, taking part in the Australian Government Agriculture Stewardship Package.

As of the end of 2021, two trial programs had been opened to Eyre Peninsula farmers - the Carbon + Biodiversity Pilot which encouraged landholders to diversify income through environmental plantings and; the Enhancing Remnant Vegetation Pilot that is about farmers being able to receive payments for managing and enhancing existing remnant native vegetation on-farm.

For more information,
visit agriculture.gov.au/
agriculturestewardship.

Australian Government | National Landcare Programme | LANDSCAPE SOUTH AUSTRALIA EYRE PENINSULA | AIR EP Ag Innovation & Research Eyre Peninsula

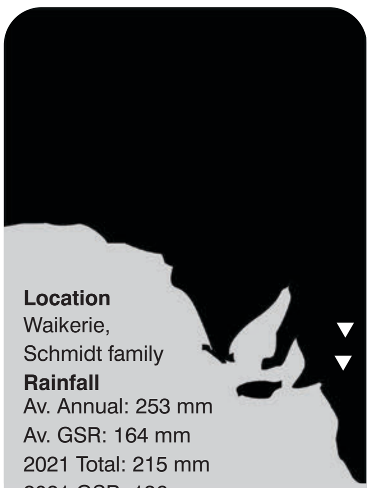
Section Editor:
Rhiannon Schilling
SARDI, Waite

Section 2

Soils

Amelioration responses in two Mallee sands

Therese McBeath[1], Lynne Macdonald[1], Rick Llewellyn[1], Bill Davoren[1], Willie Shoobridge[1], Rachel Hennessey[1] and Murray Unkovich[2]
[1]CSIRO Agriculture and Food, Waite; [2]University of Adelaide, Waite



Location
Waikerie,
Schmidt family
Rainfall
Av. Annual: 253 mm
Av. GSR: 164 mm
2021 Total: 215 mm
2021 GSR: 136 mm
Yield
Potential: Barley (Yield Prophet®) 1.1 t/ha
Actual: N/A
Paddock History
2020: Barley
2019: Barley
2018: Wheat
Soil type
Red alkaline sand
Plot size
1.68 m x 25 m x 4 reps
Trial design
Randomised complete block
Yield limiting factors
High soil strength at 15 - 55 cm depth. Soil fertility (marginal soil test phosphorus). 100% hail damage in 2021

Location
Lowaldie, Loller family
Rainfall
Av. Annual: 337 mm
Av. GSR: 237 mm
2021 Total: 229 mm
2021 GSR: 149 mm
Yield
Potential: Wheat (Yield Prophet®) 1.1 t/ha
Actual: 2.0 t/ha (ripped)

Key messages

- **Physical constraints to crop water use are present in many sandy soils of the Mallee.**
- **Lowaldie had barley yield gains of up to 1.0 t/ha in 2021, 3 years after ripping, with 3.0- 3.3 t/ha benefit over 3 years.**
- **At Waikerie there were no indications that ripping, or amendments had any benefits, 4 years after being implemented.**

Why do the trial?

The aim of this work is to increase crop water use in underperforming sandy soils in the Southern cropping region by improving diagnosis and management of constraints. Water-use and yields on sandy soils are commonly limited by a range of soil constraints that reduce root growth. Constraints can include a compacted or hard-setting layer inhibiting root proliferation, a water repellent layer causing poor crop establishment, soil pH issues (both acidity and alkalinity) and/or poor nutrient supply. To achieve the best possible profit-risk outcomes, we are testing strategies implemented with the seeder (e.g. guided row sowing, seed placement, wetting agents, fertiliser placement, furrow management), through to high soil disturbance interventions (deep ripping, spading, deep ploughing) that require specialised machinery. Here we discuss the 2021 results from our sites at Lowaldie (near Karoonda) and Waikerie where the residual effects of ripping with and without amendments (chicken litter or fertiliser) were monitored.

How was it done?

Waikerie

A range of intensive interventions were implemented at Waikerie in 2018 to evaluate the value of increasing the depth of ripping with or without amendments (chicken litter (manure) @ 2.5 t/ha or nutrient inputs from fertiliser to match chicken litter) (Table 1). The shallow fertiliser treatment was banded at 8 cm depth prior to sowing while chicken litter was spread on the soil surface. In 2021 we measured the residual (fourth crop after ripping) responses to these treatments. The trials were sown with Astute triticale on 20 May with 20 kg nitrogen (N)/ha and 10 kg phosphorus (P)/ha as urea and MAP across all treatments. The 2021 season was below average with 136 mm growing season rainfall (164 mm average) and 215 mm annual rainfall (253 mm average).

Paddock History
2020: Wheat
2019: Wheat
2018: Canola
Soil type
Deep neutral pH sand
Plot size
20 m x 2 m x 4 reps
Trial design
Randomised complete block
Yield limiting factors
High soil strength at 30 - 70 cm depth. Moderate water repellence. Low soil nitrogen

Lowaldie

A trial was established on two soil types (dune crest and deep sand) at Lowaldie in 2019 testing the response to nil, 40 cm or 60 cm ripping depth (Table 1). The plots were sown in 2021 with Spartacus barley on 1 June. A fertiliser rate of 10 kg P/ha was applied at sowing and a total of 60 kg N/ha was applied through the season (40 kg N/ha at sowing and 20 kg N/ha on 19 August). The 2021 season had below average rainfall with 149 mm in the growing season (237 mm average) and 229 mm for the year (337 mm average).

What happened?

Waikerie

The unamended control and ripped treatments had the most soil water pre-sowing with 66 (ripped) - 79 mm (control) in the top metre, while the no rip plots that received chicken litter or matching fertiliser nutrients in 2018 had the lowest level of soil water with 59 - 62 mm (Table 2). These nutrient rich plots were some of the higher yielding plots in 2020. Pre-sowing profile mineral Ns were widely varying from 86 kg N/ha/m to 241 kg N/ha/m for the fertiliser placed at 30 cm. An enriched N layer was found around the treatment depth and in the deepest layer for the deep fertiliser treatments. While fertiliser and deep chicken litter treatments had higher soil mineral N in general, the magnitude of effect was not consistent despite the same amount of N being applied for each treatment. Establishment counts were not affected by treatments and averaged 129 plants/m^2 while GS31 biomass with undisturbed plus chicken litter had more biomass than all other treatments. These differences were not present later in the growing season due to the dry conditions. Severe hail damage prevented any assessment of grain yields.

Lowaldie

At the time of sowing, there was 89 - 128 mm of water in the top m of soil in 2021 but low N availability with only 13 - 25 kg mineral N/ha (Table 3), regardless of treatments. Crop establishment was not affected by treatment averaging 96 plants/m^2 on the dune soil and 90 plants/m^2 on the crest. Crop growth was quite variable on the crest and no significant differences in biomass between treatments were measured. However, there was 0.32 t/ha more biomass in response to deep ripping at 60 cm in the deep sand.

Ripping in 2019 generated substantial barley yield benefits in 2021 with 0.47 to 0.64 t/ha increases with ripping to 40 cm and 0.66 to 1.02 t/ha increases with ripping to 60 cm depending on the soil type (crest vs. dune) (Figure 1).

Soils

Table 1. SA Mallee treatments indicating the type of physical intervention approach, amendments used, and placement strategy.

Site (Year est.)	Treatment (depth cm)	Amendment Type	Amendment Placement
Waikerie 1 (2018)	Rip (30), Rip (60)	Chicken Litter (2.5 t/ha), fertiliser matched at ripping time	deep, surface
Lowaldie (2019)	Rip (40), Rip (60)	Nil	

Table 2. Waikerie 2021 in-season measurements in response to ripping and addition of amendments and fertiliser in 2018. Within a column a treatment appended by a different letter is significantly different from another (P=0.05). Chicken litter (CL).

Treatment	Pre-sow water (mm in top m)	Pre-sow N (kg/ha in top m)	GS31 biomass for triticale (t/ha)	GS31 soil N (kg/ha in top 70 cm)
No rip	79 a	86 cde	0.21 b	47 cd
No rip_CL_surf	62 b	104 cde	0.40 a	37 d
No rip_fert_match	59 b	125 bc	0.26 b	53 bcd
Rip_30_CL _deep	70 ab	105 cde	0.24 b	52 bcd
Rip_30_fert_deep	68 ab	241 a	0.22 b	69 ab
Rip_60_CL_deep	66 ab	84 cde	0.28 b	51 bcd
Rip_60_fert_ deep	66 ab	155 b	0.20 b	72 a
LSD (P=0.05)	*12*	*42*	*0.10*	*17*

Table 3. Lowaldie 2021 in-season measurements in response to ripping and addition of amendments and fertiliser. Within a column a treatment appended by a different letter is significantly different from another (P=0.05).

Treatment Name	Pre-sow mineral N (kg/ha in top m)	Pre-sow water (mm in top m)	GS31 biomass for barley (t/ha)
Deep Sand			
No rip	25	105	0.45 b
Rip@40	17	108	0.61 ab
Rip@60	23	128	0.77 a
LSD (P=0.05)	*ns*	*ns*	*0.22*
Crest			
No rip	22	89	0.38
Rip@40	15	105	0.55
Rip@60	13	94	0.63
LSD (P=0.05)	*ns*	*ns*	*ns*

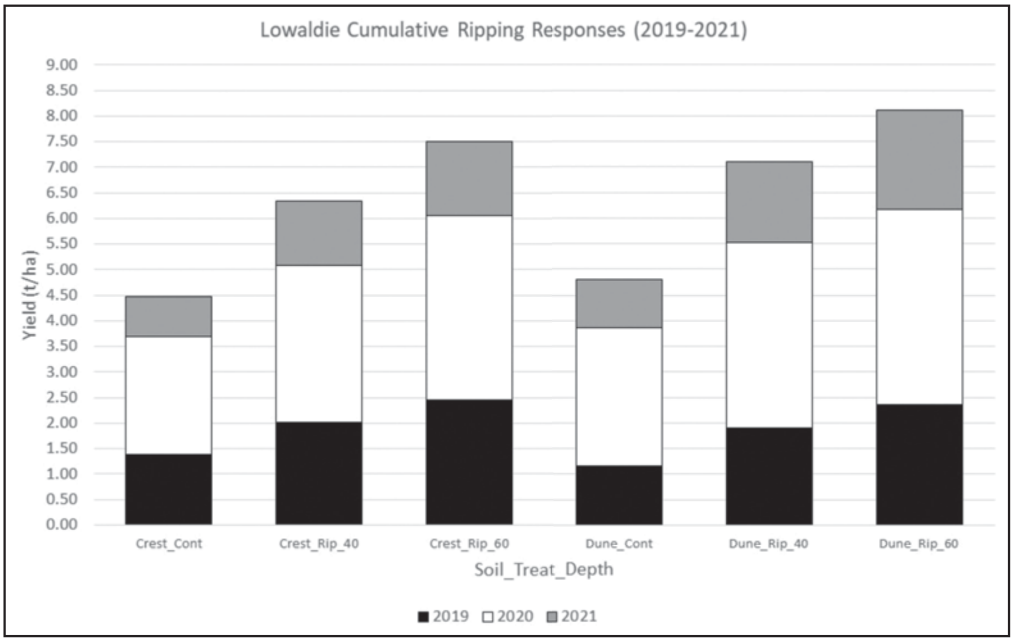


Figure 1. Cumulative cereal yield response to ripping treatments (2019-2021) at Lowaldie.

What does this mean?

Large physical interventions (ripping, spading, deep cultivation) can improve crop productivity in hard-setting sandy soils, but there are risks of small yield benefits or even yield loss in very low rainfall seasons which can be difficult to recover. At a cost of $100/ha for ripping, the Waikerie and Lowaldie sites have strongly contrasting risk vs. reward outcomes (Waikerie 4-year yield response +0.2 t/ha and Lowaldie 3 year yield response +3.32 t/ha).

The question must be asked, what is different between the Lowaldie and Waikerie sites that might cause this contrast in outcomes?

We think that the difference in rainfall is important. In 3 of the 4 seasons at Waikerie the growing season rainfall was around 100 mm, so the frequency of water stress was a critical constraint across all treatments at this site, limiting any benefits from loosened sand. In addition, the soil below the ameliorated layer is quite different at the two sites. Lowaldie is a deep sand with some clay (20%) from 70 cm depth, while Waikerie has a rocky layer from 40-50 cm depth. Therefore, it is likely that there is far less water in the Waikerie system which is accessible for the ameliorated crop to convert to extra yield.

Acknowledgements

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Trengove Consulting

CSIRO

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THE UNIVERSITY of ADELAIDE

Treating production constraints on the sandy soils of upper and lower Eyre Peninsula - Year 3

Brett Masters and Brianna Guidera
SARDI, Port Lincoln

Location
Buckleboo, Mt Damper, Karkoo, Cummins - Graeme & Heather, Tristan & Lisa Baldock, Nigel Oswald, Reece Modra, Scott & Maryanne Mickan

Rainfall
Av GSR / 2021 GSR
Buckleboo: 215 / 134 mm
Mt Damper: 218 / 210 mm
Karkoo: 338 / 366 mm
Cummins: 327 / 336 mm

Soil type
Buckleboo: Buckleboo red sand
Mt Damper: sand over sodic clay
Karkoo: clayspread sand over clay
Cummins: shallow sand over sodic clay

Plot size
Large plot trial 30 m x 12-18 m wide x 3 reps

Yield limiting factors
Seven week dry period from end of August to late October at peak growth period of flowering and grain fill.

Despite above average rainfall in October most of this fell in the last week of the month and was too late to benefit crops, particularly on lentils at Buckleboo.

Hot windy days in the first week of September caused moisture stress at flowering.

Key messages

- **Production constraints on sandy soils can be overcome with strategic deep tillage and the application of soil amendments, however, the response varies for different crops and seasons.**
- **Deep tillage boosted crop growth and yield three years after implementation on three out of four sites.**
- **Spading at Mt Damper provided higher grain yield than deep ripping with inclusion plates.**
- **Incorporated organic and nutrient amendments have provided additional yield in some years, but with inconsistent benefits.**
- **Knowledge of soil characteristics throughout the profile is vital for identifying key production constraints and determining an appropriate and effective management strategy.**

Why do the trial?

These trials aimed to:

- Compare a range of soil modification practices used to treat physical, chemical, and nutritional production constraints on different types of sandy soils on upper and lower Eyre Peninsula.
- Compare deep ripping to deep ripping with topsoil inclusion plates, and to spading.
- Identify if the addition of fertilisers, gypsum or organic material provided additional benefits.

This article summarises crop growth responses from treatments in the third crop post amelioration. For details of past trial results, see Eyre Peninsula Farming Systems Summary 2019, p. 99-104; Validating research outcomes to treat production constraints on sandy soils of Eyre Peninsula, and EPFSS 2020, p. 84-87; Treating production constraints on the sandy soils of upper and lower Eyre Peninsula - Year 2.

How was it done?

In collaboration with AIR EP, four replicated trials were established in 2019. Two on the upper EP at Buckleboo and Mt Damper, and two on lower EP districts at Karkoo and Cummins (EPFSS 2019, p. 99-104) as part of the GRDC Sandy Soils project (CSP00203).

Treatments were designed to address identified soil constraints and included a mixture of strategic deep tillage with and without the application of soil chemical and nutrient amendments (Table 1) that were implemented prior to sowing in 2019. Nutrient treatments at Buckleboo and Mt Damper were calculated as the additional nutrients required to supply potential production increases from addressing constraints over a 3 year period (i.e. monitoring period for the trials).

In 2019, the sites were all sown with wheat (Chief CL at Mt Damper and Scepter at Buckleboo, Karkoo and Cummins). In 2020 upper EP sites were sown with cereals (Scepter wheat at Mt Damper and Compass barley at Buckleboo) with both lower EP trial sites sown to 44Y90 canola. Plant density evaluated 4 to 6 weeks post sowing showed little difference in crop establishment between treatments in 2019 and 2020, apart from on the Karkoo site in 2019 where the clayed control and the clay + rip treatments recorded 14 to 19 % more wheat plants than plots which were ripped with inclusion plates (EPFSS 2019, p. 99-104).

Table 1. Summary of replicated trial sites.

Co-operator/Site ID/ Location	Key Soil Constraints	In season Measurements	Treatments
Karinya Ag (TB) with Buckleboo Farm Improvement Group, Buckleboo	Physical, nutrients	Plant emergence, dry matter, grain yield	**Control** - untreated **Deep Tillage** - deep ripping @ 35 cm, deep ripping @ 45 cm [+/- inclusion plates (IP)] **Soil amendments** - ripping + IP + fluid nutrients (APP, high cost nutrition package, or low cost nutrition package).
Nigel Oswald (MF) Mt Damper	Water repellence, physical, nutrients	Plant emergence, dry matter, grain yield	**Control** - untreated **Deep tillage** - spading @ 30 cm, ripping @ 45 cm + IP, rip+IP @ 45 cm + spading @ 35 cm (tyne spacing = 50cm). **Soil amendments** - ripping + IP + nutrients
Modra (RM) Karkoo	Physical, nutrients Note: Water repellence had been treated by previous clay spreading.	Plant emergence, grain yield	**Control** - clayspread **Deep tillage** - clay + ripping @ 40 cm, clay + ripping @ 40 cm + IP **Soil amendments** - clay+ripping @ 40 cm + IP + 5 t/ha OM (lucerne pellets)
Mickan (SM), Cummins	Water repellence, Soil acidity, physical (Shallow sodic B horizon resulting in waterlogging), nutrients	Plant emergence, grain yield	**Control** - limed **Deep tillage** - Ripping @ 30 cm, clay + ripping @ 40 cm IP **Soil amendments** - clay + ripping @ 40 cm + IP + 5 t/ha gypsum

Opportunistic biomass assessments were undertaken on some sites during spring (including Buckleboo, Mt Damper and Karkoo in 2019, and Buckleboo and Mt Damper in 2020). In 2019 ripping with inclusion plates resulted in flowering biomass increases of at least 33% compared to the control at Buckleboo, with the spading + ripping + IP, and rip + IP + nutrient treatments at Mt Damper producing more spring biomass than control plots (EPFSS 2019, p. 99-104). In 2020 the deeper ripping (45 cm) treatments with deep placement of nutrients improved biomass production at Buckleboo, with ripping with inclusion plates and spading also resulting in more biomass growth at Mt Damper (EPFSS 2020, p. 84-87). The biomass differences seen at Buckleboo and Mt Damper in 2019 and 2020 were reflected in grain yield differences (EPFSS 2019, p. 99-104 and EPFSS 2020, p. 84-87).

What happened in 2021?

In 2021 all sites were sown by the landholders and managed as per the rest of the paddock. The upper EP sites were sown with Scope CL barley at Mt Damper and Hurricane lentils at Buckleboo, with both lower EP trial sites sown to wheat.

Plant density

Plant density was evaluated 4 to 6 weeks after sowing. Mild temperatures and damp soils saw good conditions for crop establishment with only Karkoo showing any difference in crop establishment between treatments (Figure 1). Deep ripping with inclusion plates resulted in 8 to 28% less wheat plants compared to the clayed control (which had 89 plants/m^2 at establishment) and deep ripping without inclusion plates (Figure 1).

Biomass

Above average rainfall in early winter saw good early crop growth at all sites. Opportunistic biomass cuts were taken at Buckleboo and Mt Damper in late winter/early spring. Dry conditions ensued from mid August to late October. Whilst Mt Damper, Cummins and Karkoo had good subsoil moisture levels due to earlier rains, subsoils at Buckleboo dried out rapidly with the crop showing some signs of moisture stress and having variable crop growth. Spring biomass assessment in mid September did not show any treatment trends.

August biomass at Mt Damper was generally low (<2.0 t/ha), however the treatments that included spading produced >0.9 t/ha additional biomass over the control (which averaged 0.9 t/ha, Figure 2).

Grain yield

Dry conditions from the end of July forced crops to draw heavily on stored soil moisture during flowering and grain fill. The Buckleboo and Cummins trials were harvested by the landholders in late November/early December, yielding an average of 0.6 t/ha on the lentils at Buckleboo and 3.7 t/ha on the wheat at Cummins (Figures 3 and 4).

At Buckleboo all treatments where additional nutrients had been deposited in subsurface layers by ripping yielded about the same (0.6 t/ha) and had significantly higher yields than the control (0.45 t/ha, Figure 3).

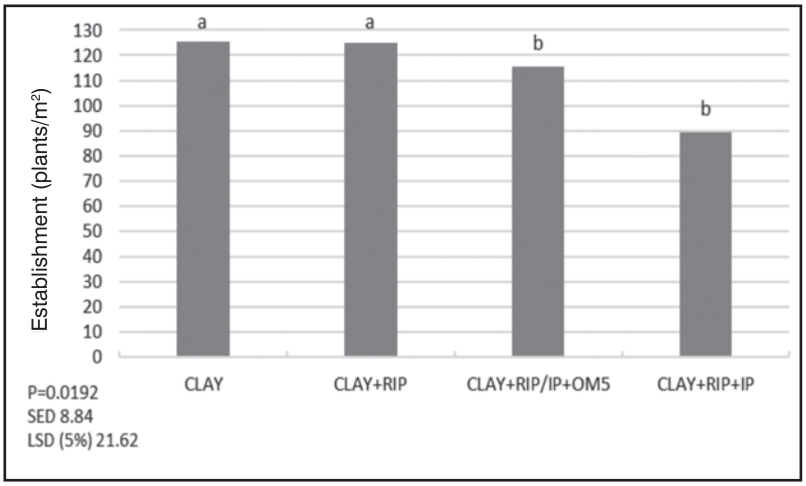

Figure 1. Plants per square metre at Karkoo at crop establishment. A different letter indicates a significant difference at P<0.05.

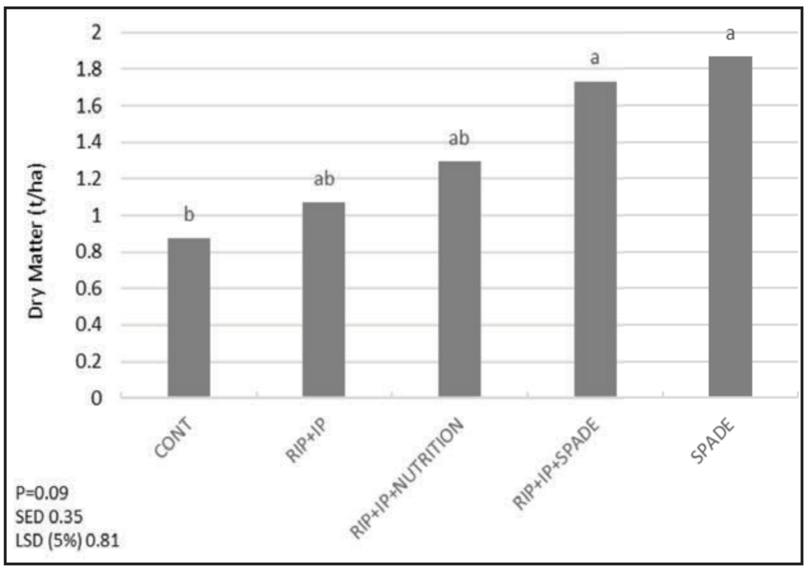

Figure 2. Winter dry matter biomass (t/ha) at Mt Damper. A different letter indicates a significant difference at P<0.1.difference at P<0.05.

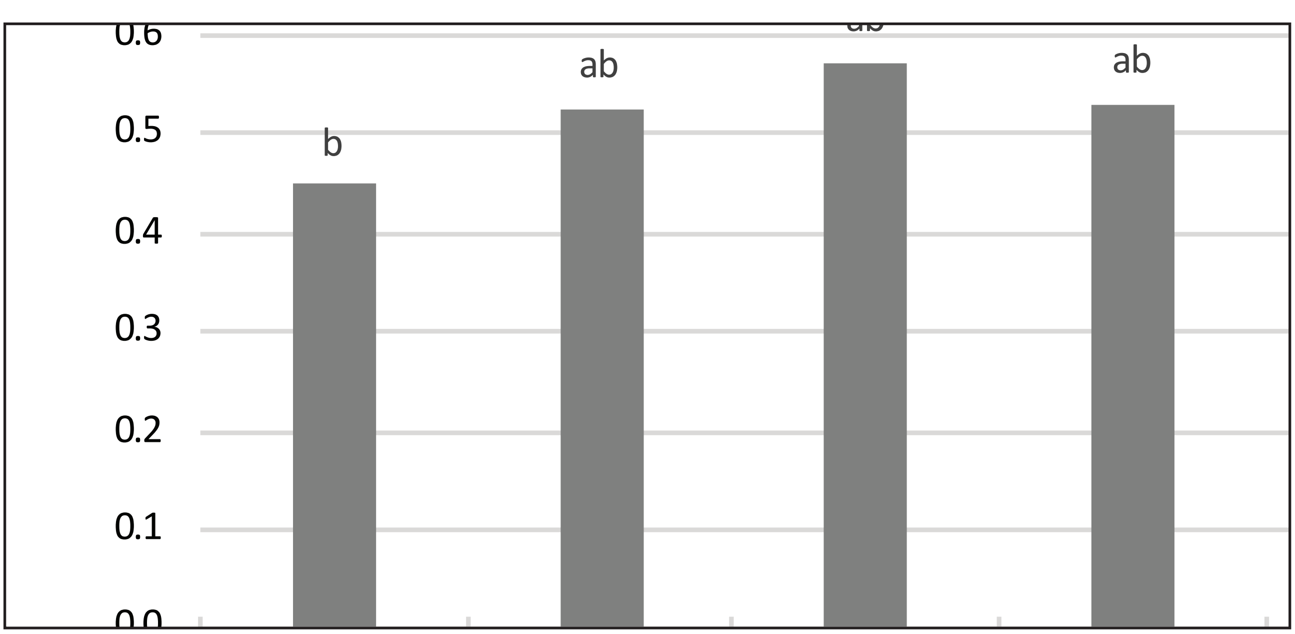

Figure 3. Lentil yield (t/ha) at Buckleboo. A different letter indicates a significant difference at P<0.05 difference at P<0.05.

Soils

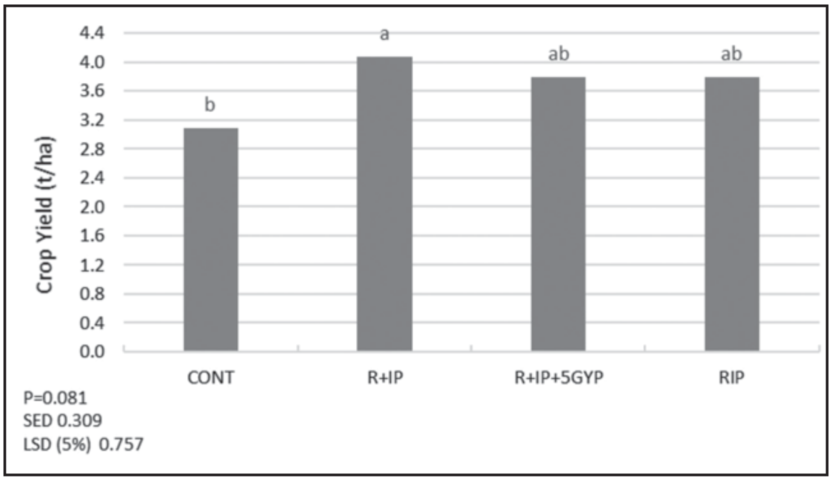

Figure 4. Wheat yield (t/ha) at Cummins. A different letter indicates a significant difference at P<0.1.

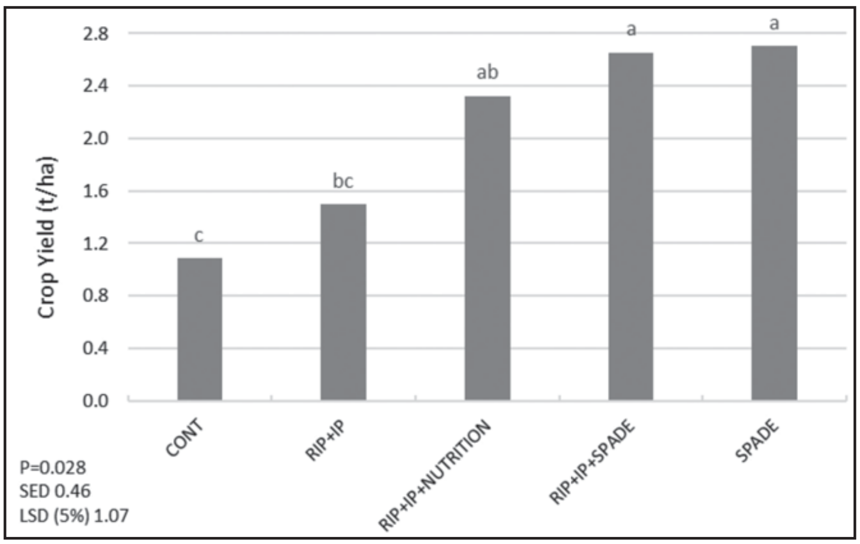

Figure 5. Wheat yield (t/ha) at Mt Damper. A different letter indicates a significant difference at P<0.05.

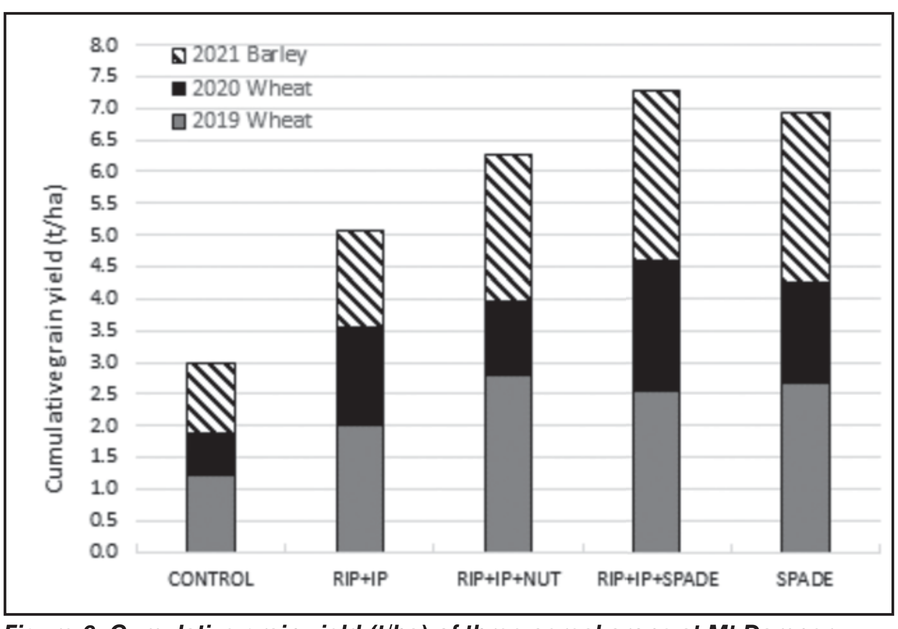

Figure 6. Cumulative grain yield (t/ha) of three cereal crops at Mt Damper.

At Cummins the ripping+inclusion plates treatment yielded significantly more (4.1 t/ha) than the untreated controls (which averaged 3.1 t/ha); there was no additional benefit from the application of 5 t/ha of surface applied gypsum (Figure 4).

Harvest cuts were taken by hand at Mt Damper and Karkoo in December (4 x 1 m crop row per plot) and extrapolated to grain yield (t/ha). The average barley yield for all treatments at Mt Damper was 2.1 t/ha. Spaded plots and rip + IP + nutrition had higher yields (ranging from 2.3 to 2.7 t/ha) than the control and rip + IP, which averaged 1.1 t/ha and 1.5 t/ha (Figure 5).

At Karkoo the average wheat yield across the site was 5.8 t/ha (with individual plots yielding 4.8 to 7.2 t/ha). Although the average grain yields were 0.8 to 1 t/ha higher on the ripped treatments compared to the control (which yielded 5.2 t/ha), these yield increases were not significant ($P>0.05 = 0.11$).

What does this mean?

In 2019 and 2020 it was hypothesised that rainfall timing and distribution was the major factor limiting crop growth and grain yield. In 2021, mild temperatures and good soil moisture combined with a lack of wind events at emergence saw no difference in crop establishment between treatments at all sites except Karkoo. Clay spreading at Karkoo has overcome water repellence, but the treatments with the highest level of soil disturbance (rip+ inclusion plate with or without OM) saw reduced emergence in 2021. This might be a result of uneven sowing depth following ripping with inclusion plates, or perhap the "topsoil slotting" of surface clay (residual from heavy clay spreading operations) deeper into the soil profile using inclusion plates has reduced its benefit in ensuring even germination. A more thorough mixing of the soil profile using a spader or other rotary machine might overcome these issues.

At Mt Damper, the more complete mixing of the profile to 30 cm using the spader resulted in much higher biomass in late winter compared to ripping with inclusion plates. These trends carried through to crop yield with the treatments which had the highest biomass at the end of winter also having the highest wheat grain yields. This may be due to the more uniform mixing and complete de-compaction of the top 30 cm that is achieved with rotary spading in comparison to deep ripping. The two treatments that included spading provided the highest cumulative grain yield after three years, providing more than 4 t/ha of additional grain (Figure 6).

Whilst the lentils at Buckleboo had good crop establishment, dry conditions in late winter saw a rapid drying and reformation of hardsetting subsurface layers, inducing restrictions to root development and crop growth. This might explain the lack of difference in winter biomass growth at this site and, as biomass production was checked by dry conditions, might explain the limited yield difference between treatments in lentils at this site.

Good growth across lower Eyre Peninsula saw high levels of biomass produced, with little visual difference between plots on either the Karkoo or Cummins trial sites. However, whilst the yield differences between treatments at Karkoo were not significant, at Cummins there was a significant yield increase compared to the controls in all ripped treatments. Ripping through a physically constrained layer in this shallow sand over clay has proven beneficial three years after it was deep ripped.

These trials support earlier work that suggests that whilst modification of soils with severe production constraints can increase biomass and grain yield, results are highly variable and it can take some time following modification to see benefits.

Acknowledgements

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More profitable crops on highly calcareous soils by improving early vigour and overcoming soil constraints

Brian Dzoma[1,3], Nigel Wilhelm[1,3,4], Amanda Cook[2,3,4], Ian Richter[2,3] and Craig Standley[2,3]

[1]SARDI, Waite; [2]SARDI, Minnipa; [3]CRC for High Performance Soils, Callaghan; [4]University of Adelaide Affiliates

Location
Minnipa
Minnipa Agriculture Centre
Rainfall
Av. Annual: 325 mm
Av. GSR: 241 mm
2021 Total: 405 mm
2021 GSR: 248 mm
Paddock History
2020: Volunteer pasture
2021: Wheat
Soil type
Calcareous grey sand
Soil test
High pH and carbonate, poor P reserves, high N reserves
Plot size
30 m x 2 m x 4 reps
Trial design
Randomised complete block design (RCBD) x 4 reps
Yield limiting factors
Moisture, nutrition, hostile subsoil

Location
Poochera
Gosling Family
Rainfall
Av. Annual: 326 mm
Av. GSR: 247 mm
2021 Total: 362 mm
2021 GSR: 221 mm
Paddock History
2020: Volunteer pasture
2021: Barley
Soil type
Grey highly calcareous sandy loam
Soil test
Very high pH and carbonate, poor P reserves, high N reserves
Plot size
30 m x 2 m x 4 reps
Trial design
RCDB with 4 replicates
Yield limiting factors
Moisture, nutrition, hostile subsoil

Key messages

- **Bespoke biochar and Neutrog incorporated into the subsoil have shown great potential to improve both crop biomass and grain yield in this first year of conducting the trials.**
- **Bespoke biochar, a high seeding rate and adequate nutrition have also shown potential to improve crop yield when considered as a lower cost topsoil strategy.**
- **High plant densities can be simply achieved on highly calcareous soils by using high seeding rates.**
- **There was an indication of less crown roots at one site when fungicides and adequate nutrition were supplied at seeding. This response requires further investigation.**
- **A beneficial deep ripping response is less likely in these soils when multiple subsoil constraints are present.**
- **Biomass and grain yield penalties are highly likely when deep ripping with or without inclusion plates results in a rough seeding bed.**

Why do the trial?

Highly calcareous soils challenge crop production with a range of constraints and this limits the effectiveness of improved agronomic practices. Early crop vigour is poor and crop production continues to be limited to very low nitrogen (N) and water use efficiencies. Major constraints include poor phosphorus (P) status in crops, low water holding capacity, high burden of rhizoctonia, poor N cycling, severe fertiliser toxicity during germination. Constraints at depth can be extremely high pH, sodicity, salinity and low fertility. This new collaborative project involves teams of researchers from SARDI, Rural Solutions and NSW DPI, and is funded by the High-Performance Soils CRC and GRDC. This project aims to overcome these constraints in order to lift crop production on these difficult soils. There is also a complementary project funded by GRDC and undertaken by CSIRO which is investigating water and nutrient cycling in these soils as well as microbial activity and function.

The aim of this research initiative is to identify and overcome the impacts of topsoil and subsoil conditions of highly calcareous soils on crop productivity on the upper Eyre Peninsula. Outcomes will focus on modified agronomic practices and improved soil conditions which increase water use efficiency (WUE) of crops and farm profitability as well as improved knowledge of the impact of high carbonate on crop performance.

How was it done?

Three sites on the Upper Eyre Peninsula (UEP) at Minnipa, Poochera and Port Kenny were established in 2021 with two replicated field trials at each of the sites. They are investigating strategies to improve early crop vigour by overcoming soil constraints on poor performing highly calcareous soils.

Location
Port Kenny
Guerin family
Rainfall
Av. Annual: 349 mm
Av. GSR: 270 mm
2021 Total: 379 mm
2021 GSR: 261 mm
Paddock History
2020: Volunteer pasture
2021: Barley
Soil type
Grey highly calcareous sandy loam
Soil test
Very high pH and carbonate, poor P reserves, high N reserves
Plot size
30 m x 2 m x 4 reps
Trial design
RCDB with 4 replicates
Yield limiting factors
Moisture, nutrition, hostile subsoil

Three of the six trials were set up to investigate long-term subsoil strategies, and the other three, short-term topsoil strategies. A replicated field demonstration trial which was established in 2020 at Poochera, was re-seeded in 2021.

Soil analysis identified medium to very high carbonates, which increased with depth at all three sites (Table 1). Port Kenny is highly calcareous with water repellence in the top 10 cm. Port Kenny and Poochera have high levels of salinity in subsurface layers while boron is high in subsurface layers at Minnipa.

Subsoil treatments were implemented on 14 May at Minnipa, on 18 May at Poochera and on 19 May at Port Kenny. These subsoil treatments included a mixture of interventions using deep ripping with or without inclusion plates and organic matter (Table 2).

All but one of the topsoil treatments (Table 3) were intended as annual strategies implemented at sowing. Sweep cultivation was implemented on 15 April at all sites to simulate a practice common in these districts and as a strategy to reduce rhizoctonia. Treatments for the field demonstration trial at Poochera were the same as the previous year (EPFSS 2020, p. 73) and were not refreshed. Biochar used in the demo trial was different to the bespoke biochar used in the topsoil and subsoil trials. Bespoke biochar is phosphoric acid activated during its preparation and was sourced from our collaborative research partners - NSW DPI.

In 2021, all the trials were sown to Scepter wheat (60 kg/ha standard rate) with 50 kg/ha DAP as a basal on 4 June (Minnipa), 5 June (Poochera) and 6 June (Port Kenny).

Plant density, early and late crop biomass, root health, nutrient status, grain yield and quality were all assessed in 2021.

Soils

Table 1. Surface (0-10 cm) and subsurface (60-80 cm) soil characterisation at 3 sites in 2021.

Site	Depth cm	pH $CaCl_2$	Colwell P mg/kg	Nitrate N mg/kg	Exch Na mg/kg	Boron mg/kg	MED (0-5 cm) molar	Carbonates %
Minnipa	0 - 10	7.9	36	45	107	2.7	0	15
	60 - 80	8.5	<10	18	2455	24		40
Poochera	0 - 10	7.9	31	33	40	2.1	0	40
	60 - 80	8.4	<10	25	665	9.1		50
Port Kenny	0 - 10	7.9	45	52	127	2.2	1.2	75
	60 - 80	8.4	<10	19	524	9.6		82

Table 2. Summary of subsoil treatments.

Treatment	Treatment details
Typical practice (Control)	60 kg/ha seed, 50 kg/ha DAP
Deep rip only	Typical practice + deep ripping
Deep rip with inclusion plates	Typical practice + deep ripping with inclusion plates
Deep rip with inclusion plates + Neutrog	Typical practice + deep ripping with inclusion plates + Neutrog pellets
Deep rip + Neutrog	Typical practice + deep ripping with Neutrog pellets
Deep rip + granular fert (to match N & P in Neutrog)	Typical practice + deep ripping + 75 kg/ha urea + 250 kg/ha DAP
Deep rip + Bespoke biochar	Typical practice + deep ripping + Bespoke biochar
Deep rip + granular fert (to match N & P in Biochar)	Typical practice + deep ripping + 375 kg/ha DAP
Deep rip + Phos acid	Typical practice + deep ripping + 115 L/ha Phos acid
Deep rip + Phos acid + trace elements	Typical practice + deep ripping + 115 L/ha Phos acid + Zn:Cu:Mn (3:2:5)

Table 3. Summary of topsoil treatments

	Treatments	kg/ha							L/ha			kg/ha		
		Seed rate	DAP at seeding	Urea*	MAP at seeding	Urea (fluid)	SOA banded	Biochar banded	Phos acid	Fungicide (Uniform)	Wetter (SE14)	Zn	Mn	Cu
1	Typical practice (Control)	60	50											
2	P + TEs delivered as a fluid	60				20			37			2	3	1
3	Urea broadcast pre-seeding	60	50	89										
4	Anti-Rhizoctonia^ + TEs chelates + fluid P and N	60				20			37	0.4		2	3	1
5	Anti-Rhizoctonia^ + TEs chelates + granular P and N	60	50				205			0.4		2	3	1
6	SE14 Wetter in the seed row	60	50								3			
7	Banded bespoke biochar + Urea*	60	50	89				500						
8	Granular N and P to match Biochar + Urea*	60	50	89	34									
9	Higher seeding rate	90	50											
10	Sweep cultivation 4 weeks pre-seeding	60	50											
11	Combination of treatments 4 and 9	90				20	205		37			2	3	1
12	Seed coating	60	50											
13	Continuous P supply (Treatment 2 + 2 x 2 kg P foliar)	60				20			37			2	3	1

^ *Uniform fungicide on the seed + banded + furrow application*
***** *Broadcast pre-seeding*

What happened?

Plant density

In the subsoil trials, deep ripping with inclusion plates caused a lot of soil disturbance which resulted in a rough and cloddy seedbed, and consequently the lowest plant densities at all sites. In comparison to typical practice (control), deep ripping with inclusion plates resulted in a 50% (Minnipa), 34% (Port Kenny) and 25% (Poochera) reduction in plant population. Furthermore, deep ripping without inclusion plates reduced plant density by 14% at Port Kenny, 20% at Poochera and 33% at Minnipa.

In the topsoil trials, mean plant density was 100 plants/m^2 at Minnipa, 103 plants/m^2 at Port Kenny, and 106 plants/m^2 at Poochera. A higher seeding rate (90 kg/ha) resulted in the highest plant densities at all sites, and none of the other strategies significantly improved plant density. Higher seeding rate resulted in 150 plants/m^2 (Minnipa), 161 plants/m^2 (Port Kenny) and 162 plants/m^2 (Poochera).

Soil compaction

Soil penetration resistance was measured on 10 August to a depth of 50 cm. Figure 1 shows that soil compaction is not a constraint likely to limit crop root growth at Poochera because penetration resistance was always below the level considered to inhibit root growth, 2500 kPa. There appeared to be a compacted layer at Minnipa at a depth of 25 cm and at Port Kenny at 15 cm. Deep ripping reduced resistance throughout the top 40 cm but may have increased it in the layer just below where the ripper tines reached at Port Kenny.

Plant nutrient status at flowering

P, sulphur (S) and zinc (Zn) were marginal to deficient for all three sites. However, potassium, manganese (Mn) and copper (Cu) levels were adequate and well above critical thresholds.

In the subsoil trials, bespoke biochar resulted in higher shoot P at Minnipa, and higher Mn at Poochera when compared to "Typical practice" (Appendix). Treatments with Neutrog also had higher Zn and Cu at Port Kenny and Poochera when compared to typical practice. Nitrogen status was highest in deep ripped plots with inclusion plates and Neutrog at Poochera.

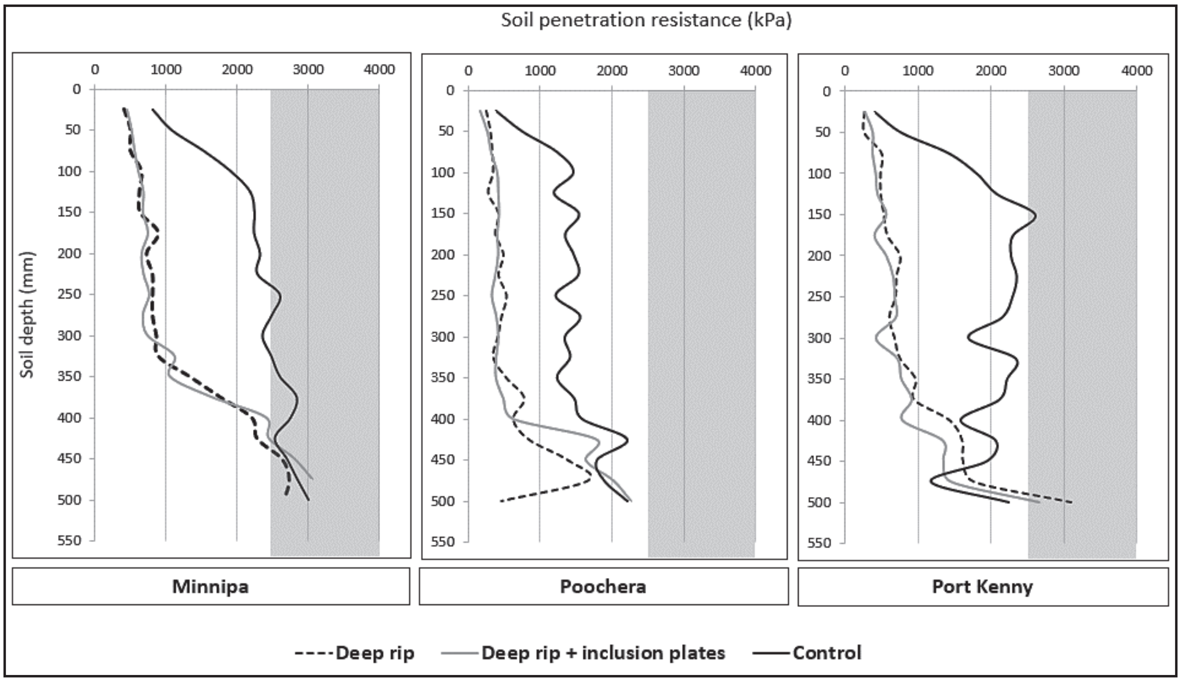

Figure 1. Soil penetration resistance (kPa) with no ripping (control) and after ripping with and without inclusion plates at Minnipa, Poochera and Port Kenny. The shaded grey zone represents "severe" penetration resistance greaten than 2500 kPa where root penetration and growth is significantly reduced.

In the topsoil trials, "continuous P" resulted in significantly higher levels of shoot P at Minnipa and Port Kenny but did not affect P levels at Poochera. The "combination" treatment resulted in significantly higher levels of leaf K, S and Mn at Minnipa, when compared to typical practice.

Root health

Root sampling was caried out on 3 August to assess root health (score 0-5 where 0 = no disease, and 5 = roots with absence of laterals and hairs, plant terminal), but only % crown roots infected and seminal scores are reported here.

In the subsoil trial, none of the treatments changed root health at Minnipa or Port Kenny. However, at Poochera, Neutrog (3.1) and deep rip (2.9) improved seminal root health when compared to the control (2.2).

In the demonstration trial at Poochera, the percentage of infected crown roots was lower with bespoke biochar (23%), Neutrog (28%) and deep ripping (33%), when compared to the control (52%).

In the topsoil trial, root health was not affected by any of the strategies implemented at Port Kenny. However, at Poochera, the percentage of crown roots infected was lower in the two treatments which had fungicides (20%), when compared to the control (48%). High seeding rate resulted in the highest % infected crown roots (70%) at Poochera (70%) and at Minnipa (77%). At Minnipa, the lowest crown root infection occurred with sweep cultivation (52%). The control had 64% infection.

Flowering biomass

In the topsoil trial, bespoke biochar and the combination strategy consistently yielded more biomass than the control. The biomass difference was 1.6 t/ha at Minnipa and Port Kenny and 0.7 t/ha at Poochera, when compared to the control (Table 4). At Port Kenny, high seeding rate increased biomass by 22% compared to the control.

Treatments imposed in 2020 did not affect flowering biomass in the Poochera demonstration trial.

In the subsoil trial, flowering biomass was not affected by any of the subsoil strategies implemented at Minnipa and Poochera. However, at Port Kenny, bespoke biochar (4.5 t/ha) and Neutrog (4.3 t/ha) had higher flowering biomass than the control (3.3 t/ha). Physical disturbance through deep ripping (with or without inclusion plates) did not improve flowering biomass at any site.

Grain yield and protein

Harvesting of trials commenced on 17 December. In the subsoil trial at Minnipa, none of the strategies improved grain yield (Figure 2) above the control which was the highest yielding treatment at 3.51 t/ha. Deep ripping with inclusion plates had the lowest yield (2.58 t/ha). At Poochera, deep ripping and incorporating 5 t/ha of bespoke biochar (3.13 t/ha) or Neutrog (3.04 t/ha) had higher yields than the control (2.57 t/ha). Deep ripping with inclusion plates and Neutrog, and deep ripping with phosphoric acid and trace elements (Zn, Cu, Mn) also yielded better than the control.

Table 4. Flowering biomass (t/ha) at Minnipa, Poochera and Port Kenny.

Treatments	Minnipa	Poochera	Port Kenny
Banded bespoke biochar + Urea	5.66 a	4.14 ab	4.68 a
Combination*	5.58 ab	4.28 a	4.65 a
Continuous P supply (Treatment 2 + 2 x 2 kg P foliar)	5.05 abc	3.28 c	2.98 cd
High seed rate (90 kg/ha)	4.89 abcd	3.33 c	3.74 b
Granular N and P to match Biochar + Urea	4.71 bcd	3.46 bc	3.24 bc
Fungicide + TEs chelates + granular P and N	4.43 cd	4.31 a	3.03 cd
Sweep cultivation 4 weeks pre-seeding	4.55 cd	3.47 bc	3.31 bc
P + TEs delivered as a fluid	4.56 cd	3.23 c	3.33 bc
Seed coating	4.40 cd	3.04 c	2.72 cd
Urea broadcast pre-seeding	4.61 cd	3.43 bc	2.88 cd
SE14 Wetter in the seed row	4.28 cd	2.97 c	2.52 d
Fungicide + TEs chelates + fluid P and N	4.09 d	3.20 c	2.69 cd
Typical practice (control)	**4.08 d**	**3.44 bc**	**3.07 cd**
P value	*0.002*	*0.004*	*<0.001*

** High seed rate + fungicide + TEs + fluid P + urea*

At Port Kenny, deep ripping with inclusion plates and incorporating Neutrog pellets resulted in the highest yield (2.51 t/ha), and deep ripping with bespoke biochar (2.24 t/ha) or with Neutrog (2.26 t/ha) also yielded better than the control (1.86 t/ha).

In the topsoil trial (Figure 3) at Minnipa, bespoke biochar had the highest yield (3.44 t/ha), while continuous P (3.24 t/ha), combination (3.27 t/ha) and phos acid + trace elements (3.19 t/ha) also yielded higher than typical practice (2.82 t/ha). At Poochera, only the combination treatment (3.27 t/ha) and bespoke biochar (3.09 t/ha) had higher yields than the control (2.66 t/ha). At Port Kenny, bespoke biochar (2.42 t/ha) and the combination treatment (2.38 t/ha) were the highest yielding treatments. The high seeding rate (2.07 t/ha) also yielded better than the control (1.7 t/ha).

In the demonstration trial at Poochera (Figure 4), biochar and Neutrog incorporated by ripping in 2020 resulted in yields better than the control in 2021. Physical intervention alone did not improve grain yield in the second crop after ripping.

In the subsoil trials, there was a trend at Port Kenny and Poochera of higher grain protein in treatments that had Neutrog, bespoke biochar, or phos acid and trace elements. Highest grain protein (12.3%, 10.2%) was in the deep ripped + granular fert (to match N and P in Neutrog) at Poochera and Port Kenny respectively.

In the topsoil trials, grain protein at Minnipa was not affected by any of the strategies and it ranged from 10.1 - 10.5%. However, at Poochera and Port Kenny, there was a consistent trend of higher protein in treatments that had fungicide + trace elements. AntiRhizo+ granNP +TEs treatment resulted in the highest grain protein at Poochera (11%) and Port Kenny (10.15%). The combination treatment (10.9%), broadcast urea (10.8%) and bespoke biochar (10.8%) also had higher grain protein than the control (10.4%) at Poochera. Higher seeding rate with standard nutrition had the lowest grain protein (10.1%).

In the demonstration trial at Poochera, both Neutrog (12.1%) and biochar (11.5%) had higher grain protein than the control (10.8%).

What does this mean?

The focus of this project is to assess long-term (subsoil) and short-term topsoil strategies that have the potential to improve early vigour, overcome constraints and improve crop production on challenging highly calcareous soils.

Our trials have shown that higher plant densities can be achieved in highly calcareous soils by an approach as simple as using higher seeding rates. However, our data also suggests that the high plant densities have to be complemented with more nutrition and fungicides for disease protection to fully realise the benefits of more plants per square metre.

On the other hand, there can be a penalty from physical disturbance using deep rippers and inclusion plates, as a result of a rough seed bed. Even where crop establishment following ripping has been reasonable, benefits from deep physical disturbance have been small or absent. This is supported by the penetration resistance measurements which are under 3000 kPa to a depth of 40 cm at all the sites. Values much higher than this are common in siliceous sands where deep ripping is producing large crop production increases.

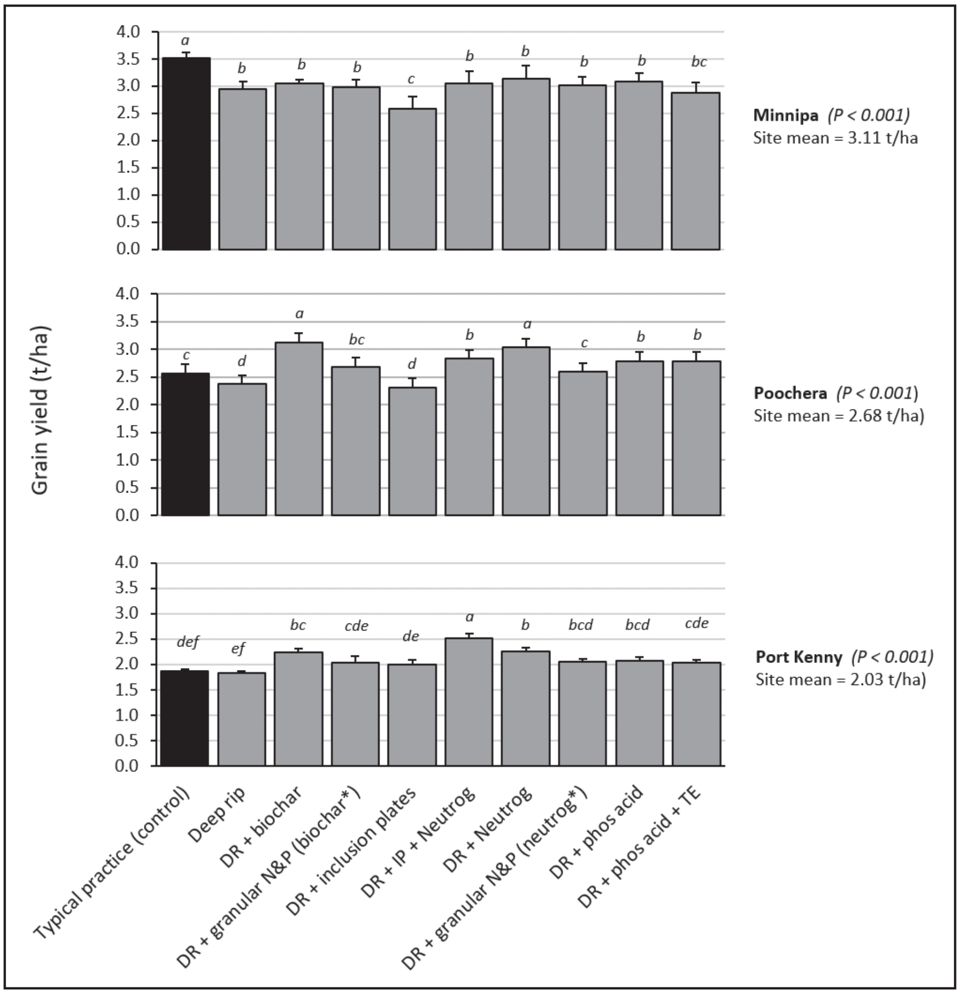

Figure 2. Grain yield (t/ha) for subsoil trials at Minnipa, Poochera and Port Kenny.
Error bars represent standard error. Acronyms DR = Deep rip, IP = inclusion plates, TE = trace elements.
** Represents treatments with nitrogen and phosphorus added as granular fertiliser to match N and P in biochar or Neutrog.*

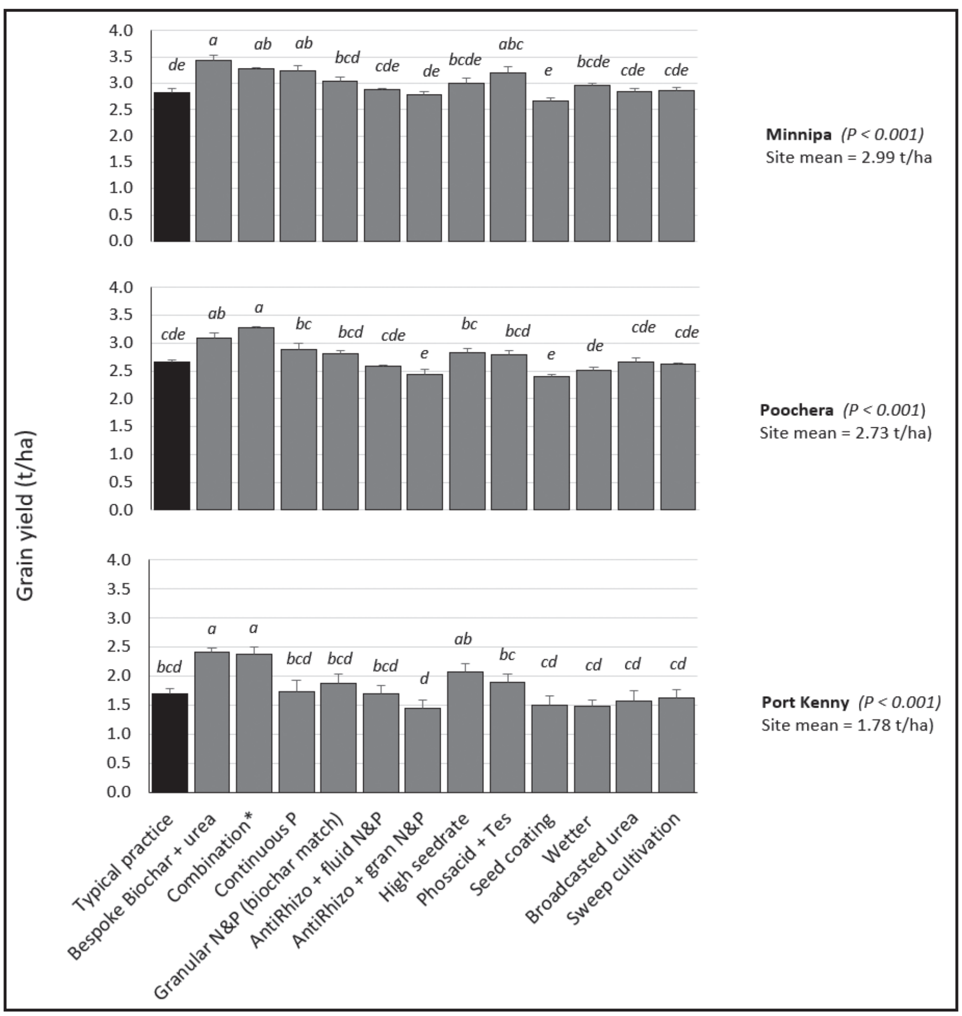

Figure 3. Grain yield (t/ha) for the topsoil trials at Minnipa, Poochera and Port Kenny.
Error bars represent standard error.
**Combination = High seeding rate + fungicide + TEs + fluid P + urea*

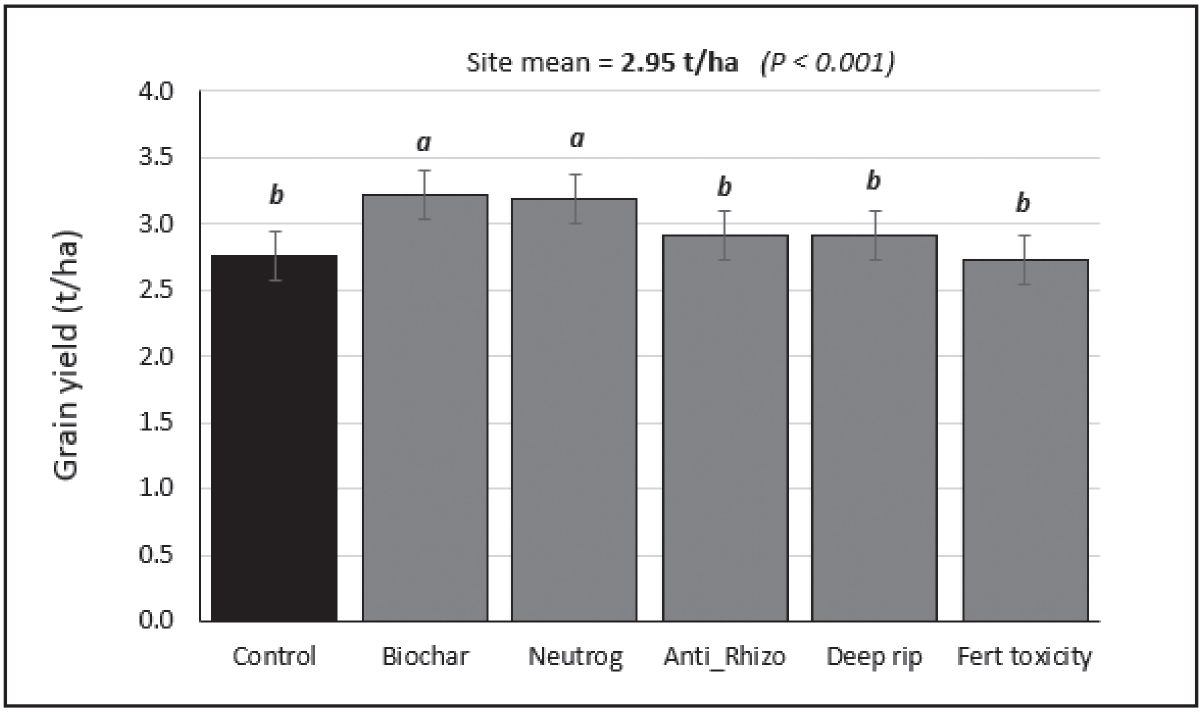

Figure 4. Grain yield (t/ha) at the demo trial at Poochera.
Error bars represent least significant differences (LSD).

Our results have been inconsistent in terms of strategies that can improve root health, however there is an indication from one of the sites (Poochera) of less crown root infection when fungicides are used at seeding with adequate nutrition.

In terms of final grain yield, deep ripping and incorporating bespoke biochar or Neutrog into the subsoil has shown promise as a way to increase grain yield at the two sites which were highly calcareous (Poochera and Port Kenny).

From the short-term topsoil strategies, the combination treatment and bespoke biochar consistently showed potential to increase grain yield at all sites. It is also important to note that the bespoke biochar used in these trials has a lot of phosphoric acid incorporated during its preparation, and out yielded the “fertiliser control”. Tissue analysis also suggests that the effect of bespoke biochar is not a simple nutrition one – it did not consistently boost nutrient levels in the crop but boosted grain yield. In a similar vein, the fertiliser control did not match the Neutrog either, so there is something about nutrient delivery from organic matter sources in calcareous soils which warrants further investigation. There was also an indication of a phosphorous and trace element response at Minnipa, a result which needs further investigation as this was not the case at the other sites. All sites had soil P reserves which were considered adequate but phosphorus levels in the crop at flowering were low for the control at all sites.

Acknowledgements

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Figure 5. Plant analysis levels for N, P, Zn, Mn, and Cu at flowering. Only treatments different to the control are listed.

		%				mg/kg					
		Nitrogen		**Phosphorus**		**Zn**		**Mn**		**Cu**	
Subsoil	**Minnipa**	ns	**Control 1.2**	0.002	*Biochar 0.13* **Control 0.08**	*<0.001*	*Neutrog 16.5* **Control 10.1**	*ns*	**Control 74.5**	*ns*	**Control 9.1**
	Poochera	ns	**Control 1.6**	ns	**Control 0.12**	*<0.001*	*DR_IP_Neutrog 19.3* **Control 11.9**	*0.003*	*Biochar 62.3* **Control 45.1**	*0.008*	*DR_IP_Neutrog 5.2* **Control 4.2**
	Port Kenny	ns	**Control 1.5**	ns	**Control 0.11**	*0.003*	*DR_IP_Neutrog 15.3* **Control 10.6**	*0.05*	**Control 33.1** *DR_IP 25.1*	*0.006*	*DR_IP_Neutrog 3.4* **Control 2.8**
Topsoil	**Minnipa**	ns	**Control 1.6**	0.02	Continuous_P 0.12 **Control 0.11**	*ns*	**Control 10.9**	*<0.001*	*Combination 70.5* **Control 54.1**	*ns*	**Control 6.9**
	Poochera	0.04	Combination 1.5 **Control 1.7**	ns	**Control 0.12**	*0.005*	*Urea_broadcast 15.5* **Control 13.5**	*ns*	**Control 46.5**	*0.03*	*Wetter_ seedrow 4.3* **Control 4.1**
	Port Kenny	0.003	AntiRhizo_granNP_TE 1.7 **Control 1.4**	0.01	Continuous_P 0.15 **Control 0.11**	*0.04*	*AntiRhizo_granNP_TE 12.8* **Control 10.3**	*ns*	**Control 24.0**	*0.005*	*AntiRhizo_ granNP_TE 3.2* **Control 2.9**

Values in shaded area represent statistical significance of treatment differences for each nutrient in each trial.

Soils

Ameliorating a deep repellent sand at Murlong four years ago still improved wheat performance in 2021

Nigel Wilhelm[1,2], Mel Fraser[3] and Brett Masters[4]

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Location
Murlong
Mark & Amy Siviour and family
Rainfall
Av. Annual: 332 mm
Av. GSR: 248 mm
2021 Total: 303 mm
2021 GSR: 211 mm
Yield
Potential: Barley - 2.7 t/ha (French/Schultz)
Actual: 1.0 t/ha in best treatments
Paddock History
2020: Vetch
2019: Barley
2018: Wheat
2017: Barley
Soil type
Deep white siliceous sand over clay
Soil test
Low fertility throughout for P, N and trace elements. Severely water repellent and compacted
Plot size
25 m x 6 rows x 4 reps
Trial design
Completely randomised block
Yield limiting factors
Late start, frost, Cu deficiency and low spring rainfall

Key messages

- **Deep tillage boosted crop growth and yield four years after implementation. Spading was the most effective tillage type, closely followed by deep ripping (to 40 cm) with inclusion plates.**
- **Incorporated organic and nutrient amendments have provided additional yield in some years, but with inconsistent and decreasing benefits.**
- **Only cheap sources of amendments that increase yields will be viable.**

Why do the trial?

Previous research has shown that deep tillage can deliver large yield increases in compacted sandy soils. However, uncertainty remains whether thorough mixing/dilution of the topsoil or adding amendments during this operation is effective or profitable. The development of inclusion plates attached to deep ripping tines is a low-cost option to increase mixing of surface applied amendments and/or topsoil, potentially with less risk of soil erosion compared to spading.

This trial aimed to:

- Determine if soil mixing and loosening improves yield in a sandy soil on eastern EP (using a rotary spader).
- Compare deep ripping with inclusion plates to spading.
- Identify if the addition of fertilisers or organic material provided additional benefits.

This article summarises crop growth responses from treatments in the fourth crop post amelioration and the accumulated grain yield benefit over four years. For details of past trial results, see the article in the 2020 EPFSS,: 'Ameliorating a deep repellent sand at Murlong in 2018 increased vetch performance in 2020'.

How was it done?

The trial is located on a broad sand dune at Murlong on eastern Eyre Peninsula and comprises 11 treatments by 4 replicates. Constraints at the site include severe water repellence, compaction (bulk density >1.7 at 12 cm), low organic carbon and poor nutrient fertility.

Crop performance in an unmodified control is being compared to spading to 30 cm or ripping with inclusion plates to 2 depths (30 cm or 41 cm) with and without the addition of high rates of mineral fertiliser or lucerne pellets (Table 1). All amelioration treatments were applied in 2018 and have not been re-applied.

Plant measurements included crop establishment, biomass at flowering and grain yield and quality. Data was analysed using standard ANOVA models in Statistix 8.

What happened?

The break of season at Murlong was late in 2021 and the trial was not seeded until 10 June. However, the seedbed was wet despite the repellent topsoil and the wheat established well, regardless of treatment. There was an average of 115 plants/m^2 across the trial. In previous years, severe water repellence resulted in low plant numbers where there was no deep soil disturbance.

Table 1. Trial establishment and cropping details for 2021 (trial was sown with Razor CL wheat in 2018, Scope CL barley in 2019 and RM4 vetch in 2020).

Date		
19 April 2018	Amendments applied	Organic matter: lucerne pellets at 5 t/ha Nutrient package: nutrients applied to match lucerne (nitrogen (N) 167, phosphorous (P) 14, potassium (K) 105, sulphur (S) 12, copper (Cu) 0.03, zinc (Zn) 17, manganese (Mn) 0.18 kg/ha). N, P, K and S applied as granular and trace elements as fluids. Amendments were applied evenly across the surface on spaded plots or in bands to align with ripper tine spacings, immediately prior to spading and ripping.
19 April 2018	Deep tillage details	• Spading to 30 cm at 5 km/hr • Ripped: 4 tines at 64 cm spacings, with inclusion plates positioned 10 cm below the soil surface and operated at 5 km/hr. • Shallow ripped (corresponding to the depth of spading) to 30 cm with 20 cm tall inclusion plates. • Deep ripped to 41 cm with 30 cm tall inclusion plates.
10 June 2021	Sowing, inter-row on 2020 crop rows	70 kg/ha Hammer CL wheat at 25.4 cm row spacing + DAP at 60 kg/ ha and 63 kg /ha banded below seed rows (all treatments). SE14 wetter sprayed into all seed rows at 4 L/ha.

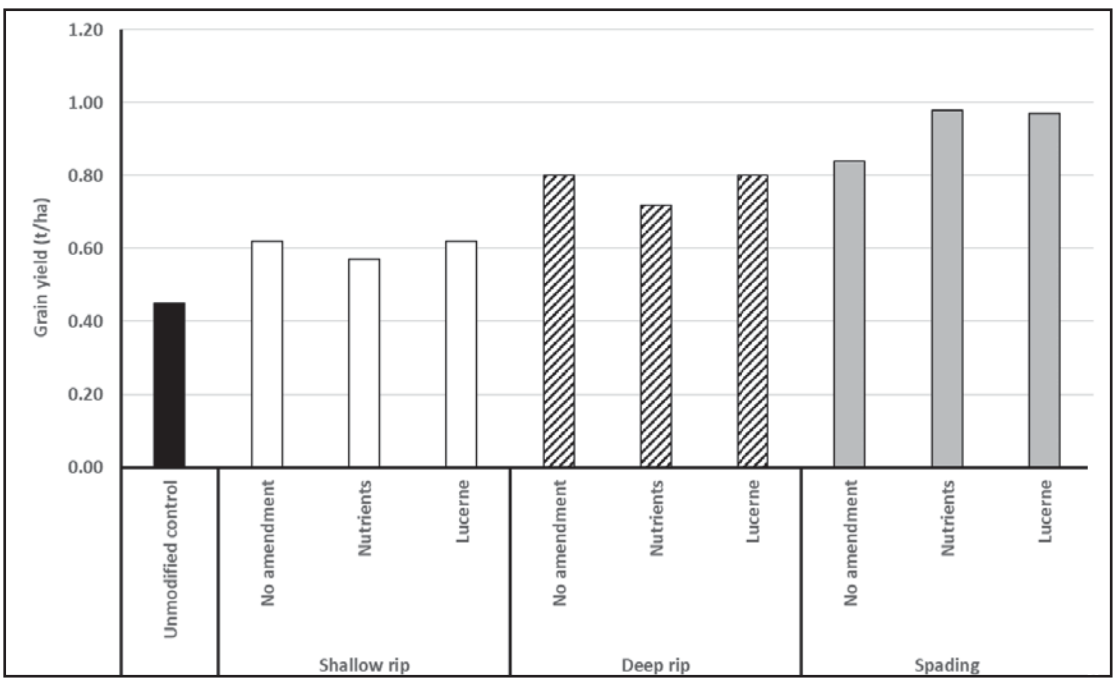

Figure 1. Effects of deep tillage and incorporated amendments on grain yield (t/ha) of wheat at Murlong in 2021 (LSD (P=0.05)= 0.09).

The spading + nutrient package provided the highest crop biomass at flowering in 2021 (3.7 t/ha compared to 2.1 t/ha for the unmodified control). However, it is not clear how incorporated nutrients boosted wheat growth because shoot analysis did not reveal any higher nutrient concentrations in this treatment compared to the controls. This was the only treatment in which an amendment improved wheat biomass at flowering. In general, the highest wheat dry matters were recorded with spading (56% higher than the unmodified controls), followed by deep ripping (42% higher than the control) and shallow ripping (21% higher).

Whilst grain yields at Murlong were generally poor in 2021, with frost, low levels of copper and zinc, a dry late winter and spring and weather damage at maturity all contributing to reduced yields, previous deep tillage still increased grain yields over the control (Figure 1). Spading more than doubled grain yield (from 0.44 t/ha in the unmodified control to 0.93 t/ha). Deep ripping with inclusion plates increased grain yields to 0.77 t/ha, and shallow ripping to 0.6 t/ha. The addition of amendments (both types) only increased wheat grain yields where they had been incorporated by spading, but only by 140 kg/ha or 16% above spading only.

Grain proteins were high, averaging 14% in the controls and 13% across the amelioration treatments. Grain quality was generally high and largely not affected by treatments; screenings were 2-3%, hectolitre weight 80-81 gm and grain weight averaged 30 gm per 1,000 grains.

The cumulative impact of amelioration strategies on four years of crop yields is shown in Table 2. All deep tillage types resulted in much better production overall, partly because the performance in the unamended soil was very poor in every year (cumulative yield of only 1.8 t/ha over the 4 years). Spading produced the highest grain totals (3.3 t/ha more than the control over the 4 years). The cost of spading is commonly between $150 and $180/ha, whereas deep ripping with inclusion plates is estimated at $55 to $120 per hectare, depending on the depth of ripping (Davies, *et al* 2019).

Given its cheaper implementation cost and lower erosion risk, with more than 2.5 t/ha of extra grain over the 4 years, deep ripping with inclusion plates was a competitive alternative to spading. Even shallow ripping resulted in 1.5 t/ha more grain over the 4 years. Amendments, especially lucerne, substantially improved crop growth and yields in the first crop but have had little or no impact since then.

In most years, the benefits of strategic deep tillage appeared to be a combination of improved crop emergence (water repellence mitigated by mixing) and improved crop growth from alleviating soil compaction. However, in 2021, crop establishment was consistently high and uniform for all treatments, suggesting that the crop was primarily responding to deeper changes that were created 4 years prior.

Table 2. Cumulative grain yield of crops (t/ha) with various amelioration strategies at Murlong from 2018 to 2021.

Deep tillage	Amendment	Wheat in 2018	Barley in 2019	Vetch in 2020	Wheat in 2021	Cumulative grain yield
None	None	0.48	0.72	0.19	**0.45**	**1.82**
Shallow Ripping	None	0.99	1.33	0.47	**0.62**	**3.41**
	Nutrients	1.20	1.37	0.52	**0.57**	**3.65**
	Lucerne	1.19	1.25	0.48	**0.62**	**3.54**
Deep Ripping	None	1.41	1.62	0.56	**0.80**	**4.38**
	Nutrients	1.90	1.52	0.49	**0.72**	**4.63**
	Lucerne	1.80	1.74	0.66	**0.80**	**5.01**
Spading	None	1.90	1.64	0.76	**0.84**	**5.13**
	Nutrients	3.22	1.83	0.72	**0.98**	**6.73**
	Lucerne	3.12	1.81	0.84	**0.97**	**6.74**
LSD (P=0.05)						***0.57***

Note: LSD for cumulative yield was calculated for a factorial analysis of disturbance x amendment (ie controls excluded).

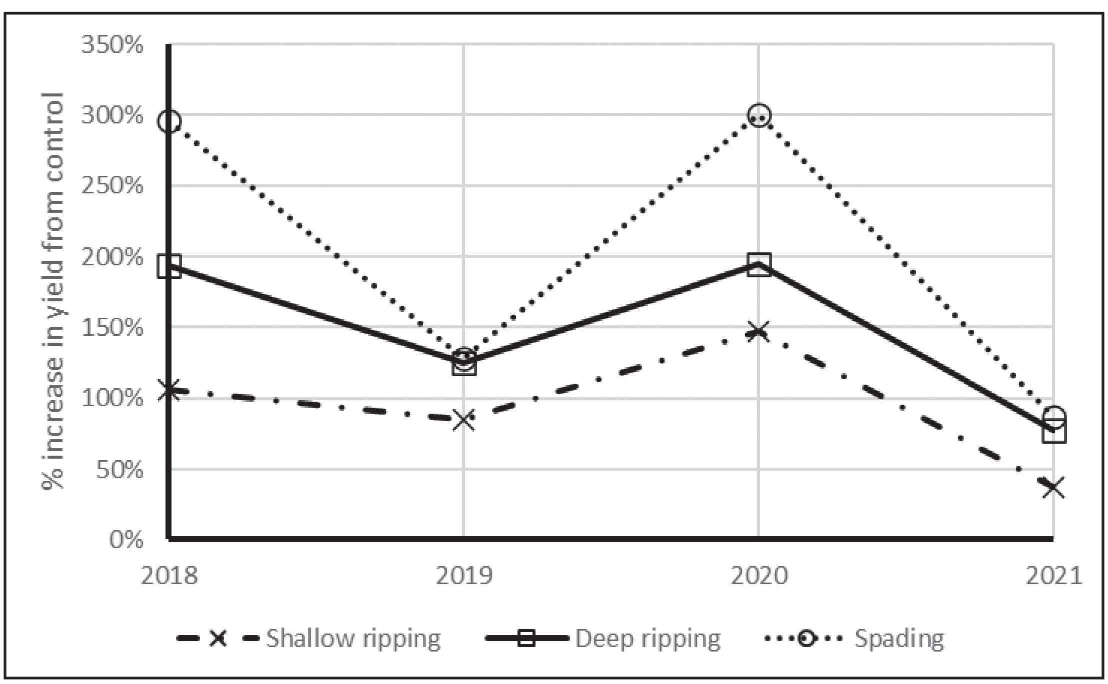

Figure 2. Benefits to grain yield of crops (% increase from unmodified controls) with 3 physical interventions at Murlong over 4 seasons; 2018 (wheat), 2019 (barley), 2020 (vetch) and 2021 (wheat) (amendments not included).

What does this mean?

Four consecutive crops have now been monitored on this deep, water repellent sand at Murlong. Figure 2 shows that there is a strong seasonal impact on responsiveness of crops to physical disturbance and no clear trend that the benefits have ceased. Deep tillage continues to deliver large production responses in crop biomass and grain yield; the prospect that benefits will continue beyond the fourth season is likely.

Spading has proven to be the most effective type of tillage for improved grain yield so far; even at a cost of $180/ha it has proven a good return on investment. Ripping to 40 cm with inclusion plates and wide rows (60 cm) is also providing very competitive economic returns. Additionally, soil erosion risk is a critical consideration when physically disturbing fragile sandy soils. Deep ripping interventions can be undertaken in a manner that does not leave the soil as vulnerable to wind erosion as can occur with operations like spading.

Deep tillage has improved early crop establishment at Murlong by disturbing and diluting surface repellent layers, leading to better crop biomass and grain production; spading is more effective than ripping in this aspect. However, seeder strategy trials conducted by the University of SA (see their articles in previous editions of the Eyre Peninsula Farming Systems Summary 2018 and 2019) have shown that there are low-cost options at seeding that can substantially improve early crop establishment on this severely repellent sand without major physical disturbance. A combination of those approaches with deep ripping could improve outcomes even further.

While incorporating lucerne hay or a multi-nutrient fertiliser package increased crop performance in 2018, the cost of these amendments will need to substantially reduce to be economically viable. They have only produced negligible grain yield benefits after the first crop.

The final year of this trial will be 2022 with the intention to deep rip one of the controls to compare against the ripping operation implemented in 2018.

Acknowledgements

Farmer Co-operator: Mark and Amy Siviour and family. Spader: University of South Australia, Groocock Soil Improvement.

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Phosphorous (P) fertiliser banded at 20 cm did not improve wheat performance compared to shallow P on a deep sand at Pinnaroo in 2021

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Location
Pinnaroo
Health Nickolls & family
Rainfall
Av. Annual: 339 mm
Av. GSR: 234 mm
2021 Total: 220 mm
2021 GSR: 146 mm
Yield
Potential: Barley 1.2 t/ha (French/Schultz)
Actual: 1.9 t/ha in highest yielding treatment
Paddock history
Pre 2021: out of production for an extended period
Soil type
Deep siliceous sand over clay
Soil test
Colwell P, 3 mg/kg in top 10 cm
Colwell P, <5mg/kg below the top 10 cm
PBI, 6
pH 6.8 near the surface, approx 7 at depth
Plot size
25 m x 6 row x 4 reps
Trial design
Randomised complete block
Yield limiting factors
Long dry spells in late winter and spring, late seeding, very infertile soil

Key messages

- **Barley performance improved strongly with P fertiliser on a deep sand with almost no P reserves.**
- **Barley performed better when P fertiliser was banded just below the seed row rather than when P was banded 20 cm below the soil surface in the first crop following application.**
- **Adding deep trace elements or having some P fertiliser with the seed did not improve the performance of P.**
- **Similar results have been obtained across south-eastern Australia on various soil types with differing degrees of P deficiency and P lockup.**
- **Residual benefits from applying P deep have proven similar to shallow P so far.**

Why do the trial?

The aim of the trial reported here is to determine whether the dual placement of shallow (10 cm) and deep (20 cm) banded P can improve crop yields compared with shallow P placement alone.

Recent research in Queensland has shown that crops can struggle to access P fertiliser which is placed in or close to seed rows because their soils are frequently dry in that layer. Placing P fertilisers deeper with moisture present (20-30 cm below the surface) has improved crop access and crop performance.

In southern Australia, although rainfall is more frequent during the growing season, periods of prolonged dry topsoils still occur and many soil profiles in southern Australia have very low P reserves below the cultivated layer. GRDC funded a new project starting in 2020 (Maximising the uptake of phosphorus by crops to optimise profit in central and southern NSW, Victoria and South Australia. DAN2001-033RTX) to investigate the merits of deeper placed P on crop performance. See an article in the EPFSS 2020 for a summary of a similar trial conducted the previous year ("P fertiliser banded at 20 cm did not improve wheat performance compared to shallow P at Brinkworth in 2020").

How was it done?

Deep P treatments were imposed in mid May 2021 with narrow profile tines on 60 cm spacings which resulted in 3 P bands per plot. P was placed 20-25 cm below the surface.

The trial was seeded with Spartacus CL barley, and shallow P applied during seeding, on 16 June. Fifteen mm of rain had fallen between implementation of deep P and seeding. Seeding was conducted in such a way that crop rows at 30 cm spacings were equally spaced between the bands of deep P. Seed was placed 1-2 cm below the presswheel trench and shallow P was 2-3 cm below the seed.

The combinations of deep and shallow P were designed in such a way that there was a series of treatments with the same shallow P rate but with increasing deep P. In addition, we had one treatment where some P was applied with the seed in addition to shallow and another treatment where fluid trace elements were applied deep in addition to a high rate of shallow and deep P.

MAP was used as the source of shallow and deep P and N was adjusted with urea to ensure that all plots had received a total of 37 kg N/ha with these products by the end of seeding. Ammonium sulphate (SOA) and potassium sulphate were also applied to all plots prior to seeding to provide an additional 24, 46 and 40 kg/ha of N, S and K, respectively. A fluid mix of Mn, Cu and Zn sulphate was also banded under seed rows in all plots during seeding to provide 4, 2 and 3 kg/ha of Mn, Cu and Zn, respectively. There was one mid-season application of 190 kg SOA/ha to the whole trial. A foliar spray of boron and copper was applied to the whole trial as the crop was starting to run up.

Establishment, growth, grain yield and quality were assessed.

Standard ANOVA models were used to analyse the data using STATISTIX 8 software.

What happened?

Crop establishment was largely unaffected by P rate or placement except for the treatment with P applied in the seed rows. This treatment had slightly lower plant numbers, 74 plants/m^2 compared to an average of 106 for the other P treatments.

Growth of barley responded very early in the season to added P on this very impoverished deep sand. Growth without any added P was stunted and development was delayed (Figure 1). Shallow P resulted in improved growth of barley at much lower rates than did deep P (Figure 2). For example, 10 kg P/ha applied shallow produced similar vigour to 40 kg P/ha applied deep.

Only high rates of P applied shallow (with or without deep P) increased shoot concentrations of P at flowering to adequate levels.

This general pattern of shallow P being more effective than deep P continued right throughout the season. Grain yields without any added P were very low (high rates of P increased yields from 0.4 t/ha to over 1.8 t/ha or a 4 fold increase). Shallow P continued to produce similar yields at much lower rates than deep P (Figure 3). Combinations of shallow and deep P struggled to produce yields similar to the same total P applied shallow. For example, the combinations of 20 or 40 kg P/ha deep with 5 kg P/ha shallow produced similar yields to 10 kg P/ha applied shallow only.

Figure 1. Early growth of Spartacus CL barley at Pinnaroo in 2021. Plot on the left has high rates of both shallow and deep P. The plot on the right had no added P.

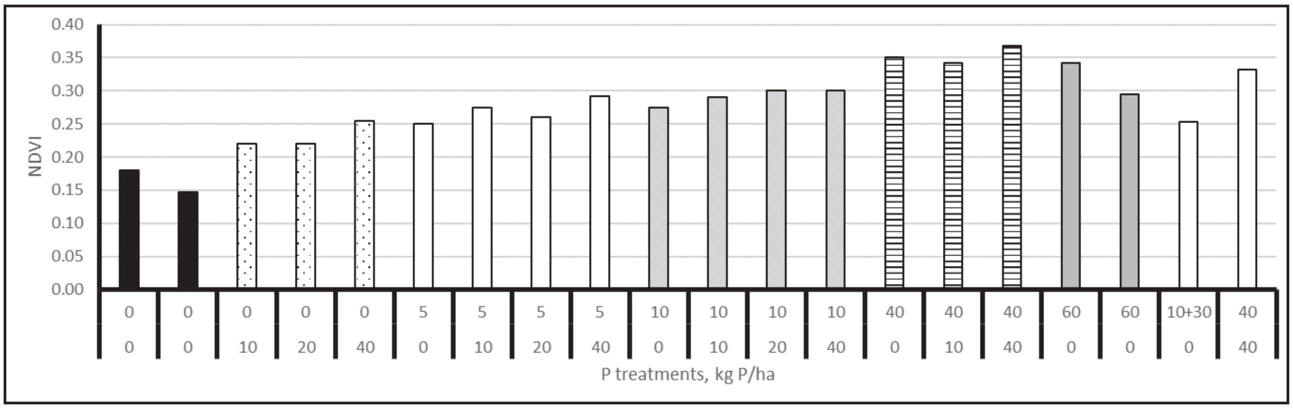

Figure 2. Effect of P rate and placement on vigour of Spartacus CL barley at early stem elongation, Pinnaroo 2021 (LSD (P=0.05)=0.03). Note: Top figures on X-axis labels are shallow P, bottom figures are deep P). First treatment is nil P and ripped, second treatment is nil P without ripping. Last two treatments are 10 kg P applied with the seed plus 30 kg P applied shallow and then dual P with deep trace elements.

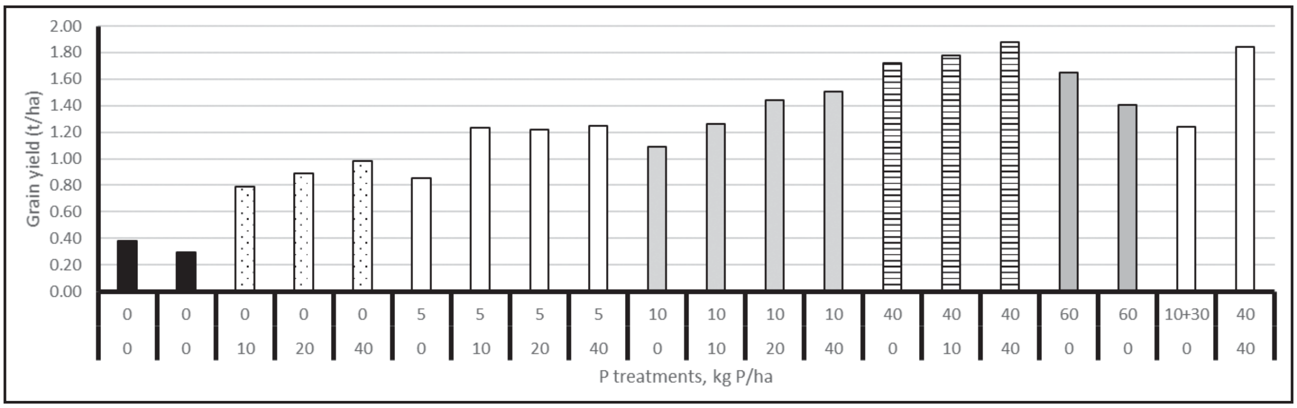

Figure 3. Effect of P rate and placement on grain yield of Spartacus CL barley at Pinnaroo in 2021. Note: Top figures on X-axis labels are shallow P, bottom figures are deep P (LSD (P=0.05)= 0.2). First treatment is nil P and ripped, second treatment is nil P without ripping. Last two treatments are 10 kg P applied with the seed plus 30 kg P applied shallow and then dual P with deep trace elements.

The trends in crop performance so far are that shallow P is more effective than deep P in the year of application for cereals in the southern zone. The trial at Brinkworth which had started in 2020 was re-seeded in 2021 with lentils. All plots received 10 kg P/h as a basal dressing and all treatments from 2020 yielded the same in 2021. This suggests that the residual benefits of deep P are conferring no additional benefits to crop performance in subsequent years. The Pinnaroo trial will be re-seeded with triticale in 2022 and the Brinkworth trial also with a cereal in 2022.

What does this mean?

- High rates of added P (at least 40 P kg/ha) were necessary to maximise barley yield on this deep sand with very few P reserves.
- Yields with deep P were generally lower than yields with shallow P at the same rate. To be a viable option for farmers, deep P needs to not only match the performance of shallow P, but also improve on it to justify the extra effort of placing P deep. So far, in 2 trials in SA and several others in Vic and NSW, crop performance in the first year with deep P has struggled to match shallow P.
- The residual benefits of deep P have not yet shown any properties which will improve it as an application strategy for treating P deficiency in broadacre crops of south-eastern Australia.
- The trials in this project are being maintained for several growing seasons to fully compare the residual benefits of both P placement strategies.

Acknowledgements

Thank you to Heath Nickolls and his family for the site at Pinnaroo and Leigh Fuller and his family for allowing us to run the trial at Brinkworth. Also to Sean Mason (Agronomy Solutions), Sam Trengove (Trengove Consulting) and Jeff Braun for identifying trial sites for us.

Persistence of the herbicide clopyralid in Eyre Peninsula soils

Mick Rose[1,4], Lukas Van Zwieten[1,4] and Amanda Cook[2,3,4]

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Location
Minnipa
Minnipa Agricultural Centre, S2
Rainfall
Av. Annual: 325 mm
Av. GSR: 241 mm
2021 Total: 406 mm
2021 GSR: 248 mm
Soil type
Red sandy loam
Paddock History
2020: Wheat
2019: Pasture
2018: Barley

Location
Poochera
P Carey
Rainfall
Av. Annual: 326 mm
Av. GSR: 247 mm
2021 Total: 283 mm
2021 GSR: 143 mm
Paddock History
2020: Volunteer pasture
2019: Wheat
2018: Volunteer pasture
Soil type
Grey highly calcareous sandy loam

Key messages

- **Clopyralid herbicide carryover may harm some legumes - a sensitivity ranking of species to the herbicide has been established.**
- **Clopyralid carryover from 2020 to early 2021 was significantly lower than the previous season at four EP sites and was unlikely to affect legume crops.**
- **Higher rainfall was the likely reason for more rapid clopyralid dissipation in the 2020-21 season than the previous season.**

Why do the trial?

The overall aims of this work are to determine the persistence of clopyralid herbicides over multiple seasons in different soil types and whether soil borne residues will injure subsequent crops.

Clopyralid has been identified by growers as a potential cause for plant-back issues constraining crop rotations on the Eyre Peninsula. It is difficult for growers and advisors to predict whether clopyralid residues will cause issues beyond the "label" plant-back period, because its behaviour depends on numerous site-specific factors, including soil (texture, chemistry, organic matter, microbial activity), stubble and climatic conditions. This is the second season of measuring clopyralid persistence in soils of the Eyre Peninsula. In the previous season (EPFSS 2020, p. 107) we found clopyralid residues at all sites 6 months after application (i.e. in Jan 2020) in the order of 2-5 ng/g (i.e. 0.002-0.005 mg/kg). Comparison of these concentrations to toxicity thresholds that we had previously derived for crop seedlings suggested a potential risk of injury to field pea and lentil crops. Here we report the persistence of clopyralid applied in the 2020 crop through to sowing of the 2021 crop at four different sites on the Eyre Peninsula and compare these results to the previous season.

How was it done?

The persistence of clopyralid was measured at four field sites during the 2020 growing season through until mid-2021. Site details, including soil characteristics and herbicide applications are provided in Table 1.

Four soil samples at two depths: 0-10 cm and 10-30 cm comprising of homogenised sub-samples were taken from quarter grids within a 100 m by 100 m georeferenced grid at participating farmer paddocks prior to sowing the 2020 winter crop (May 2020). Repeated soil sampling occurred throughout 2020 and 2021 after the in-crop application of clopyralid according to the following schedule: 1, 7, 21, 42, 84, 168, 364 days (d) after herbicide application. Soil samples were refrigerated and transported to NSW DPI, where they were dried at 40°C and then stored frozen until analysis for herbicide residues. Herbicides were extracted from soils, derivatised and analysed via GC-MS, with spike-recoveries for each soil type to ensure satisfactory sensitivity, accuracy and precision. Sample analysis results are presented for the samples taken 168 d after application, which were taken in January 2021.

What happened?

Six months after clopyralid application, the average clopyralid concentration in topsoil (0-10 cm) at three of the four sites was below 1.0 ng/g, which is the limit of quantification of the analytical method (Table 3). Residues were only consistently detected at low levels (average of 1.1 ng/g) at the SA3 Minnipa site. These values are significantly lower than the levels of clopyralid in samples taken at a similar time in the previous season, 6 months after application in 2019 (Table 3). Concentrations of clopyralid in the 10-30 cm soil depth were also below the limit of quantification (< 1.0 ng/g).

Table 1. Site locations, soil type and cropping details.

Site	Location	Soil type	Product	Date of Application	Product Rate (L/ha)
SA1	Minnipa	Red loam	Lontrel® Advanced 600	23 June 2020	0.04
SA2	Poochera	Grey alkaline sandy loam	Lontrel® Advanced 600	16 July 2020	0.03
SA3	Minnipa	Sand	Lontrel® Advanced 600	6 July 2020	0.045
SA4	Kimba	Sand	Lontrel® Advanced 600	16 July 2020	0.1

Table 2. Preliminary phytotoxicity dose thresholds (ng/g) for 20% shoot biomass reduction (ED20) for different crop species growing in Minnipa sandy loam spiked with clopyralid. Thresholds are for 21 d old seedlings (EPFSS 2020, p. 108).

Species	Clopyralid concentration (ng/g)
Lentil	3.4
Field pea	1.9
Lupin	54
Chickpea	6.2
Faba bean	25

Table 3. Concentration of clopyralid in topsoil (0-10 cm) at different sites taken in January 2020 (previous season results) and January 2021 (this season results), at approximately 6 months after clopyralid application.

Year of soil sample	ID	Location	Clopyralid application date	Clopyralid application rate (g/ha)	Rainfall 0-180 d post-spray (mm)	Mean clopyralid concentration @ 180d after application (ng/g) (n=3)	Higher risk crops
2020	SA1	Minnipa	25 June 2019	45	120	4.2	Lentil, Field pea
2020	SA2	Poochera	25 June 2019	30	75	3.8	Lentil, Field pea
2020	SA3	Minnipa	23 July 2019	27	108	4.9	Lentil, Field pea
2020	SA5	Mt Cooper	4 July 2019	24	117	3.3	Field pea
2021	SA1	Minnipa	23 June 2020	40	204	<1.0	-
2021	SA2	Poochera	16 July 2020	18	217	<1.0	-
2021	SA3	Minnipa	6 July 2020	27	158	1.1	-
2021	SA4	Kimba	16 July 2020	60	214	<1.0	-

The clopyralid concentrations in the January 2021 soil samples were lower than all legume toxicity thresholds (Table 2) and were unlikely to affect any crops during the 2021 season. This is in contrast to the clopyralid concentrations detected in the January 2020 samples, which may have impacted lentil or field pea seedlings sown at those sites.

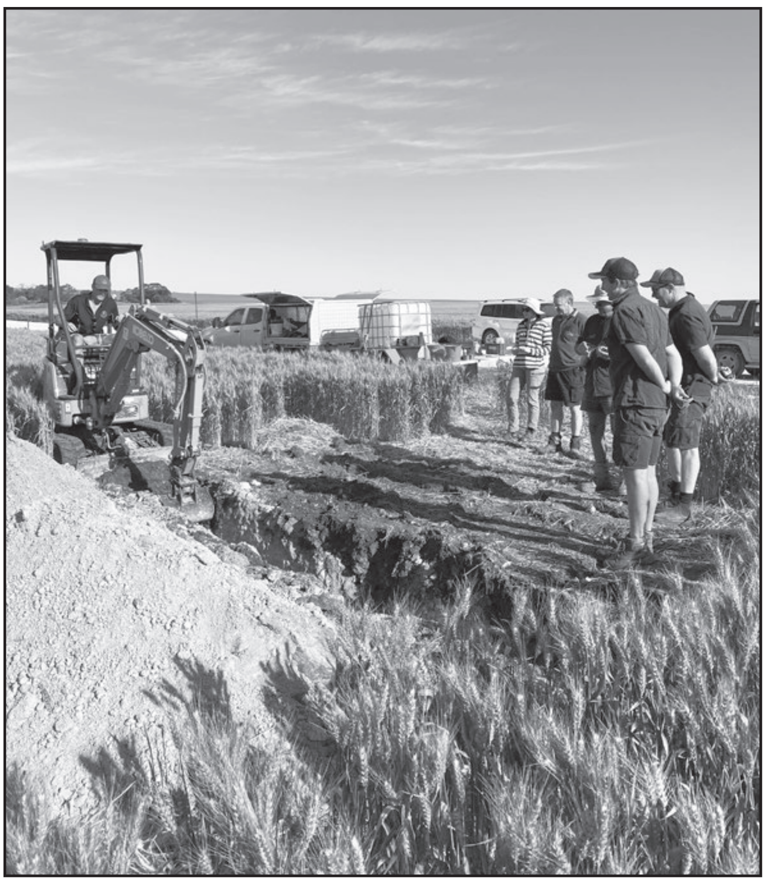
What does this mean?

The results from two seasons of monitoring clopyralid residues in the summer fallow prior to sowing demonstrate the dominant influence that rainfall has on dissipation of herbicides with residual properties like clopyralid. In the 2020-21 season, rainfall was 50-100% higher than the previous season at each of the sites. This meant that although residue levels were still detectable at 84 d after application (data not shown), residues had fully dissipated to negligible levels by 168 d after application.

This data reinforces product labels that emphasise the importance of rainfall, particularly in the summer months, for sufficient clopyralid breakdown to ensure protection for subsequent crops. Our data also shows that soil testing for herbicide residues can increase confidence in the decision-making process, particularly if crop toxicity thresholds are available for representative soil types. More information and advice for soil and plant testing for herbicide residues will be provided at the conclusion of this project in April 2022, with details available on the Soil CRC Website (see below for weblink).

Acknowledgements

This work has been supported by the Cooperative Research Centre for High Performance Soils whose activities are funded by the Australian Government's Cooperative Research Centre Program, as part of the 'Improved management of herbicide residues in soil' Project (Project 4.2.001). More information https://soilcrc.com.au/current-projects/#project_4_2_001 Thanks to Lee Kearney, Terry Rose, Scott Petty, Kelvin Spann, Ian Richter and Katrina Brands for technical support.



Digging a soil pit at Brimpton Lake for soil characterisation, 2021.

THE UNIVERSITY of ADELAIDE

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Eyre Peninsula

SOIL CRC
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How much incorporated organic matter do you need to boost crop production on a poorly performing white siliceous sand?

Nigel Wilhelm[1,2], Mel Fraser[3] and David Davenport[4]

[1]SARDI, Waite; [2]The University of Adelaide Affiliate; [3]SARDI, Struan; [4]Davenport Soil Consulting, Port Lincoln

Location
Brooker, Lower EP
Challinger family

Rainfall
Av. Annual: 399 mm
Av. GSR: 315 mm
2019 Total: 320 mm
2019 GSR: 294 mm
2020 Total: 423 mm
2020 GSR: 330 mm
2021 Total: 415 mm
2021 GSR: 313 mm

Yield
2019 Potential: Wheat - 3.7 t/ha (French/Schultz)
2019 Actual: 3.8 t/ha
2020 Potential: Canola - 3.3 t/ha (French/Schultz)
2020 Actual: 1.2 t/ha in the best part of the trial.
2021 Potential: Wheat - 4.3 t/ha (French/Schultz)
2021 Actual: 3.2 t/ha in the best part of the trial

Paddock history
2019: Wheat
2018: Wheat

Soil type
White siliceous deep sand

Soil test
Low levels of organic matter and K, Cu reserves. Severe repellency

Plot size
20 m x 6 rows x 1-3 reps

Trial design
Partially randomised complete block

Yield limiting factors
Ryegrass (moderate), repellency (severe), low fertility (severe), compaction (moderate)

Key messages

- **Incorporating high rates of lucerne pellets into a poorly performing siliceous sand by spading caused a substantial boost in crop production over the first 3 years. The first couple of t/ha of lucerne had little impact on crop yields and rates more than 15 t/ha also had little further impact. Within these two extremes, yields increased steadily with increasing rates of incorporated lucerne.**
- **A very cheap source of N-rich organic matter and mode of incorporation will be necessary before this approach will be profitable.**
- **Incorporating fertiliser which supplied nitrogen (N), phosphorous (P), potassium (K) and sulphur (S) performed as well as an equivalent rate of incorporated lucerne for both all three crops.**

Why do the trials?

Crop production on poorly performing sands can be substantially improved by incorporating N-rich organic matter (OM) well below the cultivated layer. However, most of the research into this approach has involved only one or two rates of OM, and those rates have tended to be high (10-20 t/ha) because the research has been testing proof of concept rather than trying to define the lowest rates which are effective or feasible. For example, a trial at Murlong on eastern EP is testing the impact of lucerne incorporated by deep ripping or spading on crop production but only one rate of 5 t/ha has been used. See the latest article in this EPFSS for more details of the Murlong trial, "Ameliorating a deep repellent sand at Murlong four years ago still increased wheat performance in 2021".

The aim of the trial reported here was to map the response of crops to increasing rates of incorporated lucerne pellets to better inform economic evaluation of the approach. This report summarises crop performance over the first three years since incorporation of the lucerne.

How was it done?

A site of poorly performing deep (more than 50 cm) white siliceous sand was found on the Challingers' property at Brooker on the lower EP. Analysis of the profile showed it was low in OC, N, K and Cu, especially below 10 cm but had moderate P and high S status. The surface was severely water repellent and the site had a very high population of herbicide resistant annual ryegrass.

The trial was set up in 2019 by incorporating multiple rates of lucerne pellets with a spader prior to seeding. Lucerne pellets were spread evenly across the surface of 20 x 2 m wide plots prior to rotary spading to 30 cm in early May 2019. Nine rates of lucerne pellets were used ranging from 0 to 20 t/ha.

There was also an unspaded treatment which received no lucerne (unspaded control) and a further treatment which had fertiliser broadcast evenly over the plot area prior to spading to supply the same amounts of N, P, K and S as in 4 t/ha of lucerne.

In response to very low soil K levels, potassium was surface applied in all three years to half of every plot, in a randomised split plot design, to additionally test crop responses to applied K. In 2019, K was applied mid-season and prior to seeding in 2020, both as 100 kg/ha of muriate of potash. In 2021, 150 kg/ha of muriate of potash was broadcast onto sub-plots the day after seeding. The same sub-plot for all main plots was treated with K in all 3 years.

Six of the main treatments were replicated three times to allow analysis with standard ANOVA models (both controls plus the 4, 8 and 15 t/ha of lucerne and fertiliser only treatments). Standard curve fitting models were used to investigate the effect of lucerne rate on crop production using all sub-plots in the first two years and only the no K sub-plots in 2021 (because added K partially compensated for the response of wheat to incorporated lucerne in 2021).

Starter N and P fertiliser were used for all treatments at sowing to simulate commercial practice, but extra N and P were applied to nil and low lucerne treatments in the first two years. A similar approach was taken for mid-season applications of N; for applications to the first two crops, sulphate of ammonia rates were reduced as lucerne rate increased in recognition that high rates of lucerne also supply high rates of N. In 2021, the same basal fertilisers were used for all plots because pre-seeding soil tests showed fertility was similar for all treatments. SOA was applied at 200 kg/ha across the whole trial mid-season to top up 120 kg/ha of SOA applied before seeding and 60 kg N/ha during seeding.

Razor CL wheat was seeded on 11 May 2019, plots were re-sown with 44T02 TT canola on 20 May 2020 and Hammer CL wheat was seeded on 10 June 2021 @ 100 kg/ha with 4 L/ha of SE14 wetter jetted into seed rows.

Establishment, growth, grain yield and quality were assessed in all three crops.

What happened?

Crop establishment in the first two crops was poor, especially in unspaded plots and in low lucerne rate treatments (data not shown). Water repellency has contributed to poor crop establishment, but we suspect other factors have been at play as well, such as K deficiency and herbicide residues. In 2021, seeding was delayed by the dry start to the season but seed bed conditions in early June were quite good, and with a wetting agent in the seed row, wheat establishment was solid and even across all treatments. Plant populations averaged 123 plants/m^2 across all treatments.

Ryegrass was severe in all years and competed heavily with the wheat crop in 2021 in many plots, despite several control attempts from seeding onwards.

Growth of wheat and canola throughout each season in the first two years was stronger with increasing rates of incorporated lucerne and grain yields followed a similar trend. In 2019, wheat showed no clear response to K despite low reserves in the soil which may be due to wheat being tolerant to low soil K or because K was applied too late in the season to be fully effective. In 2020, grain yields of canola increased on average by 0.16 t/ha with added K, regardless of lucerne rate.

In 2021, wheat growth during the season was not improved by increasing rates of incorporated lucerne but a response to added K was very clear. At flowering, wheat dry matter averaged 4 t/ha without K (regardless of rate of incorporated lucerne) but averaged 6 t/ha with added K across all lucerne treatments. Wheat vigour in 2021 was very poor in plots which had not been spaded in 2019 (and hence had not received any lucerne) and averaged only 2.3 t/ha at flowering. Three years of adding K to the same sub-plot of each main plot barely increased K concentrations in the whole shoots of wheat at flowering in 2021 (from 0.84 to 0.95 %) despite increasing dry matter by about 50%. Concentrations of other nutrients in flowering shoots of wheat were barely affected by treatments and were generally in the adequate range.

Figure 1 shows that grain yield for all crops increased as the rate of lucerne increased. Wheat in 2019 only showed some sign of levelling out as rates exceeded 15 t/ha, but for canola, there was little increase in yields above 8 t/ha of lucerne, applied the year before. The rate of increase in wheat yield in 2021 with previously incorporated lucerne was only approximately one-third of the rate recorded in the first year. These increases in crop performances with incorporated lucerne occurred despite the lower rates receiving more N and P over the first two seasons.

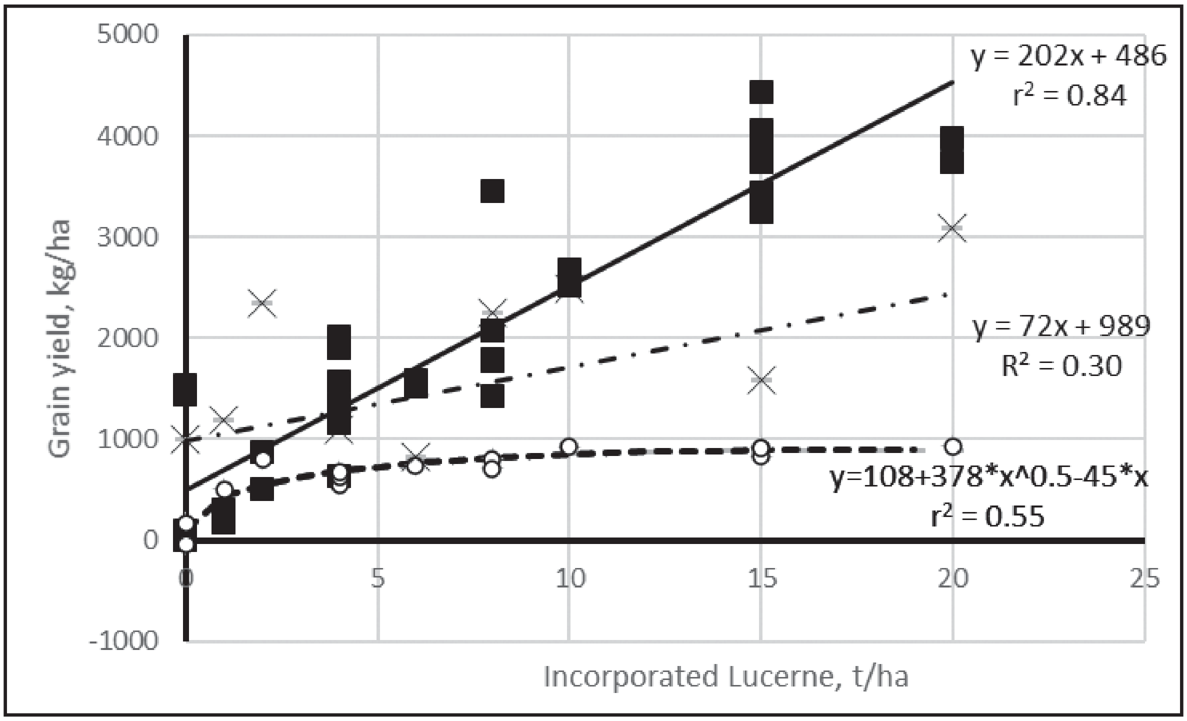

Figure 1. Increasing rates of incorporated lucerne increased grain yield of wheat in 2019, canola in 2020 and wheat in 2021 at Brooker, lower EP. Solid squares are wheat in 2019 (all sub-plots used because there was no clear K response), hollow circles are canola in 2020 and asterixis are wheat in 2021 (only no K sub plots used in 2020 and 2021 because there was a K response in both years).

Table 1. Effect of incorporated lucerne or fertiliser on grain yield (t/ha) of wheat in 2019, 2021 and canola in 2020 at Brooker on lower EP.

Treatment	**Wheat in 2019**	**Canola in 2020**	**Wheat in 2021**	**Cumulative grain yield**
Unspaded control	0.03	0.07	0.86	0.96
Spaded control	0.50	0.19	1.32	2.01
Incorporated fertiliser1	1.44	0.31	1.82	3.57
Incorporated lucerne at 4 t/ha	1.33	0.51	1.72	3.56
Incorporated lucerne at 8 t/ha	2.10	0.78	2.05	4.92
Incorporated lucerne at 15 t/ha	3.90	0.73	2.02	6.65
LSD (P=0.05)	*0.81*	*0.35*	*0.70*	

[1]Fertiliser supplied the same amounts of N,P,K and S as 4 t/ha of lucerne.

Amanda Cook, Marina Mudge, Katrina Brands, Ian Richter, Sue Budarick, Brianna Guidera, Craig Standley and Rhaquelle Meiklejohn doing the Resilient EP soil characterisations, October 2021.

Combining the trends from all 3 crops means that for every tonne increase in incorporated lucerne over the range of 0-15 t/ha, there was an increase in combined grain yield over the 3 seasons of approximately 0.32 t/ha. For the approach to break even, the cost of the lucerne (or another source of OM which provided similar benefits) would need to be 32% of the $ value of the extra yield gained over the 3 years, ignoring the costs of incorporation and the savings in fertiliser.

Incorporating fertiliser which supplied the same amounts of N, P, K and S as 4 t/ha of lucerne produced similar crop benefits over the 3 years (Table 1). However, neither treatment produced crops near the levels achieved with a much higher rate of incorporated lucerne. However, due to the lower cost of incorporated fertiliser compared to lucerne, it is a more financially attractive option at this stage, even with current fertiliser prices.

What does this mean?

- Incorporated lucerne resulted in substantially increased grain yields for at least 3 years after application into a poorly performing siliceous sand at Brooker on the lower EP. An important component of this increase was that both the mode of incorporation (rotary spading) and lucerne itself, improved crop establishment on this severely repellent sand. However, in 2021, wheat yields were increased by lucerne in the absence of any establishment benefits.
- This trial has shown that the benefits of incorporated lucerne increase with rate of application over a wide range. However, this rate of increase in yield is low compared to the cost of lucerne. The lowest 2 rates (1 and 2 t/ha) had little impact on crop yields and rates above 15 t/ha rarely further increased yields.
- The rates of incorporated lucerne used in many trials in recent research (10 - 20 t/ha) have been high. The results of this trial suggests that if lower rates of lucerne had been used in those trials, benefits to crop performance may have been smaller and less effective per unit input.
- Based on the results of this trial so far, a very cheap source of OM which provides the same benefits of lucerne to crop performance needs to be found before this approach will be cost effective.
- The spaded fertiliser treatment, which was designed to match the nutrients supplied in 4 t/ha of lucerne pellets, performed comparably to that treatment. This result is consistent with those from the trial at Murlong.
- K deficiency was a substantial constraint on this deep infertile sand and might be a poorly recognised issue on this soil type.
- This trial is now completed.

Acknowledgements

Thanks to the Challinger family for having the trial on their property and the Minnipa Agricultural Centre team especially Ian Richter, Craig Standley and Katrina Brands for implementing and maintaining this trial.

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An informed approach to phosphorus management in 2022

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

[1]Trengove Consulting; [2]Agronomy Solutions.

Key messages

- **Opportunities are available for reformed Phosphorus (P) rates under high fertiliser prices, but background knowledge is key.**
- **Gross margin analysis with P application rates is sensitive to soil available P, yield potential, fertiliser and grain prices.**
- **On Phosphorus responsive soil types return from fertiliser (P) investment is normally greatest and most stable with cereal phases.**

Why do the trial?

Fertiliser prices for P inputs have more than doubled since those used for the start of the 2021 season and for a three-year rolling price average. Currently these high fertiliser prices are coupled with high grain prices which offsets potential decreases in partial gross margins but in the current global scenario there is high uncertainty if grain prices will hold until the end of 2022. Higher input costs will naturally generate a mindset of simply reducing these input rates, but it is important to have background knowledge supporting these decisions so yield returns are not compromised. Combined with high fertiliser prices there have been the observations that P replacement programs have been inadequate in meeting phosphorus demand in some soil types. This paper aims to outline gross margin scenarios under a range of fertiliser and grain prices which could be vastly different to those set up in previous seasons. Importantly, the gross margin analysis will be performed using a range of different background P levels, soil type characteristics and yield potentials. Identification of likely paddock responsiveness and the variability in that response across the paddock is important. Several tools are available to assist with this determination which will be explained.

How was it done?

Through various research projects across the last 10 years both Agronomy Solutions and Trengove Consulting have obtained over 50 replicated field trials across the broadacre regions of South Australia, with most of them (> 40) being within the last 5 years. Most of these trials have assessed wheat and barley responses to P applications across a range of soil types. This dataset is highly valuable to assess gross margin scenarios under a range of conditions and the accuracy of various data layers in predicting P requirements.

For this paper, we have used the P rate which is associated with the greatest partial gross margin (PGM) return when factoring in fertiliser prices and returns from grain yields. This is calculated by fitting grain yield response curves derived from the P rate trials. We have used this dataset to test the accuracy of various data layers in predicting PGM under current conditions and from the most accurate data layers looked at the effect of changing fertiliser to grain price ratios for expected 2022 scenarios. Determination of PGM has used recent price trends of MAP at $1250, Wheat (APW) at $400 and Barley (F1) at $295. This dataset is concentrated in the Yorke Peninsula and Mid North regions of South Australia but is applicable to wider regions where soil types vary in alkalinity within paddocks driven by the presence of carbonates.

What happened?

Current soil P levels

Reviewing the large soil test database from PROC9176604 reveals the overall P status of the broadacre cropping regions of SA and VIC. Over 1300 soil surface samples were collected in 2019 and 2020 with both Colwell P and DGT P levels placed in deficient, marginal, and sufficient categories (Table 1) based on published data (Moody 2007, Mason et al. 2010). The PBI value for each site was used to determine a critical Colwell P position. Over half (52%) of sites were above critical DGT levels and as much as 73% of sites were sufficient in P using Colwell P. Using these soil test results to make a P recommendation for the sites sampled, shows that there are between 73% and 83% of sites that require < 10 kg P/ha to maximise yields. This proportion of sites is similar to what has been observed in the trial series associated with SAGIT project TC119 and TC221 discussed below.

Site soil characteristics driving P responses

The intensive field trial dataset produced by Trengove Consulting from 2019 to 2021 (SAGIT projects TC119 and TC221) where 33 replicated field P response trials have been established on various soil type x NDVI/grain yield zones is a powerful tool to test multiple data layers, including Colwell P and DGT P as discussed and other accessible data layers such as NDVI, pH and yield.

Table 1. Soil P test results (Colwell P and DGT P) through the southern broadacre cropping region sampled in 2019 and 2020 placed in deficient, marginal, and sufficient categories with associated determinations of required P rates to maximise yields.

		Sufficient	Marginal	Deficient	
		0 kg P/ha	0-5 kg P/ha	5-10 kg P/ha	> 10 kg P/ha
Colwell P	Number of sites	970	68	72	218
	% Split	73	5	5	16
DGT P	Number of sites	685	113	163	367
	% Split	52	9	12	28

Table 2. Summary of soil characteristics averaged across the 12 responsive P sites compared to 21 non-responsive sites through Yorke Peninsula and Mid-North regions of SA. PGM was calculated based off MAP at $1250, Wheat (APW) at $400 and Barley (F1) at $295.

Response category	Number of sites	P rate at max PGM (kg/ha)	pH ($CaCl_2$)	Colwell P (mg/kg)	PBI	DGT P (ug/L)	Colwell P/PBI	pHn NDVI
Significant ($P < 0.05$) (response to Phosphorus)	12	20	7.56	28	91	26	0.42	9.3
Non-significant ($P > 0.05$) (no response to Phosphorus)	21	0.3	6.61	45	60	94	0.91	6.6

Of the 33 sites, 64% recorded non-significant ($P>0.05$) responses to applied P (Table 1), leaving 12 with positive responses. Of these 12 responsive sites, at current prices the average P rate required to maximise PGM was 20 kg P/ha which highlights the continued importance of identification of P responsive soil types. Responsive soil types are characterised by soil pH ($CaCl_2$) between 7.5-7.8, higher PBI values (P retention) driven by the presence of soil carbonate and low comparative NDVI values (Table 2).

Relationships between the P rate at maximum PGM at each trial site and several data layers were used to find the layer(s) that most accurately predict P responsiveness at each site. Of the soil P tests, DGT P ($R^2 = 0.72$) was superior to Colwell P alone ($R^2 = 0.44$), at identifying sites where high P rates would produce high PGM's at current pricing and where reduction in P rates would not cause a decrease in PGM (data not presented). However, where Colwell P is combined with PBI (Colwell P divided by PBI) the Colwell P relationship improves to $R^2 = 0.73$, highlighting the importance of including PBI with Colwell P interpretation and measuring PBI at the same or similar intensity as Colwell P if that soil test is used for soil P mapping.

The most accurate combined data layer to provide a P rate requirement for max PGM was an index of the soil pH and NDVI at approximately GS30 (Figure 1). The index divides soil pH with the NDVI normalised to the paddock average. Areas that have high pH and low NDVI are typically highly P responsive, the level of response declines as pH decreases and historical NDVI at GS30 increases. The higher soil pH coupled with poor early vigour (low NDVI) occurs in the presence of soil carbonate, higher PBI values and lower residual P. The index is yet to be tested on soil types where high PBI is driven by other soil attributes such as Al or Fe, where there is a tendency of soil pH to be < 6 in these soils (e.g., Ferrosols on Kangaroo Island). For these areas a normalised NDVI index alone could be appropriate, or if pH is still an important factor, combining the data layers in a different index such as pH times by nNDVI, where the lower values are more likely to be responsive to P however, this needs further investigation. A case study of a paddock associated with the SAGIT project TC221 using this method is presented later in this paper.

Partial gross margin analysis for fluctuating fertiliser and grain prices

While there is some clarity with fertiliser prices for the 2022 season there is difficulty in predicting the grain price towards the end of 2022. At current grain prices the identification of P responsive sites still pays but what happens if grain prices fall? Using an accurate data layer (DGT P or pHnNDVI) we can present the influence of changing fertiliser and grain prices on optimal P rates for max PGM (Table 3). Based off 2021 fertiliser prices as a comparison and expected 2022 prices this analysis suggests economic P rates will be slightly less than half of that required in 2021.

Opportunities for 2022 - Time of Sowing (TOS)

Recent SAGIT funded project (AS216) outlined the effect of TOS on P requirements through trials established on P responsive sites between 2017 and 2018 due to the prevalence of earlier sowing times. Results outlined that if adequate soil moisture was present in April for sowing, P rates can be reduced without any impact on yield.

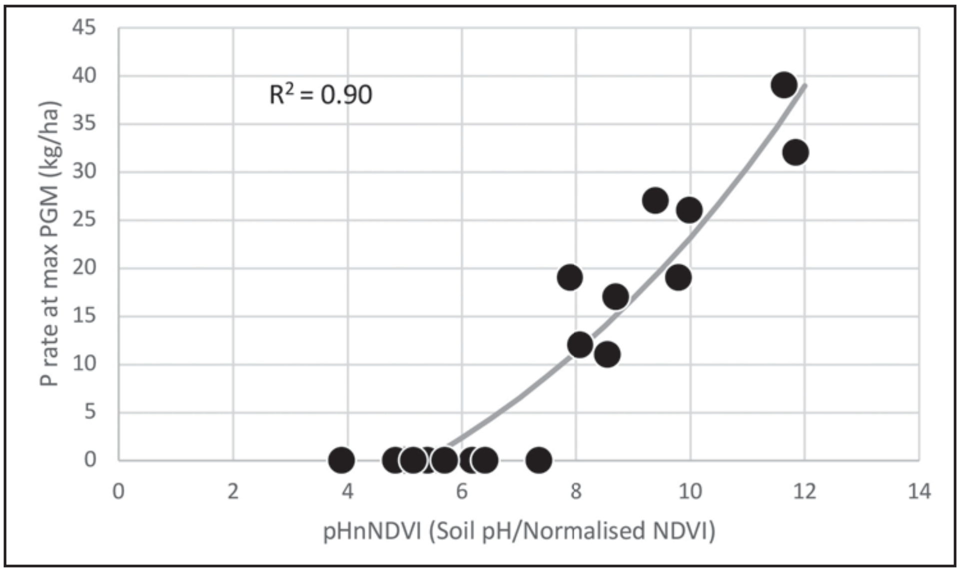


Figure 1. Relationship between the P rate associated with max PGM for P response trials (2019-2021) pHnNDVI.

Decile 1 Grain prices: Wheat (APW1) - $214t, Barley (F1) - $165

MAP ($/t)	pHNNDVI					Soil DGT P				
	4	6	8	10	12	> 150	100	50	30	< 20
$500	0	3	11	19	28	0	4	16	28	40
$750	0	1	7	13	19	0	3	12	21	30
$1,000	0	1	5	10	14	0	2	9	16	24
$1,250	0	0	4	7	10	0	1	7	12	18
$1,500	0	0	3	5	7	0	1	5	9	13

Decile 5 Grain prices: Wheat (APW1) - $275t, Barley (F1) - $230

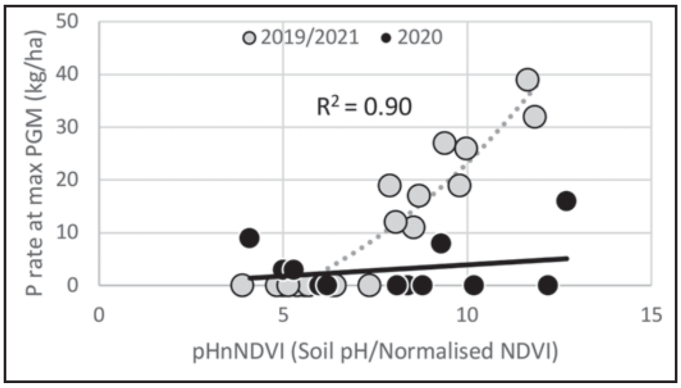
MAP ($/t)	pHNNDVI					Soil DGT P				
	4	6	8	10	12	> 150	100	50	30	< 20
$500	0	5	16	26	36	0	6	20	34	47
$750	0	2	10	18	25	0	4	15	26	38
$1,000	0	1	7	13	19	0	3	12	21	31
$1,250	0	1	6	10	15	0	2	10	18	25
$1,500	0	1	4	8	12	0	2	8	14	21

Decile 9 Grain prices: Wheat (APW1) - $332t, Barley (F1) - $293

MAP ($/t)	pHNNDVI					Soil DGT P				
	4	6	8	10	12	> 150	100	50	30	< 20
$500	0	8	20	31	42	0	9	23	37	51
$750	0	3	12	21	31	0	5	18	31	44
$1,000	0	2	9	16	24	0	3	14	25	36
$1,250	0	1	7	13	19	0	3	12	22	31
$1,500	0	1	6	11	16	0	2	10	18	26

Table 3. Sensitivity analysis of optimal P rates required for max PGM (kg/ha) for moving MAP prices at three decile grain prices (1, 5, 9) using either the pHnNDVI index or DGT P as a guide of deficiency (see Figure 1). Grain price deciles from 2010 onwards, source: Mercado.

Figure 2 and Table 4. Influence of high rainfall and high soil moisture at the 2020 sites compared to 2019 and 2021 and the impact of lower P requirements at P deficiency indices.



Site	Year	Rainfall to May (mm)	Rainfall for April (mm)
Koolunga	2019	13	4.4
Bute	2019	9.1	3.2
Brinkworth	2020	180	64
Bute	2020	119	67
Kybunga	2020	154	78
Crystal Brook	2021	29	2.6
Spalding	2021	43	4.4
Hart	2021	42	10

This benefit diminished if either there was low moisture in April or sowing times moved to mid-May and beyond, with June sowing times producing linear but relatively flat uneconomic responses. Under high soil moisture and warm temperatures crop root systems develop effectively and therefore exploration of residual P is high, placing less reliance on fertiliser P inputs. Diffusion rates of P in these conditions are also optimised. Data from Trengove Consulting supports this theory as the 2020 field trial data set, sown early May under good moisture revealed a lower pHnNDVI with optimal P rate relationship (Figure 2) compared to 2019 and 2021 with dryer conditions and later sowing (Table 4). This is a potential option for 2022 if wet conditions in April prevail.

Case study

One paddock included in the trial series associated with the SAGIT project TC221 is located at Crystal Brook in the Mid North of South Australia. This paddock was selected to be part of the SAGIT project to evaluate the methodology of predicting P response using data layers and investigate a range of long-term P management strategies. Two data layers that are readily available were used to predict the P response at four sites in the paddock and P rate trials were established. The data layers used included, pH (calibrated to $CaCl_2$) captured using a Veris pH mapping machine, taking approximately 8 samples per ha, and satellite imagery captured at approximately GS30 in a wheat crop in 2020 (Figure 3). These two data layers were used to calculate the pHnNDVI (as explained above) to identify four trial sites with different predicted P responsiveness. This process was repeated at a paddock at Hart and Spalding. A similar process was used in 2019 and 2020 to select sites in the previous SAGIT funded project TC219 to predict the P response across five paddocks.

At each of the four sites in each paddock a P rate response trial was established with rates of P up to 90 kg/ha (409 kg MAP/ha). Very high rates of P are required to find the maximum yield on very high P demand sites. In the previous project the maximum rate was 50 kg P/ha, and some sites were still responding even at this level. At the site which was predicted to have the largest response a larger trial was established to investigate long-term (3 year) management strategies. This site included two treatments where 75 kg of P was broadcast in front of the seeder either as MAP or Chicken litter, these treatments also had 15 kg P/ha as MAP applied in the furrow at seeding.

The grain yield response at each of the four sites in the paddock at Crystal Brook is shown in Table 5. The sites with low predicted P response (site 22 and 24) did not have any response to P fertiliser, the nil treatments produced the same amount of grain yield as the 90 kg P/ha treatments. At the site which was expected to have a moderate response there was also no response to P fertiliser. At this site there was significant variation in soil test results between replicates, with DGT-P soil test levels ranging from 38 (rep 1) to 151 (rep 3). This level of variation explains why this site did not have a significant P response even though it was expected and highlights short scale variability that can be difficult to map and manage. At site 25, the most responsive site, significant yield responses were observed all the way up to 90 kg P/ha, indicating a highly P responsive soil. This is not to suggest that these rates were economic, for a current pricing scenario of $1,250/t for MAP and $295/t for barley 32 kg P/ha (145 kg MAP) was required to maximise partial gross margin at site 25. The treatments that had 75 kg P/ha broadcast in front of the seeder followed by 15 kg P/ha below the seed, produced similar grain yield to the standard 90 kg P/ha applied below the seed. This suggests that the broadcast P was readily available. In previous trials this has not been the case, and this needs further investigation.

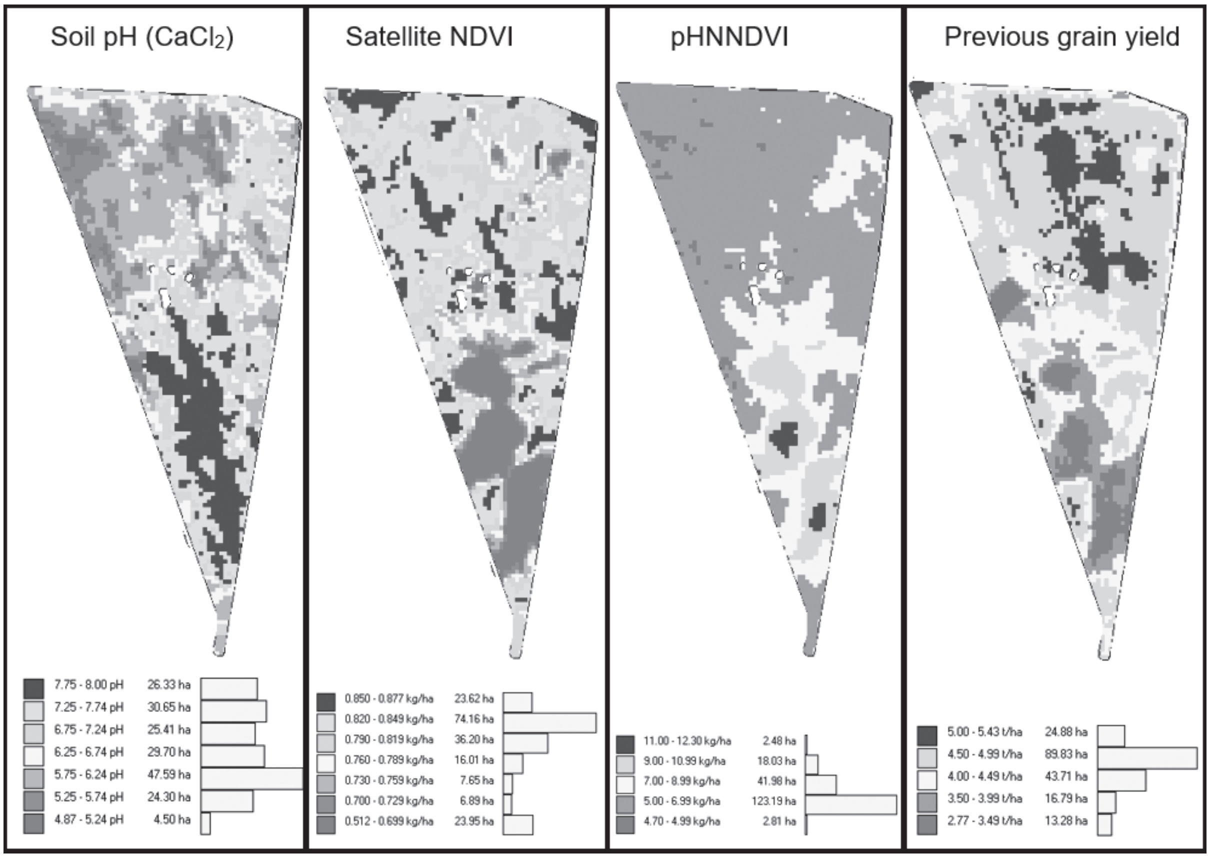


Figure 3. Soil pH, Satallite NDVI of wheat crop in 2020, approximately GS30, calculated pHnNDVI (pH / normalised NDVI) and historical grain yield for a paddock at Crystal Brook.

Table 5. Grain yield (t/ha) for the four P rate response trials at Crystal brook in Compass barley in 2021, treatments with different letters are significantly different with in a site where the P value is < 0.05.

Site	**22**	**23**	**24**	**25**	
Expected response	**Low**	**Moderate**	**Low**	**High**	
P rate (kg/ha)					
0	2.70	4.32	3.98	2.71	f
7.5	2.47	4.36	3.83	3.41	e
15	2.77	4.44	3.78	3.84	d
22.5	2.51	4.38	3.58	4.10	c
30	2.56	4.35	3.64	4.22	c
50	2.94	4.44	3.65	4.54	b
90	2.73	4.31	3.54	4.74	a
CL				4.75	a
Spread MAP				4.75	a
P value<0.05	*0.318*	*0.946*	*0.155*	*<0.001*	

Table 6. Results from four modelled scenarios where high grain prices are coupled with a range of MAP prices and fertiliser strategies.

Scenario	Grain Price	MAP Fert Price ($/t)	Min MAP fert rate (kg/ha)	MAP fert rate range (kg/ha)	Av. MAP fert rate calculated (kg/ha)
1	Decile 9	750	0	0-200	44
2	Decile 9	1500	0	0-130	24
3	Decile 9	1500	20	20-130	32
4	Decile 9	750	Replacement from previous yield	50-200	90

Soils

The yield data from the four trials in isolation is useful for measuring site specific responses within a paddock. But it becomes more powerful when a response curve is generated for each of the 33 sites, and these are put into a database to generate response curves based on the data layers used for site selection. From this database we can predict the P response based on pHnNDVI for each of the sites and use that data to generate partial gross margins. This can then be extrapolated to every point in a paddock to generate a P fertiliser application map.

Table 6 shows the results from four modelled scenarios where high grain prices are coupled with a range in MAP prices and different fertiliser strategies. In scenario 1 using MAP fert price of $750/t, the optimum P rate ranges from 0 to 200 kg MAP/ha, averaging 44 kg/ha for the paddock. Increasing fertiliser price to $1,500/t in scenario 2 reduces the average MAP rate to 24 kg/ha.

In some scenarios, we may prefer to ensure that all areas receive a minimum rate of starter fertiliser, rather than receiving nil in the areas that are predicted not to be P responsive. In scenario 3 the minimum fertiliser rate is set to 20 kg MAP/ha, so that no zone receives less than this. This increases the average fertiliser rate for the paddock from 24 to 32 kg MAP/ha.

Scenario 4 is an example of a long-term strategy, where the minimum fertiliser rate for any given area is set by calculating P replacement based on the previous year's yield map. This strategy ensures P reserves are not being 'mined' on any soil, but being maintained on non-responsive soils, with higher rates still targeted to the P responsive soils. Each location receives whichever of the two rates is higher, the rate calculated from pHnNDVI or yield replacement. Scenario 4 increases the average rate to 90 kg MAP/ha, compared with 44 kg/ha in scenario 1.

Given record high P fertiliser prices for 2022, scenarios 2 and 3 provide an opportunity in this paddock for reducing average MAP fertiliser rates by 58-66 kg MAP/ha compared with scenario 4, a saving of $87-99/ha.

What does this mean?

High P fertiliser price is currently slightly offset by high grain prices but with uncertainty if these grain prices will continue into 2022 it is advised to revise P applications in 2022 due to significant impacts on optimal P rates required to maximise gross margins. Several data layers are available to assist with identifying areas where P rates can be safely cut back and those that will still return a profit with increased grain yields through adequate P applications.

Acknowledgements

The research undertaken as part of this project was made possible by the significant contributions of growers through both trial cooperation and the support of the GRDC and SAGIT, the authors would like to thank them for their continued support. We would like to acknowledge the growers involved in SAGIT funded project TC219 and TC221 and SAGIT for funding support for projects AS216, TC219 and TC221.

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Eastern Eyre Peninsula soil management project

David Davenport[1] and Josh Telfer[2]

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Key messages

- **Soil amelioration through ripping with inclusion plates or clay delving has supported the development of plant cover on areas with a history of wind erosion.**
- **Mixed species pasture systems can present an opportunity to increase soil cover and feed levels.**
- **Summer cover crops can deliver higher levels of soil cover over summer, providing increased soil protection and can support soil amelioration practices, such as ripping with inclusion plates.**
- **Compared to stubble treatments, summer cover crops can lower soil water levels when growing, but soil water levels measured post germination showed mixed results. Even where soil water is lower, there may not be a negative impact on biomass or yield in the subsequent crop as shown in 2021.**

Why do the trial?

In 2021 the north-eastern area of Eyre Peninsula had been affected by four years of below average rainfall conditions. On water repellent sands and sodic, sandy clay loams, the lack of rain made it difficult to grow enough biomass to provide sufficient soil cover to prevent soil erosion. Amelioration of water repellent sands by clay application have been constrained due to the high costs involved. There were also concerns about increasing soil erosion risk when using more cost-effective options such as ripping with inclusion plates.

A few farmers have been experimenting with summer cover crops to increase soil protection but there are questions and concerns about the impact of reduced soil water on following winter crops. Mixed species winter pastures are also gaining farmer interest but with limited uptake to date.

This project aimed to provide support to landholders in the north-eastern area of the EP to address bare areas with repeated soil erosion events. This was done by providing funding to trial a range of practices to increase soil cover and providing technical support to deliver and evaluate these practices.

How was it done?

Funding was provided to Agricultural Innovation & Research Eyre Peninsula (AIR EP) by the Eyre Peninsula Landscape Board. A committee was established to steer the project and included representatives from the Buckleboo Farm Improvement Group, and the Roberts-Verran and Franklin Harbour Agricultural Bureaus. A target range of activities were identified and expressions of interest from farmers were sought for grant funding.

Funding constraints did not allow for detailed replicated trials however, monitoring to support extension activities was conducted with some soil data and a pictorial record of results collected. Farmers also collected their own data.

Activities and monitoring included:

1. Soil amelioration - data was collected on the impacts of ripping with inclusion plates on a sandy paddock between Arno Bay and Cleve. The landholder conducted ripping with inclusion plates on areas with and without erosion and double sowed eroded areas.

   Ripping was undertaken at a 15-degree offset to the sowing line. Anecdotal evidence from Western Australia suggests this improves uniformity of sowing depth. To reduce erosion risk there was no levelling post ripping which allowed for maximum surface cover and the maintenance of surface roughness that may have assisted in reducing wind speed at the soil surface. Plant numbers, plant biomass and yield data were collected on both the treated and untreated areas and these were compared to unripped sites that had not been subject to soil erosion.
2. Summer cover crops - to assess the impact on subsequent winter crops, soil water levels with and without summer cover crops were compared on three sites (Kimba, Arno Bay/Cleve and Wharminda). Soil sampling was conducted to 70 cm depths in January, March-April and at germination. Samples were weighed, dried for a minimum of 48 hours at 50 degrees Celsius and then reweighed. Soil gravimetric water (percent water) was converted to volumetric water (mm) using an estimated soil bulk density. Pre-seeding soil nitrogen data was also collected at each site and yield data was collected on the Wharminda site.

3. Mixed species pasture systems - three paddocks were sown to a range of mixed species pastures at Elbow Hill (Table 1). Stock exclusion cages were established following germination and prior to grazing at two locations under each species mix. A pictorial record was collected throughout the season with dry matter data collected from each cage in July and September 2021.

What happened?

1. Soil amelioration

- Where ripping was undertaken without additional levelling operations there was very limited wind erosion or drift observed. One site was sown in very strong wind conditions and even on previously eroded areas that had been ripped there was very little drift observed.
- Landholders considered that ripping at a slight angle to the seeding line appeared to improve management of sowing depth.
- On the Arno Bay site, plant numbers were highly variable in both ripped and unripped treatments with no significant differences between the treatments.
- Plant biomass and yield was generally higher on ameliorated treatments with one landholder reporting header yield data showed delved and ripped areas yielding between 2-2.5 t/ha compared to less than 0.5 t/ha on untreated areas.

2. Summer covers

Soil water measured in the January and March/April periods showed low levels of soil moisture on all sites (data not presented). At germination there was little difference in soil water between paired sites at the Kimba and Arno Bay sites. Soil water levels under the cover crop were lower than under the stubble cover at the Wharminda site (Figure 1).

Soil mineralised nitrogen at seeding was lower under summer cover crops on the Kimba and Arno Bay sites but higher on the Wharminda site (Table 2). There is no obvious reason for this as both of the Wharminda sites have been in a similar rotation for the previous two seasons.

Yield data was only collected on the Wharminda site and showed that despite lower soil water levels the cover site yielded as well as or better than the stubble site (Figure 2).

3. Winter mixed species pasture

On the Elbow Hill site mixed species biomass data showed great variability both within and between the paddocks (Table 3). Soil differences between sites may have had an impact with the landholder considering the Little Ducks paddock to be more productive than the other 2 paddocks. However, the dry September and early August visually appeared to impact on species such as plantain, kale and chicory more than other species. Despite this the landholder was very pleased with the results and reported higher levels of grazing than volunteer pastures. Also, the mixed species persisted longer and made use of later rains in spring when volunteer pasture had hayed off. There may also be beneficial soil impacts with the tillage radish forming larger tap roots that may improve the poorly structured soils in these paddocks.

Soils

Table 1. Elbow Hill species mixes sown for winter 2021.

Paddock name	Base species mix
Little Ducks	Smart radish, oats, vetch, plantain, field peas
Fox Hole	Tillage radish, barley (CL Spartacus), vetch, chicory, field peas
One Pole	Smart radish, barley (CL Spartacus), vetch, kale, field peas

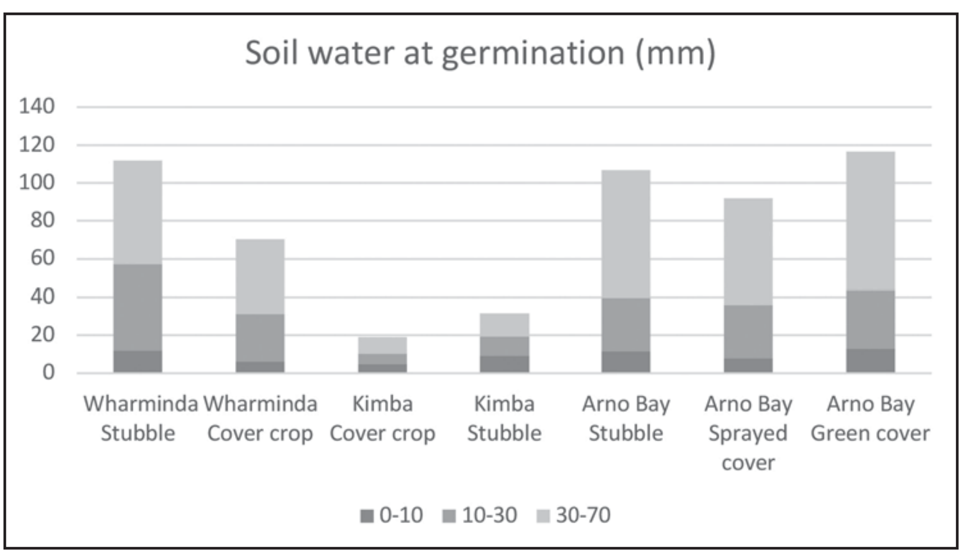

Figure 1. Soil water at germination in autumn 2021. Note that higher rainfall occurred in April at the Arno Bay, and Wharminda sites than at Kimba. This impacted on soil moisture levels and sowing dates.

Table 2. Soil mineralised nitrogen at germination, autumn 2021.

Site	Nitrate N (mg/kg)	Ammonium N (mg/kg)
Wharminda stubble	11	5
Wharminda cover crop	21	33
Kimba stubble	20	1
Kimba cover crop	6	1
Arno Bay stubble	48	2
Arno Bay sprayed cover crop	14	2
Arno Bay cover crop	13	1

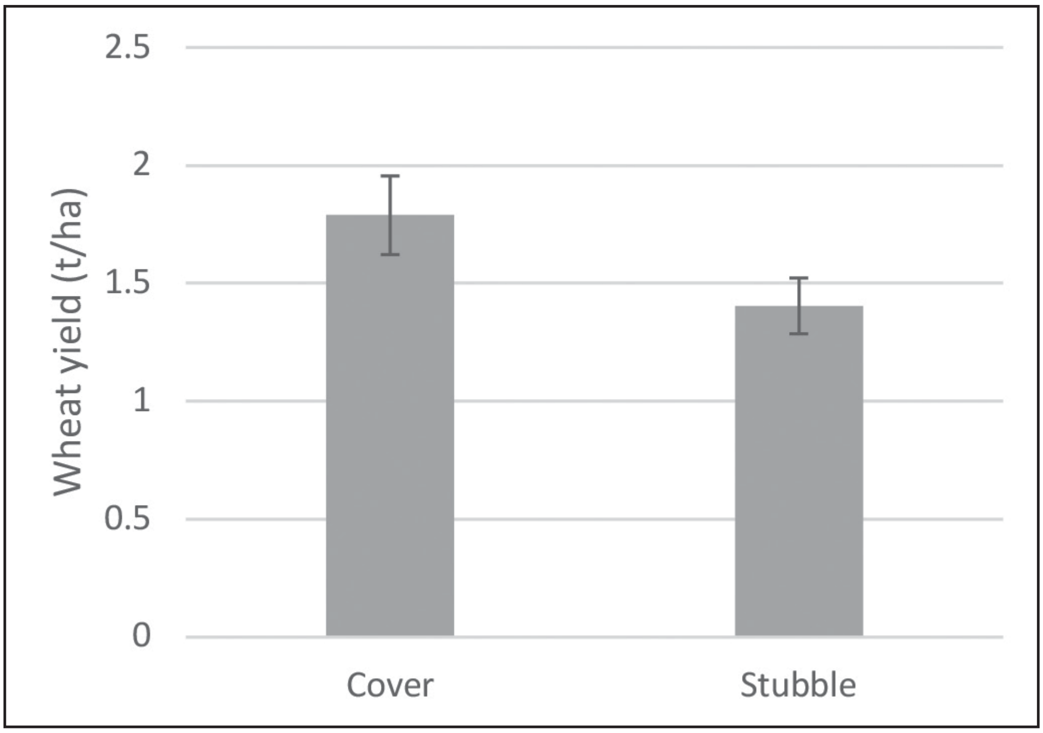

Figure 2. Wheat yield (t/ha) at the Wharminda site in 2021, error bars represent error of the mean.

Table 3. Winter mixed species biomass (t/ha) at Elbow Hill in 2021.

Site	Dry matter 9 July (t/ha)	Dry matter 11 September (t/ha)	Total dry matter (t/ha)
Little Ducks North	2.1	6.4	8.5
Little Ducks South	2.6	11.7	14.3
Fox Hole SW	0.7	4.7	5.4
Fox Hole SE	0.9	6.0	6.9
One Pole NE	0.8	4.6	5.4
One Pole W	1.7	3.4	5.1

What does this mean?

Although these studies require further validation there have been a number of conclusions and questions arising that include:

- Ripping with inclusion plates on light textured soils has been shown in other studies to increase yields that persist for a number of years. While concerns regarding the potential for wind erosion have been raised, this limited study has shown that ripping without levelling post ripping has resulted in no or limited erosion. Also, that the need to level to support control of sowing depth may not be as necessary if ripping is conducted at a slight offset to the sowing line.
- This study has suggested that the current view that a reduction in soil water following summer cover crops will have a negative impact on a subsequent winter crop is not always the case. Although all sites had lower levels of soil water under growing summer cover crops, differences in soil water were less obvious at germination. This could be due to covers providing a mulching effect, or improving water infiltration, or may be due to high rainfall in early winter. Even where there were clear measured differences in soil water, this did not seem to impact on biomass or yield. This study was only limited to measuring the total amount of soil water and not able to quantify differences in plant available water. However, it should be noted that this was a very limited study conducted over one season only. Also, this data should not be seen to support decisions on summer weed control as cover crops may have a different impact compared to summer weeds.
- Mixed species pastures appear to be an option to replace volunteer pasture phases in low rainfall environments. They appear to provide greater biomass, improved soil cover and grazing. Anecdotal reports suggest they also may support increased soil biological function and improve soil structure. Further research needs to be undertaken on the best mixes for different soils and climates and the most cost-effective pasture systems.

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LANDSCAPE SOUTH AUSTRALIA EYRE PENINSULA

AIR EP Ag Innovation & Research Eyre Peninsula

Brian Dzoma and Steve Jeffs applying soil additives at the Minnipa calcareous soil trial, March 2021.

Section Editor:
Nigel Wilhelm
SARDI Minnipa Agricultural Centre/ Waite

Section 3

Farming Systems

Improving the early management of dry sown cereal crops

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[1]SARDI, Minnipa; [2]University of Adelaide Affiliate

Location
Minnipa - Airport
Rainfall
Av. Annual: 325 mm
Av. GSR: 241 mm
2021 Total: 406 mm
2021 GSR: 248 mm
Soil type
Red sandy loam
Paddock History
2021: Scepter wheat
2020: PBA Butler Peas
2019: CL Spartacus barley
Plot size
12 m x 1.7 m x 3 replicates

Location
Streaky Bay - Kelsh
Rainfall
Av. Annual: 377 mm
Av. GSR: 303 mm
2021 Total: 428 mm
2021 GSR: 297 mm
Soil type
Red calcareous sandy loam
Paddock History
2021: CL barley
2020: Medic pasture
2019: Barley
Plot size
12 m x 1.7 m x 3 replicates

Key messages

- **Greater plant establishment was achieved with fertiliser placed 3 cm below the seed.**
- **Lower plant establishment occurred with urea placed with the seed.**
- **In 2021, dry sowing or sowing at the break of the season did not influence overall plant establishment, except at Cungena where dry sowing was better.**
- **In 2021, there was a yield increase of 0.1 t/ha at Cungena and 0.2 t/ha at Streaky Bay for dry sowing compared to sowing at the break of the season.**
- **New long coleoptile wheats may provide another option where soil moisture is available up to 10 cm deep for early plant establishment and vigour.**
- **Sowing seed at a depth to utilise soil moisture for germination is important.**
- **Dry sowing early with barley has been a good management option in previous seasons.**

Why do the trial?

With larger seeding programs, increased summer weed control to conserve soil moisture and more variable autumn rainfall patterns, many growers Australia wide are continuing to dry-sow. More traditionally, growers may have previously 'dabbled a little' in dry-sowing and are observing with interest the successes and failures of dry-sowing systems.

On the upper Eyre Peninsula in 2017 and 2018, seed was placed in the soil for many weeks with limited soil moisture; some seed still germinated but the delayed plant emergence often resulted in low plant establishment. This raised questions by EP farmers and consultants about the soil factors which influence seed germination and establishment in dry conditions.

Research trials were established in 2019-21 to assess the impact of management on seed germination and establishment on three different soil types in field trials and pot experiments: a red loam [Minnipa Agricultural Centre (MAC)] and two grey calcareous soils (Cungena and Streaky Bay) for:

- Impact of fertiliser type (P and N) and fertiliser placement,
- Impact of practices, herbicides and seed dressings.

This article reports on field trials undertaken in 2021 at three sites.

Location
Cungena - Tomney
Rainfall
Av. Annual: 284 mm
Av. GSR: 239 mm
2021 Total: 380 mm (100 mm in November)
2021 GSR: 214 mm
Soil type
Grey calcareous sandy loam
Paddock History
2021: Scepter wheat
2020: Medic pasture
2019: Mace wheat
Plot size
12 m x 1.7 m x 3 replicates

How was it done?

Each site had two trials with CL Razor wheat sown @ 72 kg/ha, aiming for 180 plants/m^2. The CL Razor wheat seed had 97% germination in the laboratory. The trials were sown with a small plot seeder on 26 cm row spacing with Harrington points and press wheels. The seeder had the ability to sow the fertiliser either with the seed or deeper (up to 11 cm), or the fertiliser could be split (50% with seed: 50% below the seed). The trials were sprayed with Trifluralin @ 1.5 L/ha, LI700 @ 300 ml/100L, and Weedmaster DST @ 1.5 L/ha (Streaky Bay only), at both times of sowing. Dry sown treatments were sown on 19, 20 and 21 April at Minnipa, Cungena and Streaky Bay respectively. Break treatments were sown at all sites on 26 May.

On 9 July at Streaky Bay and Cungena, and on 14 July at MAC, broadleaf weeds were sprayed with Lontrel @ 80 ml/ha and BS1000 @ 250 ml/ha.

The treatments in the trials at each site were:

Trial 1: Sowing (dry sown vs break/wet conditions) x fertilisers (9 treatments)

- Nil - Control (no fertiliser)
- 60 kg/ha DAP (diammonium phosphate, 18:20:0:0) with the seed
- 60 kg/ha DAP below the seed
- 80 kg/ha DAP with the seed
- 80 kg/ha DAP below the seed
- 55 kg/ha MAP (monoammonium phosphate, 10:22:0:1.5) and urea (5 kg N/ha to balance nitrogen with 60 kg/ha of DAP) with seed
- 55 kg/ha MAP with seed and urea below the seed (5 kg N/ha to balance nitrogen)
- 60 kg/ha DAP split; 30 kg/ha with the seed and 30 kg/ha below the seed (deep)
  Phosphoric acid (12 kg P/ha) and urea (11 kg N/ha) below the seed.

Trial 2: Management - Dry sown with 13 management treatments including long coleoptile wheats

In 2019 and 2020, management treatments of seeding depth influenced plant establishment more than any of the fungicide or herbicide treatments EPFSS 2020, p 33). In 2021 the management trial tested if new long coleoptile wheat varieties, which can be sown deeper and hence into better soil moisture, could be used in current farming systems for dry sowing and earlier plant establishment.

Seed was accessed from different sources and plant breeding companies. The seed was tested for germination in the laboratory and seed size, from which the seed weight for the targeted plant density was calculated.

- Nil - Scepter Control (no fertiliser) at normal depth 3.5 cm
- CL Razor with 60 kg/ha DAP below the seed at normal depth 3.5 cm
- Scepter with 60 kg/ha DAP below the seed at 3 depths - normal depth 3.5 cm, shallow 2.5 cm and deep 6 cm
- CL Spartacus barley at 3 depths - normal depth 3.5 cm, shallow 2.5 cm and deep 6 cm
- LRPB Bale sown at 10-11 cm - new long coleoptile awnless dual purpose wheat for hay and grazing
- AGT Calibre (RAC2721) at 11-12 cm - new long coleoptile wheat
- Halberd (77% germination) sown at 11-12 cm - older long coleoptile wheat variety
- Yitpi sown at 7.5 cm - older medium length coleoptile wheat variety
- Magenta sown at 7.5 cm - older medium length coleoptile wheat variety.

During the growing season the trials were assessed for plant establishment, early and late dry matter, grain yield and grain quality. Plant establishment was counted seven times from first emergence (10 May - 3 July), early dry matters were taken at 10 weeks (3-4 leaf stage) in the dry sown trials on 12 July, and with break sowing on 28 July. Late dry matter was taken on 20 October for all trials. The Minnipa site was harvested on 9 November, the Streaky Bay trial on 24 November and Cungena on 29 November.

What happened?

The 2021 season had average to below average rainfall for most regions on the upper Eyre Peninsula (EP) with a later than ideal seeding (late May/June) as little rainfall was received before 24 May. June and July rainfall were average on the upper EP resulting in full soil moisture profiles. September and October rainfall events were well below average resulting in moisture stress before flowering and during grain fill with shallow soils dying off across the region. Heavy rains occurred too late in early November to benefit crops but resulted in delayed harvesting and reduced grain quality. Streaky Bay had decile 6 growing season rainfall (April to October), with Cungena and Minnipa both a decile 4.

At all three trial sites, dry sown treatments with longer coleoptile wheats began emerging on 18 May. Dry sown fertiliser treatments began emerging on the 1 June. At all sites, break fertiliser treatments began emerging in the first week of June after significant rain on the 24 May.

Trial 1: Sowing x fertilisers

The 2021 season was a late break to the season but there was little rain between dry sowing and the break to the season. At the break the seeding conditions were ideal with good moisture levels and no drying of the topsoil before the next rainfall event.

Earlier dry sowing with CL Razor wheat increased establishment at all plant counts. Although final plant numbers were not different in 2021, dry sown treatments emerged slightly earlier at all sites and before the break of the season treatments.

The Cungena trial experienced some wind erosion due to strong wind events on 31 May which resulted in dry sowing plants being wind damaged and 'cut off' and an increase in sowing depth by 1-2 cm in the dry sown treatments due to the furrows filling with blown sand.

At all sites, sowing trial treatments began emerging on 1 June (Table 1), with the dry sown treatments having higher plant numbers than the 'break' treatment at all sites (Table 2).

In 2021, season break sowing had lower emergence at Cungena compared to the other sites (Table 2).

On 24 June, dry sowing of CL Razor wheat had slightly higher establishment with 108 plants/m^2 and sowing at the break having 102 plants/m^2 (Table 2). On 24 June, overall emergence over the 3 sites was 105 plants/m^2 which was much lower than the targeted plant density of 180 plants/m^2. The Cungena site had the lowest overall emergence with 96 plants/m^2, Minnipa red soil had 115 plants/m^2 and Streaky Bay had 104 plants/m^2.

In 2021, dry seeding did not make crops any more susceptible to fertiliser at seeding, however it must be noted in the period between dry sowing and the break to the season there was very little rainfall (less than 10 mm in March) to activate the germination process.

Urea and DAP fertiliser placed with the seed had lower crop establishment than those where the seed and fertiliser were separated (Figure 1). The treatments which separated the fertiliser from the seed had similar germination to nil fertiliser.

Dry sowing treatments produced higher late dry matter than sowing at the break at all sites in 2021. Minnipa had the greatest dry matter production compared to the grey calcareous soils. The highest dry matter occurred with 80 kg/ha DAP banded below the seed, and the lowest dry matter were with no fertiliser (data not shown).

Table 2. Plant establishment of CL Razor wheat at different times of sowing in 2021, averaged over 3 sites.

Date	Dry sowing	Break	*LSD (P=0.05)*
1 June	74 a	0 b	*7.3*
8 June	115 a	104 b	*7*
17 June	117 a	110 b	*6*
24 June	108 a	102 b	*4*
29 June	106 a	93 b	*9*

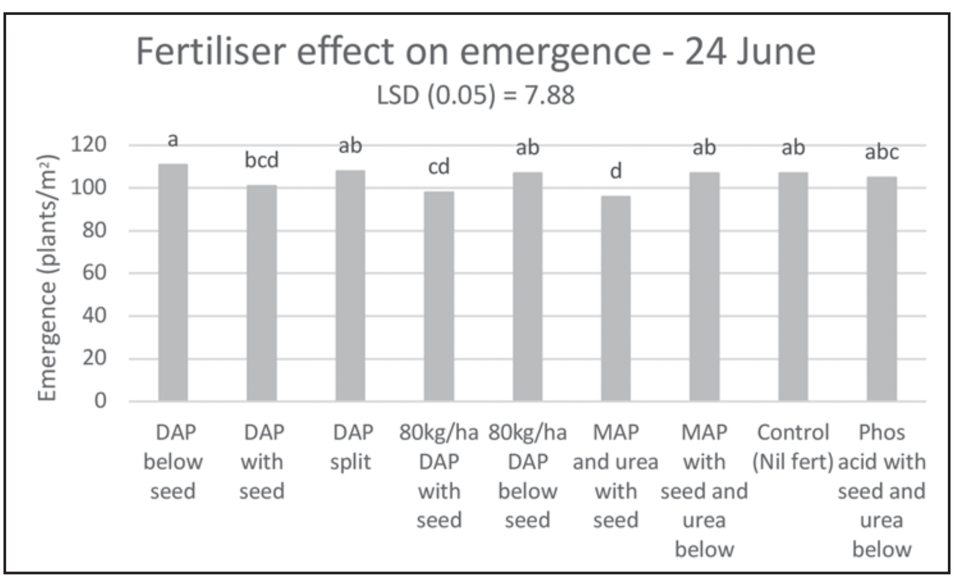

Figure 1. Plant establishment of CL Razor wheat over the three trial site locations with fertiliser treatments on 24 June 2021. (LSD (P=0.05) = 8).

Table 3. Grain Yield of CL Razor wheat at different times of sowing in 2021.

Location	Dry sowing	*Break*
Minnipa	3.27 a	3.21 a
Streaky Bay	2.10 b	1.87 c
Cungena	1.63 d	1.53 e
LSD (P=0.05)		*0.07*

Grain yield was significantly higher due to the trial locations and timing of sowing. Minnipa yielded an average of 3.2 t/ha, which was more than Streaky Bay (av. 2.0 t/ha) and Cungena (av. 1.4 t/ha). In the 2021 season at Streaky Bay and Cungena dry sowing compared to waiting until the break of the season resulted in a 0.2 t/ha and 0.1 t/ha yield increase respectively (Table 3).

In 2021 there were differences in grain yield between fertiliser treatments (Figure 2). The Nil fertiliser treatment performed poorly at all sites. At Cungena the Nil fertiliser, 80 kg/ha DAP with the seed and the MAP fertiliser with urea placed with the seed treatments were lower yielding compared to MAP with the seed and urea placed below the seed.

At Streaky Bay, 80 kg/ha DAP placed below the seed yielded higher than other fertiliser treatments, and the Nil fertiliser treatment was lower yielding than all other treatments. In the Minnipa trial the Nil fertiliser treatment was lower yielding than all other treatments, and the 60 kg/ha DAP below the seed also yielded lower.

Trial 2: Management trial

Standard sowing depth achieved across the three trials was less than the deeper sown treatments (Table 4). Deeper sown treatments (Halberd, LRPB Bale, Magenta and AGT Calibre) germinated earlier at Cungena and Minnipa due to subsoil moisture. At Minnipa the shallow sown Scepter and Spartacus barley treatments also germinated early. The only treatment which had germinated at Streaky Bay by 18 May was the deeper sown CL Spartacus barley (data not shown).

On 29 June, Cungena site had the highest overall emergence with 108 plants/m^2, Minnipa red soil had 83 plants/m^2 and Streaky Bay had 93 plants/m^2 (Table 5). Lower establishment at Minnipa was due to the 'cloddy' nature of the heavier soil after the deeper sowing treatments compared to the sandier soils.

Farming Systems

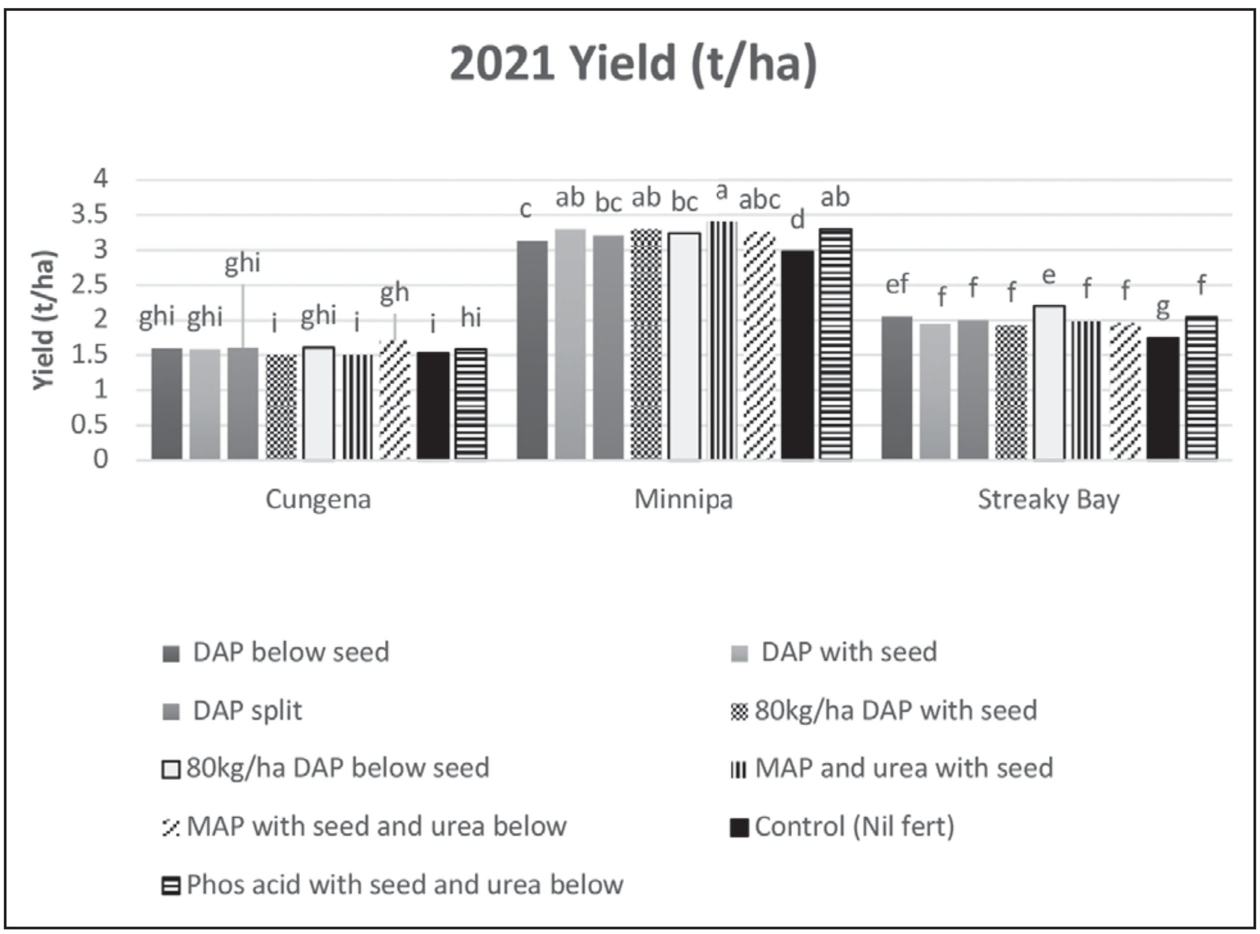

Figure 2. Grain Yield (t/ha) of CL Razor wheat over three sites with fertiliser treatments, 2021. (LSD (P=0.05) = 0.14).

Table 4. Average seeding depth of management treatments in 2021.

Variety	*Average seeding depth (cm)*
CL Spartacus Barley	4.6
CL Spartacus Deep	5.9
CL Spartacus Shallow	3.7
Halberd	10.6
LRPB Bale	9.9
Magenta	9.0
AGT Calibre	9.8
Scepter	4.5
Scepter Deep	5.7
Scepter Nil - Control (no fertiliser)	4.8
Scepter Shallow	3.9
Yitpi	6.8

Table 5. Emergence in management treatments for three sites on 29 June 2021 (plants/m²) (LSD (P=0.05) = 19).

Treatment	Cungena	Minnipa	Streaky Bay
CL Spartacus Barley	112 abcd	102 bcdefg	112 abcd
CL Spartacus Deep	87 ghijk	100 cdefgh	80 lmn
CL Spartacus Shallow	97 ghijk	86 ghijk	60 mn
Halberd	101 bcdefgh	91 fghij	92 efghij
LRPB Bale	95 defghij	60 n	82 hijk
Magenta	111 abcde	79 jklm	98 cdefghi
AGT Calibre (RAC2721)	122 a	81 ijk	90 fghij
Scepter	110 abcde	61 mn	70 klmn
Scepter Deep	122 a	90 fghij	100 bcdefgh
Scepter Nil - Control (no fertiliser)	109 abcdef	71 klmn	100 cdefgh
Scepter Shallow	122 a	101 bcdefgh	108 abcdef
Yitpi	124 a	93 efghij	119 b
CL Spartacus Barley	116 abc	71 klmn	100 bcdefgh
LSD (P=0.05)	*19*		

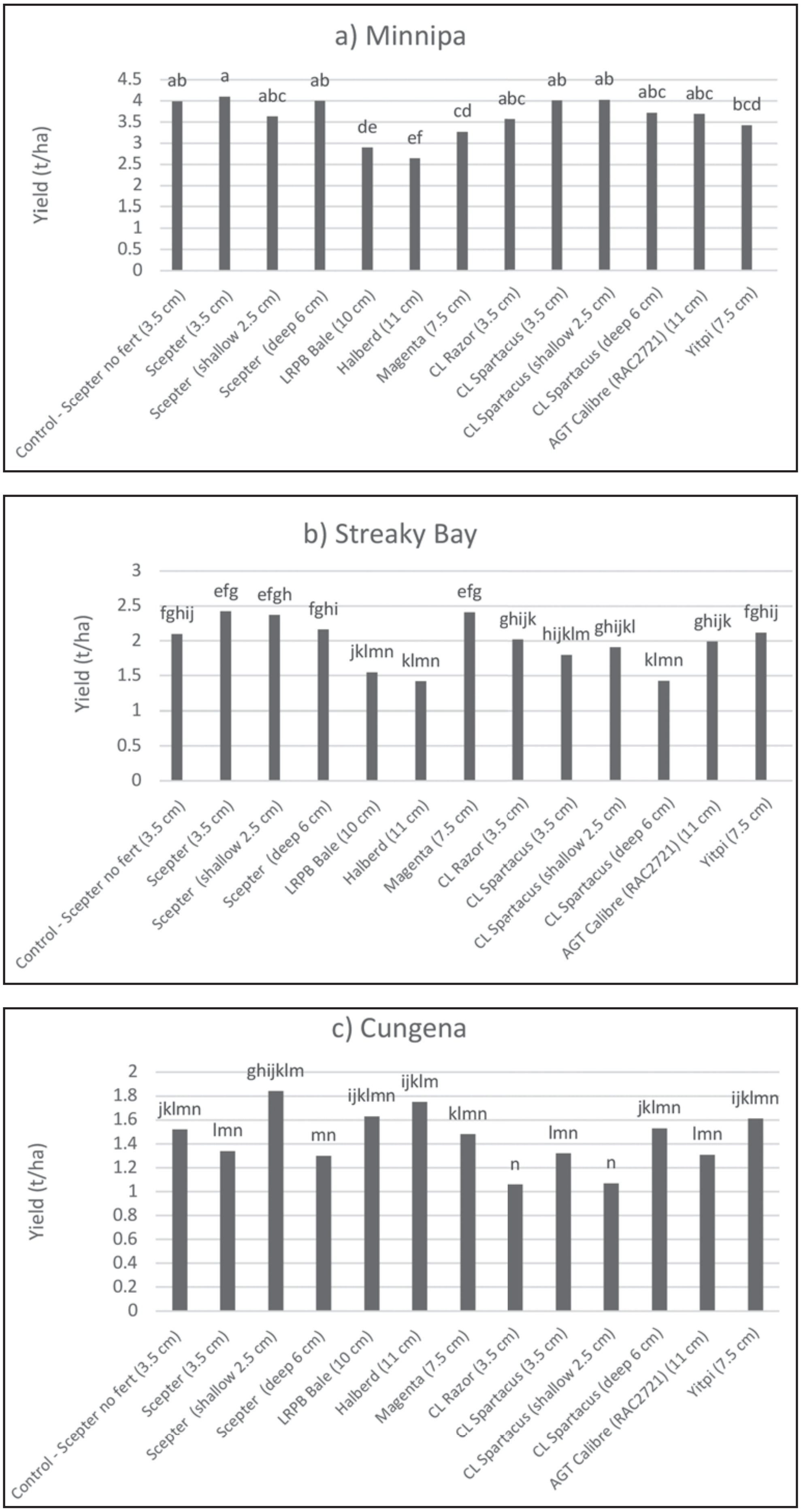

Figure 3. Yield of the management treatments over the three trial site locations, 2021. (LSD (P=0.05) = 0.61).

Early and late dry matter was higher at the Minnipa red site compared to the other sites, (data not shown). The Nil fertiliser treatment had lower dry matter production at all sites (data not shown).

The Minnipa red soil had higher yields than the other sites (Figure 3). In 2021, deeper sown Halberd and LRPB Bale yielded lower than the other treatments. The deeper sown LRPB Bale treatment had lower plant establishment which may have influenced yield. Halberd is an older less adapted variety, however it performed well at Cungena.

Sowing seed in a position to utilise current moisture was important as the dry sown deep treatments had earlier emergence at the Minnipa red site and Cungena. The long coleoptile wheats may provide an option for earlier plant establishment and dry matter production where subsoil moisture is present between 0-10 cm.

What does this mean?

Even with a reasonable start to the season, overall plant establishment achieved at all sites was much lower than the 180 plants/m^2 targeted (for the third season in a row). In 2021, earlier dry sowing increased germination. Although final plant establishment was not different the dry sown treatments germinated slightly earlier at all sites in 2021 and before the break of the season treatments.

Better plant establishment was achieved by separating the fertiliser to 3 cm below the seed, which achieved similar germination to the no fertiliser treatment. The fertiliser treatment which had urea with the seed had lower plant establishment, so if possible place urea below the seed at sowing or consider applying urea pre or post seeding. If fertiliser separation cannot be achieved due to seeding systems then using MAP (10:22) is a safer option than placing DAP with the seed.

The highest early dry matter was achieved by the dry sowing treatments with 80 kg/ha DAP banded below the seed treatment, and the lowest dry matter were the Nil Control (no fertiliser) treatments.

Dry sowing does not necessarily result in better yields than seeding on the break. There were no differences in grain yield at Minnipa due to the timing of sowing in 2021. There was a 0.1-0.2 t/ha yield increase at Cungena and Streaky Bay with dry sowing. Having Nil fertiliser resulted in lower yields compared to the other fertiliser treatments at all sites.

The management trial which evaluated seeding depth and the new long coleoptile wheats showed early and late dry matter was best at the Minnipa red site. The Nil fertiliser treatment had lower dry matter production at all sites indicating in all soils the addition and replacement of fertiliser is important for production. Deeper sown Halberd and LRPB Bale yielded lower than the other treatments, however LRPB Bale had a lower plant establishment so needs further evaluation. LRPB Bale is an awnless dual purpose wheat for hay and feed production.

Sowing seed in a position to utilise moisture present at the time was important as the dry sown deep management treatments had earlier emergence at the Minnipa red site and Cungena. The long coleoptile wheats may provide an option for earlier plant establishment and dry matter production where subsoil moisture is present between 0-10 cm.

This was the final season of research to determine the impacts of dry sowing and management on plant establishment. The final research report will be complied in mid-2022. Some research on plant growth on calcareous soils will still occur through the Soils CRC and GRDC funded research project.

Acknowledgements

This research was funded by SAGIT through the ‘Improving the early management of dry sown cereal crops’ (S419). Sincere thanks to SAGIT and their extremely valuable input into regional South Australian research and researchers. Thank you to the Kelsh and Tomney families for having field trials on their property. Thank you to Katrina Brands and Marina Mudge for field work and processing samples.

Latest technological innovations showcased at Minnipa Ag Centre

John Kelsh
Farm Manager (ex. AgTech Extension Officer)
SARDI, Minnipa

Key outcomes

- **Minnipa Ag Centre (MAC) established as an AgTech demonstration site.**
- **Expressions of interest remain open to AgTech providers.**
- **Farm-wide WiFi rollout now underway at MAC.**

Background

The AgTech Program is a PIRSA initiative which aims to improve on-farm productivity through promotion of, and raising awareness about, readily available technological innovations for agricultural enterprises. In late 2021, the establishment of AgTech start-up hubs and testbed services augmented the demonstration program, giving AgTech providers an opportunity to have a presence at facilities like MAC. The AgTech testbed service enables the validation and development of solutions not yet ready to go to market. All these elements work hand-in-hand with the AgTech Growth Fund to help grow and promote our AgTech industry and new innovations in local agricultural systems.

What happened?

AgTech demonstration participants

In 2021, there were several additions to the AgTech demonstration at MAC, a summary of each demonstration is provided below:

eAgronom

eAgronom is a web-based farm management platform with accompanying phone & tablet apps. Though the platform originates from a European base their commitment to the Australian farming systems is evident from their level of support and willingness to integrate local ideas into their product offering. eAgronom provides a paddock diary, crop rotation planner, task management facilities, inventory management, harvest recording, crop & paddock analysis inc. gross margins. For more information see eAgronom.com or reach out to Karlis Atrens on 0416 430 604.

Laconik

Laconik's Combine was a fertiliser decision support tool aiming to make sense of the profit provided by different levels of fertilisation giving farmers the opportunity to optimise future applications, getting the best value for money from their fertiliser. Combine was trialled during 2021 in one paddock on MAC, North 7. Several trial strips in different areas of the paddock were sown with either nil, half, normal and double rates of Granulock SS. Combine neatly overlaid these trial plots over the top of our zoned yield maps to create a variable rate fertiliser prescription.

Unfortunately, in the latter part of the year Laconik ceased trading, no longer offering their product.

Bruder Australia

Mt Barker based Bruder Australia identified the need for an air compressor designed specifically for agricultural use. Their offering is the result of more than 20 years of experience in the industry and features a European screw-compressor mated to a turbo-diesel Kubota engine, on a heavy-duty trailer as standard. Available in 176 and 250 CFM options the larger is big enough to blow down two headers simultaneously. Safety and easy serviceability are key features of the Bruder offering with a top-exit exhaust, battery isolator, turbo & glow timer, single air filter, and canopy mounted on gas struts. More information is available on bruderaustralia.com.au or they can be contacted on 1800 088 990.

A Bruder AG176, hose reel and Force 5 Megablaster is located on-site at MAC, see below for demonstration opportunities.

Agworld

Many are already familiar with the Agworld brand and their farm management product offering. Features of the platform include: farm planning, budgeting, input tracking, job management, compliance, agronomy services, precision application planning.

Agworld also integrates with other platforms including: APAL, PCT-Agcloud, Xero, Shed, Microsoft Power BI, Slingshot and John Deere ops centre making their ecosystem increasingly feature rich. Agworld also provides an interface to your agronomist allowing for the seamless two-way flow of data and recommendations. More information is available at agworld.com.au or via Graham Morgan on 0448 054 281

Precision Technology
Previously part of Farmscan Ag, Toowoomba based Precision Technology offers entry-level guidance, auto-steer, variable-rate, automatic section control, mapping and record keeping solutions at accuracy levels from uncorrected GPS through to RTK. These solutions cater for those trying precision ag for the first time, or where investment in precision ag has previously been discounted due to the expense involved. More information online at precision-technology.net or they can be contacted on 07 4602 4150

Ellenex
A manufacturer of industrial grade IoT sensors, Ellenex provides monitoring solutions for tank levels (incl. silos), pressure, flow & water quality monitoring, temperature monitoring, pump operation control, weighing systems. Their range of connectivity options includes LoRaWAN, NB-IoT, Satellite and WiFi. Alhough none of these sensors are on-farm yet, some will be set up soon. More information can be found online at ellenex.com

DIT AgTech
Increasing livestock productivity through soluble nutrition is DIT AgTech's objective. The major benefit of water supplements over traditional mineral supplements is that while shy feeders can choose another source of nutrition all animals have to drink. The uDose Pro is the mechanism of delivery incorporating a micro-dosing system, internet connected controller (mobile or satellite), solar panel and battery for 24x7 operation. Monitoring is provided by an app and web dashboard capable of email and SMS alerts and daily status updates. For more details see ditagtech.com.au or get in touch with Ben Munzberg on 0448 369 983

A DIT AgTech uDose Pro is located on-site at MAC, see below for demonstration opportunities.

Mobishear Australia
Greenpatch's Mobishear Australia offer cordless tools for livestock maintenance including a cordless handpiece, cordless hoof-trimmers, cordless horse & cattle clippers and two sizes of cordless pruning shears. They are built tough and designed to last, with local parts stock, two year warranty, and self-serviceability as key features. Perfect for unexpected dagging and crutching jobs in locations without access to 240v power. More information online at mobishear.com.au or via Arnd (0421 062 697) or Heidi (0409 289 532) Enneking

Other projects - Farm connectivity
It was an early focus of the program, and a key finding of the 2020 and 2021 AgTech surveys, that connectivity to support technological expansion on-farm is a major issue. While MAC has reasonable mobile phone coverage throughout, the deployment of sensors based on other communications technologies meant that an upgrade to farm-wide WiFi, including the provision for LoRa based IoT, would set MAC up for future on-farm tech deployments and better capability to demonstrate these technologies on-site. The network was designed with assistance from Internet Innovations - specialists in delivering better internet services in regional areas.

The hardware for the network has been purchased and deployment is underway, with the intention to have the farm-wide WiFi setup before the next MAC annual field day.

What does this mean?

Demonstration opportunities
If you would like a more in-depth look at any of the technologies listed here, including hands-on, MAC staff are available for appointments to discuss online or face-to-face at MAC. To book an appointment please call the Minnipa Agricultural Centre on 08 8680 6200.

Acknowledgements

AgTech Principal Consultant: Dr. Ben Baghurst (PIRSA, Adelaide)

South Australian Drought Resilience Adoption and Innovation Hub update

Stephen Lee, Rhiannon Schilling and Tony Randall
SA Drought Hub, University of Adelaide Roseworthy Campus

Farming Systems

Key messages

- **A Drought Hub has been established in SA to assist in increasing farming system resilience to drought.**
- **The SA Drought hub has 59 partner organisations from across all agricultural sectors and roles.**
- **Ideas and priorities for increasing drought resilience come from local producers, farmer groups, industry groups, and researchers, and projects are implemented regionally.**
- **An SA Drought Hub office (node) will be established at the Minnipa Agricultural Centre in February 2022**
- **Eyre Peninsula drought resilience projects will commence in 2022.**
- **Regional stakeholder advisory groups will allow the farming community to provide feedback on the SA Drought Hub's activities and projects.**

SA Drought Hub Overview

The South Australian Drought Resilience Adoption and Innovation Hub (SA Drought Hub) was established in May last year to help primary producers across the State adopt innovative practices and tools that will enable farming systems and regional communities to become more resilient to drought. There are seven other Drought Hubs across Australia. Our Hub is led by the University of Adelaide and is a partnership between 59 organisations, including grower and farmer groups, advisers, agribusiness, industry organisations, government agencies, traditional owners, universities, and research organisations. The Hub brings together the knowledge, skills, and resources of these partners.

A key requirement in the design and delivery of the Hub's drought resilience programs and projects is ensuring they meet producer needs. To this end, a series of workshops and consultations were held across the State with industry organisations, farmer groups, researchers, and regional communities to identify their priorities for increasing drought preparedness and resilience, and how programs and activities can be specifically tailored for each agricultural region. The workshops and consultations generated 991 ideas from the wide range of participants, with the highest priority ideas identified for each region through a further round of consultations with Hub partners. The process of identifying regionally specific drought resilience initiatives is ongoing, and new project ideas will be identified and welcomed from project participants and local producers as more people engage in Hub activities and relevant projects being delivered in other parts of the country.

Eyre Peninsula priority project ideas

The SA Drought Hub Minnipa Node will be up and running at the Minnipa Agricultural Centre in February 2022, with the local Node coordinator starting at this time. Farmers, advisers, agribusiness and community members are welcome to drop into the office to learn about the latest drought resilience projects being undertaken in the low rainfall areas of the Eyre Peninsula, as well as relevant projects in other parts of the State and nation. Feedback on these projects and ideas for improving drought resilience on Eyre Peninsula are encouraged.

Figure 1. Workshop held at Wudinna in August 2021 where 34 people attended and 83 project ideas were generated by local producers, grower groups, researchers and farm advisors.

A number of priority projects have been identified for implementation this year in low rainfall areas of the Eyre Peninsula. While this list will need further refinement, it provides an idea of the scope and type of projects that have been proposed through the workshops and consultations:

- Mixed species pastures trials, multiple species summer crops trials
- Summer weed spraying timing and moisture loss, other risks and input costs
- Economics of mixed farming through a crop sequencing trial
- Understanding the profitability of farming systems at different rainfall deciles and under different debt scenarios
- Optimising dry sowing of crops
- Comparing Strip and disc with conventional sowing and harvest systems

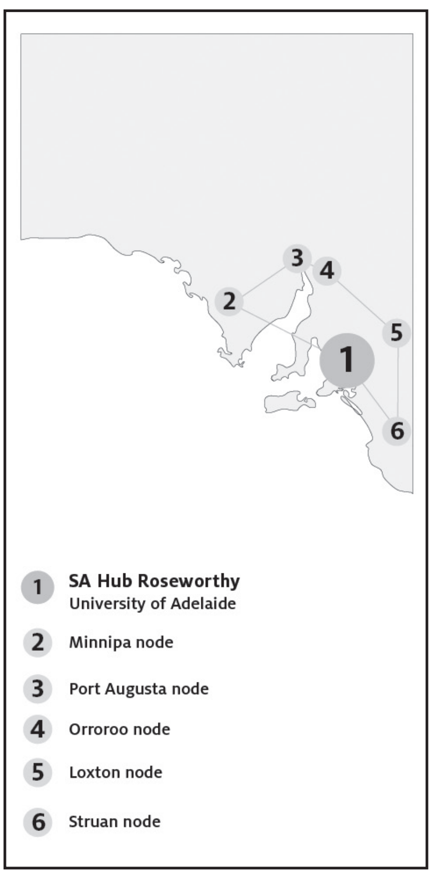

Figure 2. SA Drought Hub and Node locations.

- Collection of case studiesand advice from farmers who have managed well through drought.
- Increasing the soil bucket size.

The University of Adelaide's Roseworthy campus will house the Hub headquarters, interacting with the University's Waite and North Terrace campuses. Regional Hub Nodes across the pastoral, low, medium and high rainfall zones of SA are being established in Minnipa, Port Augusta, Orroroo, Loxton and Struan (Figure 2). Each Node will have a Node Coordinator and will be a shopfront where farmers and community members can discuss drought resilience opportunities and ideas and access information on the latest drought resilience projects being undertaken at local, state and national levels

An enormous amount of effort and activity has been occurring behind the scenes to establish the project investment and financial management frameworks required for such a large and diverse program of works. Once these frameworks and operational plans are bedded down, members of the SA Drought Hub team are looking forward to spending more time meeting and collaborating with Hub partners and other stakeholders across the State.

Next Steps

We will be working with Hub partners to refine the priority project ideas into detailed projects and will commence contracting the delivery of services by local farming system groups and other Hub partner organisations. We anticipate projects starting on the ground this year. These projects will be a mix of field trials and demonstrations, workshops and field days, information resources and tools.

Two Stakeholder Advisory Groups will be established with representation from local Hub partner organisations and producers (a Minnipa node and a High Rainfall node). The purpose of these groups will be to seek feedback from the low and high rainfall Eyre Peninsula farming communities on the SA Drought Hub's activities and projects, advising the SA Drought Hub on the value and effectiveness of projects, identifying ideas for new projects, and identifying resources that may be required to assist in project delivery.

If you have ideas for building drought resilience within Eyre Peninsula farming systems and communities, please call into the SA Drought Hub Node office at the Minnipa Agricultural Centre to discuss these with the Node Coordinator once appointed in February. Alternatively, you can contact the SA Drought Hub Knowledge Broker on tony@agex.org.au or 0402 245 747 to discuss project ideas, be involved with the delivery of project activities or provide feedback on the SA Drought Hub.

Acknowledgements

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

The SA Drought Hub is supported by financial and in kind contributions from 59 partner organisations including Farming Systems and Grower Groups, Agribusiness and farm advisors. Universities, Government Departments and Agencies, Agricultural Industry Groups, Research Organisations, and Local Government.

Long coleoptile wheat on the Eyre Peninsula

Rhaquelle Meiklejohn[1], Andrew Ware[1], Therese McBeath[2] and Greg Rebetzke[2]

[1]EPAG Research; [2]CSIRO Agriculture and Food

Location
Cootra - Todd Matthews
Rainfall
Av. Annual: 340 mm
Av. GSR: 241 mm
2021 Total: 413 mm (71 mm Nov, 5 mm Dec)
2021 GSR: 268 mm
Yield
Potential: 4.9 t/ha yield prophet
Actual: 4.6 t/ha (highest yielding treatment)
Paddock history
2020: Wheat
2019: Pasture
2018: Barley
Soil type
Sand over sandy clay loam
Soil test 0-10cm
Texture: Sand, pH $CaCl_2$: 6.67, Org C: 0.43%, Nitrate: 6.2 mg/kg, Colwell P: 13 mg/kg
Trial design
randomised complete block, split plot
Yield limiting factors
Some yellow leaf spot

Key messages

- **Longer coleoptile wheat varieties provide opportunities and flexibility to successfully establish crops in situations where previously not possible.**
- **The coleoptile provides protection to the emerging shoot. Longer coleoptiles allow wheat to successfully emerge from deeper sowing.**
- **2021 trials conducted on sandy soils at Cootra found that both a Mace and a version of Mace with a long coleoptile gene emerged equally well from a sowing depth of 10 cm.**
- **The long coleoptile genetics did not show any yield penalty when sown at 10 cm.**
- **Four newly released commercial varieties with longer coleoptiles all were all able to establish well from a depth of 10 cm.**

Why do the trial?

Improving the reliability of early plant establishment plays an important role in increasing water use efficiency and yield potential in dryland cropping environments. Establishing plants earlier in the season extends the growing period of a crop, and when combined with optimal phenology, provides more time for a plant to develop resources that ultimately contribute to grain fill and yield.

Seeding deeper, into soil moisture present below the ‘normal seeding bed’ may help to establish plants earlier without relying on an autumn break for germination. Currently, wheat growers are restricted to a seeding depth of 3-5 cm because modern wheat varieties have a shortened coleoptile associated with dwarfing genes that were introduced in the 1960’s to increase yields. The length of a coleoptile restricts seeding depth because it is a hollow shoot that protects the first leaves as they grow towards the soil surface during germination. Breeders have now identified an alternate dwarfing gene ‘Rht18’ that allows a coleoptile up to 12 cm long, whilst maintaining the reduced height associated with modern high yielding wheat varieties.

The trials reported here assessed the performance of long coleoptile wheats in an Eyre Peninsula farming system.

How was it done?

Two trials were established on a sand over sandy loam soil in the Cootra area (central EP). Trial 1 compared three wheat varieties with standard length coleoptiles, to a CSIRO developed, long coleoptile derivative of Mace. All varieties were sown at three depths; 5, 8 and 10 cm. In this article, only Mace and LC (long coleoptile) Mace will be reported.

Trial 2 compared four newly released varieties Calibre, LR Bale, LR Dual, and Valiant CL Plus, all marketed to have long coleoptile traits, at three depths of seeding.

The trial was sown on 7 May 2021 with seeding rates targeting 160 plants/m^2. At seeding, the trial was fertilised with 16 kg/ha of phosphorus, and 14 kg/ha nitrogen. A further 106 kg/ha of nitrogen was applied post-emergent. A foliar application of 120 gm/ha Zinc, 150 gm/ha Manganese and 45 gm/ha Copper was applied at late tillering. Weed control was achieved through the application of 118 g/ha of Sakura®, and 1.6 L/ha of Avadex Xtra® applied prior to seeding and 25 g/ha of Paradigm®, 300 mL/ha of LVE MCPA, 500 mL/100L of Uptake®, applied post-emergent. 300 mL/ha of Prosaro®, 600 mL/ha of Aviator® and 70 mL/ha of Alpha Scud®, was applied to control disease and insects. Both trials were harvested on 1 December 2021.

Measurements were taken for: emergence, coleoptile length, sub-crown internode length, seeding depth, tillers, above and below ground biomass (at Zadoks growth stages: GS 12 and 21), growth stages, head density, harvest index, grain yield, grain protein, screenings and test weight. Only a selection of these measurements are reported here. Results were analysed using Genstat® version 19.

What happened?

The site had good levels of moisture below the traditional 'seedbed' and a dry topsoil when the site was sown prior to the break in the season. At sowing there was sufficient moisture from 8 cm for establishment. Small rainfall events in the week post seeding assisted in wetting soil at shallower depths.

Mace type trial (Trial 1)

Emergence

Eleven days after seeding LC Mace had established 44% more plants than the standard Mace variety when sown at 8 cm and 50% more plants when sown at 10 cm. However, by the time the trial had fully emerged, there were no differences in plant number between the two varieties. Overall, the deeper sown treatments had poorer final emergence, regardless of coleoptile genetics. Plant numbers decreased by 10% at 8 cm and by 20% at 10 cm, but all treatments had populations in excess of 110 plants/m^2 by 23 June.

Biomass

At the two-leaf stage, plants in the treatments sown deeper had greater biomass than those sown at 5 cm. By early tillering (GS 21), plants in treatments sown at 8 cm had greater biomass than at 4 cm and 10 cm.

When comparing varieties at each seeding depth: LC Mace had a greater biomass at two leaf stage when sown very deep, and Mace had a greater biomass at early tillering when sown at 4 cm. Generally, Mace had grown more biomass than LC Mace by early tillering, especially in the shallow sown treatments.

Yield

Overall, the highest yields were recorded with seeding at 8 cm and Mace yielded higher than LC Mace. However, the yield gap between the varieties closed with depth, and when sown at 10 cm, the two varieties yielded the same.

Commercial variety trial (Trial 2)

The two LongReach varieties emerged earlier than Calibre or Valiant (table 2). The trial fully emerged by 23 June 2021. There was no yield penalty for planting any of the varieties at 10 cm compared to 5 cm and treatments planted at 8 cm yielded the highest. Valiant and Calibre yielded higher than the two awnless LongReach varieties, regardless of seeding depth.

Table 1: Emergence, early season biomass production and grain yield of Mace and LC Mace at Cootra, 2021.

Seeding depth (cm)	Wheat Variety	Emergence 18 May (plants/m^2)	Emergence 23 June (plants/m^2)	Biomass @ GS 12 (gm/plant)	Biomass @ GS 21 (gm/plant)	Grain Yield (t/ha)
5	Mace	53	148	0.37	4.44	4.24
	LC Mace	53	155	0.28	2.90*	3.66*
8	Mace	47	133	0.58	4.06	4.56
	LC Mace	84*	137	0.60	3.75	4.17*
10	Mace	29	122	0.45	3.51	4.18
	LC Mace	59*	113	0.73*	3.33	4.05
LSD (P=0.05)		*25.4*	*20.7*	*0.22*	*1.13*	*0.36*

** = Mace and LC Mace means are statistically different at the same sowing depth (P=0.05)*

Table 2: Early emergence (18 May) and grain yield of long coleoptile wheat varieties at Cootra in 2021.

Depth	Valiant CL Plus		LR Bale		LR Dual		Calibre		Average of depths	
	Emergence (plants/m^2)	Yield (t/ha)	Emergence (plants/m^2)	Yield (t/ha)	Emergence (plants/m^2)	Yield (t/ha)	Emergence (plants/m^2)	Yield (t/ha)	Emergence (plants/m^2)	Yield (t/ha)
4 cm	110	4.07	111.5	2.91	89.6	3.02	77	3.95	97 *	3.49 a
8 cm	93.7	4.24	124.1	3.09	117	3.36	90.7	4.32	106.4 *,**	3.75 b
10 cm	88.1	4.08	172.6	3.06	135.9	3.26	71.5	4.07	117 **	3.62 a
Average	*149.5**	*4.13 a*	*151.3***	*3.02 b*	*151.3***	*3.22 b*	*146.4**	*4.11 a*		

variety x depth LSD (P=0.05): Emergence = 33.4, Yield = 0.35

What does this mean?

These trials showed that in a late Autumn break, seeding before the break into deeper moisture increased yields. This occurred with all varieties, regardless of the length of their coleoptiles.

Although LC Mace emerged faster than Mace, there was no difference in final establishment. Mace achieved greater biomass and yields than LC Mace, except yields were the same when plants were sown at 10 cm.

Early vigour demonstrated by LC Mace suggests a longer coleoptile can be advantageous; and the equivalent yields to Mace when sown at 10 cm suggests the long coleoptile variety may have a role in deeper seeding systems.

The combination of a sandy soil type and a favourable growing season allowed standard Mace to establish successfully from sowing at 10 cm. In season measurements found Mace's coleoptile to be 7 cm (data not shown), meaning the unprotected emerging leaf was able to successfully push through and emerge through the remaining 3 cm of soil. Similar experiments conducted on different soil types across Australia in 2021 found this was not always possible with reductions of up to 32% in emergence (Rebetszke *et al*, 2022 GRDC Updates).

The high yields achieved by the newly released commercial varieties sown at depth mean that this technology is ready for growers to adopt on sandy soils without non-wetting issues, however more research is needed to evaluate their performance on non-wetting sands and heavier soil types that restrict emergence from depth.

Long coleoptile varieties not only have the potential to enable earlier seeding when deeper soil moisture is present, and the topsoil is dry but may also have other benefits. These include being able to successfully seed over rough terrain after soil amelioration, having confidence to seed deeper to avoid pre-emergent herbicides and being able to establish crops when adverse weather collapses press-wheel furrows (inadvertently deepening the seeding depth).

There are still challenges to developing complete deeper sowing packages. There is a need to understand the impact of varying soil types, moisture availability and depth to moisture on success of the technique, if current seeders require modifications to allow them to successfully seed deeper, the interaction of deep seeding approaches and soil-active herbicides and if further advances/ understanding of long coleoptile genetic material are necessary to work across a number of soil types and environments.

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Multiple frosts at Tooligie in 2021 caused losses of grain yield and quality across a range of varieties

Rhaquelle Meiklejohn[1], Andrew Ware[1] and Michael Hind[2]

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Location
Tooligie Hill
Tim Zacher
Lock/Murdinga/Tooligie Ag Bureau
Rainfall
Av. Annual: 331 mm
Av. GSR: 250 mm
2021 Total: 335 mm
2021 GSR: 225 mm
Yield
Potential: 2.5 t/ha (wheat)
Actual: 1.8 t/ha (F3 barley)
Paddock history
2021: Chief CL wheat
2020: Lupins
2019: Canola
Soil type
Sand
Plot size
1.5 m x 10 m 3 reps, with no gaps between plots or around trial
Trial design
Randomised complete block
Yield limiting factors
Frost - high impact

Key messages

- **In frost prone areas of Eyre Peninsula, relying on Bureau of Meteorology (BOM) stations as a record of frost events may see many events pass without notice.**
- **Barley and slower maturing wheat varieties were able to produce some grain yield in an extremely frosty environment, whereas earlier maturing wheat varieties almost failed.**
- **Frost affected grain quality of all varieties in 2021.**
- **High biomass production in this environment was achieved and may have been useful for grazing or hay production as an alternative to grain.**

Why do the trial?

Frost events over the past four years have caused extensive crop damage and financial loss in large areas of Central and Eastern Eyre Peninsula. Frost damage through this time appears to be affecting similar areas at both a district and paddock level.

Anecdotal evidence suggests that damage from Eyre Peninsula frost events can still occur late in the growing season and that utilising strategies such as growing longer season varieties that flower later to avoid frost isn't an effective management strategy.

Telemetry based, in-paddock weather recording stations, that instantly report climatic conditions are still relatively new technology. There use in frost prone areas over the past four years has highlighted more frost events in these areas than previously thought.

In 2021 a site was established in the Tooligie area to test whether planting varieties or mixtures of varieties with differing phenology would mitigate frost damage. To monitor the timing of frost events during the season. Multiple temperature loggers were positioned throughout the trial.

How was it done?

On 26 May 2021 eight varieties/varietal mixtures were sown in an area that had experienced frost damage in previous years. The trial was sown without any gaps between plots and without any bare area around the trial to avoid corridors within the trial which allow unusual air flow.

Treatments were six wheat varieties that differed in phenology: Vixen (quick spring), Mace (quick-mid spring), Scepter (mid spring), RockStar (mid-slow spring), LR Dual (mid-slow spring awnless), Denison (slow spring); a mixture of Vixen and Denison and one barley variety (Spartacus, very quick spring).

Four temperature loggers were installed prior to the crop reaching stem elongation and recorded temperature at 15-minute intervals in different positions within the trial:

- 1.2 m above ground (standard BOM height)
- 1.2 m above ground with screen (BOM standard)
- 5 cm below ground (soil temp)
- Crop height (moved fortnightly to match plant growth)

The trial was sown at 200 plants/m^2 and fertilised with 60 kg DAP/ha + 100 kg urea/ha. The site received a pre-emergent herbicide application of 1 L trifluralin/ha and 118 g Sakura®/ha. Post-emergent weeds were controlled with 750 ml MCPA LVE/ha + 100 ml Lontrel®/ha. The trial was harvested on 10 December 2021. Extra care was taken at harvest to capture all grain, regardless of size. Grain samples were carefully cleaned in lab prior to grain testing.

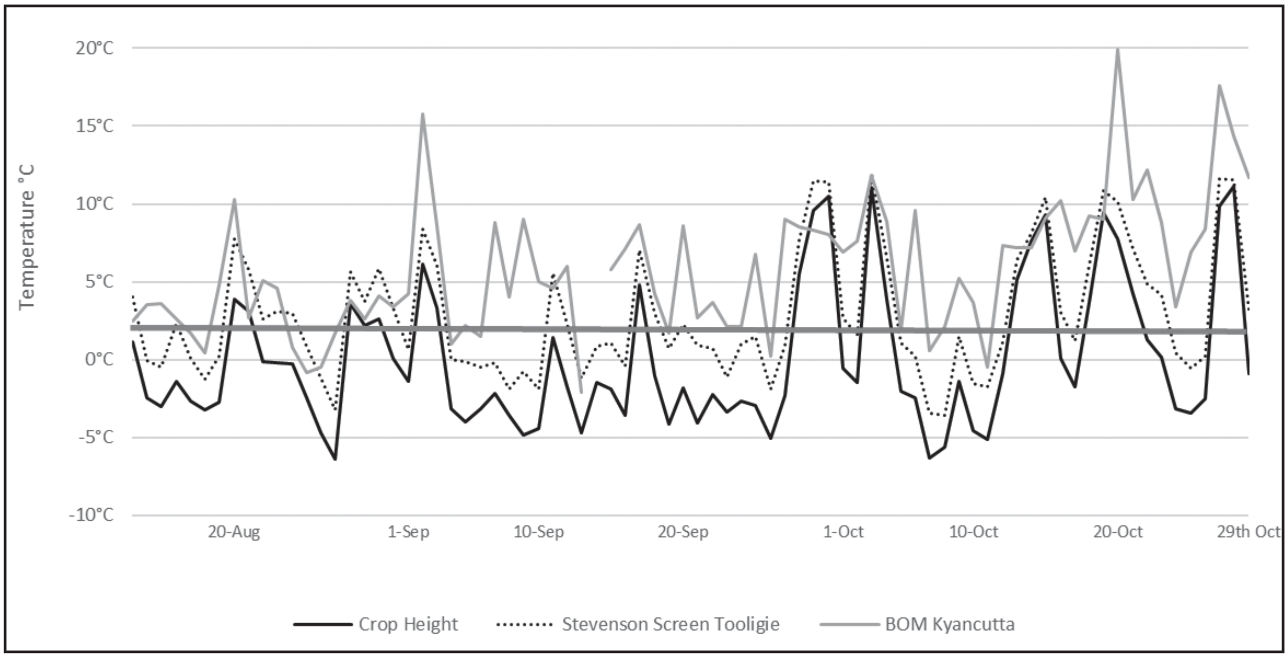

Figure 1. Minimum temperatures from BOM Kyancutta and from the Tooligie trial site (in Stevenson screen and at crop height) from mid-August to end of October 2021. Thick horizonal line denotes the minimum threshold for frost damage (2°C) in Stevenson screen.

Table 1. Biomass in October, grain yield and quality of wheat and barley at Tooligie in 2021.

Variety	Biomass (t/ha) 19 Oct	Grain Yield (t/ha)	Grain Delivery Grade
Spartacus	5.3 ab	1.84 c	F3
Denison	5.6 ab	1.56 bc	Undeliverable
RockStar	6.6 b	0.62 ab	Undeliverable
Scepter	5.8 b	0.60 ab	AUW1
Mixture	5.8 b	0.56 ab	AGP1
Mace	6.8 b	0.31 a	Undeliverable
LR Dual	3.9 a	0.31 a	FED1
Vixen	5.6 ab	0.27 a	FED1
LSD (P=0.05)	*1.38*	*0.80*	

Temperature during the season, growth stages, biomass, yield, and grain quality were measured. Results were analysed in GenStat version 19.

What happened?

The loggers recorded 38 possible frost events (where minimum temperature fell below zero) at crop height throughout the vulnerable stages of crop growth (stem elongation to late grain fill), see figure 1. Within this same timeframe, Kyancutta BOM station only recorded a minimum temperature below zero on four days. Temperature at crop height was generally 2.2°C lower than with the screened logger, 1.2 m above the ground; and was almost always lower than the BOM records. However, the relationship between temperatures at crop height at Tooligie and Kyancutta BOM records was not sufficiently consistent for BOM records to be in indicator of temperatures at Tooligie, 90 km away (Figure 1).

Spartacus barley and Vixen wheat were the earliest to flower (18 September), and Denison wheat the last to flower (25 September).

Spartacus and Denison yielded 1 t/ha more than the faster maturing wheat varieties. Yields of the fastest maturing variety Vixen and the mid to late maturing variety RockStar were similar and very low.

Test weights of Denison, RockStar and Mace were below receival standards.

Biomass of cereal varieties in mid-October varied between 3.9 and 6.6 t/ha, with biomass of LR Dual being lowest.

What does this mean?

The frequency and severity of frosts between stem elongation and grain fill at that this site made it very hard for any variety to escape frost damage, regardless of its maturity type. Higher yields were achieved by a very fast maturing barley or a slow maturing wheat but yields of each of these were still well short of water limited yield potential and grain quality was poor.

Biomass production of between 3.9-6.6 t/ha indicated that grazing or hay production may have been more profitable than grain production, but these options come with added workloads and machinery/infrastructure costs that may not suit all businesses.

It was only through recording temperatures at the site during the growing season that the frequency and severity of frosts in the area could be accurately measured. This information may be more useful for planning frost risk mitigation strategies in future seasons than BOM records from a distant station.

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Resilient EP - Improving our understanding of soil moisture and how to utilise it

Jacob Giles and Andrew Ware
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Location
Minnipa
Rainfall
Av. Annual: 324 mm
Av. GSR: 241 mm
2021 Total: 376 mm
2021 GSR: 212 mm
Paddock history
2021: Canola
2020: Wheat
2019: Lentil
2018: Wheat
Soil type
Red loam

Location
Buckleboo
Rainfall
Av. Annual: 288 mm
Av. GSR: 162 mm
2021 Total: 289 mm
2021 GSR: 162 mm
Paddock history
2021: Barley
2020: Wheat
2019: Pasture
2018: Barley
Soil type
Sandy clay loam

Location
Cootra
Rainfall
Av. Annual: 334 mm
Av. GSR: 249 mm
2021 Total: 249 mm
2021 GSR: 219 mm
Paddock history
2021: Wheat
2020: Wheat
2019: Pasture
2018: Barley
Soil type
Sand over light clay sand

Key messages

- **Out of season rainfall and stored soil moisture were found to be key factors in driving grain yields across most farming systems on the Eyre Peninsula in 2021.**
- **Collating and interpreting information from a range of sources including plant available water, previous grain yields and soil testing across the landscape can maximise returns and reduce risk.**
- **Improving knowledge of soil characteristics can add considerable value to monitoring soil moisture probes.**

Why do the trial?

It is well understood that rainfall limits grain and pasture production across Eyre Peninsula. Farmers also understand the value of measuring rainfall but measuring how much of that rain is present as soil moisture at any one time and where it is in the profile using tools such as soil moisture probes (SMPs) is a relatively new innovation.

On face value, if a shortage of water is the biggest limiting factor to the farming business, then knowing the quantity of soil water present and understanding crop water use patterns should be useful. However, this knowledge only becomes powerful when profitable decisions can be made using the information.

To increase understanding of soil water across Eyre Peninsula and investigate opportunities to utilise it more effectively in a variable and changing climate, AIR EP, together with its research and extension partners have developed a project aimed at improving the resilience of EP farmers into the future.

How was it done?

Step 1: Creating a viewing platform

SMPs are a relatively cheap and reliable tool to measure soil moisture. Being able to quickly view and assimilate information that SMPs provide not only encourages regular use but also increases knowledge of the effects that different rainfall events, and crop/pasture growth have on SMP outputs, with the flow on of confidence in using this tool to make management decisions.

Through the Resilient EP project, AIR EP engaged software development company Square V to develop a new platform to display SMP data from the 42 probes on the EP network in an intuitive manner that would allow users to quickly gather required information with a few clicks optimised for use on a mobile phone.

Links to all 42 SMPs that are part of the AIR EP network can be found at: https://probes.airep.com.au/

Location
Lock
Rainfall
Av. Annual: 385 mm
Av. GSR: 249 mm
2021 Total: 322 mm
2021 GSR: 228 mm
Paddock history
2021: Canola
2020: Vetch
2019: Wheat
2018: Wheat
Soil type
Sandy loam over sandy clay loam

Location
Cockaleechie
Rainfall
Av. Annual: 421 mm
Av. GSR: 340 mm
2021 Total: 418 mm
2021 GSR: 327 mm
Paddock history
2021: Wheat
2020: Canola
2019: Wheat
2018: Wheat
Soil type
Clay loam over medium clay

Step 2: Soil characterisation

SMPs provide information on relative changes in soil moisture, through measuring changes in capacitance at a range of points (usually 10 cm intervals) down the soil profile. However, these outputs do not readily equate to mm of plant available water and have been found to be affected by higher temperatures over summer and soils with higher levels of salt/ electrical conductivity.

To help understand the relationship that SMPs readings have with plant available water and to improve accuracy of the outputs AIR EP have engaged SARDI to characterise soils for plant available water capacity and CSIRO to work through correction factors to improve SMP accuracy.

Algorithms are currently being applied to soil moisture probe outputs to improve their accuracy in high temperature/electrical conductivity situations. These are being incorporated into probe outputs found using the above link to the AIR EP website.

At the conclusion of the 2021 growing season 31 of the soils adjacent to SMP sites have been characterised for plant available water, a process that involves calculating how much water a soil can hold (drained upper limit), how much moisture a crop can remove from the profile (crop lower limit), including the effect of toxic elements such as boron, and calculating soil bulk density that allows conversion from gravimetric measurements to mm of soil moisture (volumetric).

This knowledge derives plant available water capacity or ‘bucket size’ - how many mm of plant available water that soil can hold. Bucket sizes are largely driven by soil texture and how deep in the profile toxic elements such as boron and salinity occur. On Eyre Peninsula plant available water content of some soils has been found to be as low as 20 mm and as large as 150 mm. The capacity of a soil to store water can greatly vary across a paddock, however SMPs as part of the AIR EP network have tended to be on soils well between these extreme values.

The quantity of plant available water becomes important at times when crop/ pasture growth is using more moisture than is being replaced by rainfall. This is often most noticeable when crops and pastures are large, temperatures are higher, and rainfall is more sporadic such as in spring.

Step 3. Using soil water to create a yield target.

Once a soil’s water holding characteristics are understood, the information can be used in combination with climatic conditions to help create a potential yield.

Plant growth models such as Agricultural Production Systems sIMulator® (APSIM®) are able simulate a crop’s growth in a given climate and soil type to provide a range of scenarios on how crop/ pastures will perform, with soil moisture being a critical parameter in calculations.

Yield Prophet® utilises APSIM® outputs to deliver information on crop growth, yield potential, and potential nitrogen requirements based on historical climatic conditions for a location in way designed to be easily understood by growers and advisors. Having accurate soil characterisation is critical to accuracy of Yield Prophet. Using the characterisations completed as part of this project in 2021 saw a high correlation between Yield Prophet® predictions and actual yields. This means tools such as Yield Prophet® can be utilised with some confidence to help plan target yields.

Step 4. Evaluating management strategies, based on increased understanding of soil moisture.

Once water limited target yields are established, then a range of hypotheses can be explored to improve profitability and/or reduce risk. To test and work through management options based on these hypotheses across the broad range of soil types and environments found on Eyre Peninsula, EPAG Research worked across eight focus paddocks in 2021 (Figure 1).

Figure 1. Map displaying the position of 8 focus paddocks across the Eyre Peninsula; Wangary, Cockaleechie, Yeelanna, Lock, Wharminda, Cootra, Pinkawillinie and Minnipa.

Farming Systems

What happened?

The eight paddocks were monitored with:

- Segregation of zones by historical yield potential within the paddock.
- Pre-season deep N testing across yield zones.
- Understanding of plant available water capacity at the soil moisture probe.
- Group discussions with local grower groups on yield potential and its use in combination with soil moisture, nutrition, and seasonal forecast information.
- Yield and protein data post-harvest.

Small discussion groups were held in paddock to bring together growers, consultants and researchers. The approach was to understand the information available, and how growers used it to decipher yield potential. Information such as starting N, historical yields, and soil type to depth were all supplied to those involved. Once yield potential was considered and a target was decided on, how individual farmers intended on proceeding from this point regarding inputs was discussed.

Some factors that influenced decision making when it came to inputs were the inclusion of livestock into their system or not, grower optimism, growers' belief in N remaining for following seasons, soil type (risk of leaching), climate risk (frost, heat) and cost of inputs/ outputs.

Lessons learnt from five of the focus paddocks are reported below. All eight paddocks were not included as they either taught a similar lesson to another or did not add to the depth of this discussion.

Cockaleechie

How historical soil moisture can be used to increase confidence with in-season decision making.

Once a soil moisture probe has been in place for several seasons, growers are able to use the relative outputs in combination with yields obtained to increase their confidence in targeting grain yields.

In 2019 the Cockaleechie SMP indicated stored soil profile in July was below half full (Table 2). Soil moisture in 2021 was higher at around 75% full. Rainfall after July in 2019 was below average and the crop took a yield hit of an estimated 0.5 t/ha with a wind event just prior to harvest.

As soil moisture levels were higher at the end of July 2021 than at the same time in 2019, the grower had increased confidence that crop yields would exceed the yields of 5.5 t/ha achieved in 2019 when below average rain fell between August and October. This confidence was applied in the form of applying extra in-season N to target yields around 6 t/ha, which were realised at harvest.

Table 1: Focus paddock history, rooting depth, April 2021 plant available water (PAW), April 2021 mineral nitrogen (N) and grain yield in 2021.

Paddock	Crop 2020	Crop 2021	Rooting depth (mm)	April PAW (mm)	April N (kg/ha)	April -Oct rainfall (mm)	Yield (t/ha)
Cockaleechie	CL Canola	Wheat	1200	27	105	327	6.57
Lock	Vetch	CL Canola	800	91	110	228	1.50*
Cootra	Wheat	Wheat	1100	11	60	219	3.44
Minnipa	Wheat	TT Canola	1100	10	195	212	1.10*
Pinkawillinie	Wheat	CL Barley	600	60	45	162	2.93

*NB all grain yields were adjacent to SMP except canola crops marked with *which were whole paddock yields.*

*Table 2. Comparison between yields given higher stored moisture levels mid-season in 2021 and similar end of season rainfall. *2019 saw a significant wind event at harvest when an estimated 0.5 t/ha was lost.*

	Crop prior	Crop	End July stored soil moisture	Aug- October rainfall (mm)	Yield (t/ha)
2019*	Wheat	Wheat (Scepter)	40%	91	5.5
2021	Canola	Wheat (Vixen)	75%	103	6.2

Lock

Understanding yield potential so opportunities are not missed

Target yields for canola in the Lock area on the soil type where the SMP is located are typically set at 1 t/ha. April PAW of 91 mm was the highest recorded stored soil water since the probe had been installed (in 2016). This presented an opportunity to push 'usual' yields.

Starting soil nitrogen (110 kg N/ha), N applied at seeding (10 kg/ha) and Yield Prophet® in-season N mineralisation predictions (10 kg/ha) totalled 130 kg/ha of N available to the canola crop. Using a N efficiency of 80 kg N/tonne of grain suggested the crop had sufficient nitrogen to achieve 1.63 t/ha with existing N after sowing.

In July Yield Prophet® simulated yields of 2.2 t/ha or higher in 50% of years, based on historical climatic conditions. This also means that canola yields could be lower than 2.2 t/ha in 50% of years. In this instance, after a group discussion on the range of possibilities, the grower decided not to target 2.2 t/ha but was comfortable that sufficient N was available to achieve a canola yield at least 50% higher than his target yield for most of the paddock. But to hedge bets, another 30 kg/ha N was applied to areas of the paddock where yield was historically higher.

The dry period from mid-August to end of September reduced the Yield Prophet® 50% yield simulation to 1.5 t/ha. This yield was realised at harvest.

The extra information provided through soil testing at the start of the season, the SMP output and Yield Prophet simulation gave the grower confidence to adjust yield expectations to a level where he was comfortable with the level of risk and was able to achieve higher than average grain yield without having to apply more N fertiliser across the whole paddock.

Cootra and Minnipa

Paddock variation and using it to your advantage.

Understanding paddock variation, in terms of how changes in soil type can affect yield potential can prove highly beneficial. Variable rate technology, prescription maps and specialists that can employ its use on farm are available (at a cost), to those that want to implement its use on farm.

Two focus paddocks at Cootra and Minnipa have highly variable soil types within the paddock with yields varying from 1.5 to 3.5 t/ha in each season. To put within paddock variation into context, if there were two paddocks side by side and one yielded 2.5 t/ha better than the other should they be treated the same?

Preliminary results from using variable rates within each paddock revealed several main points.

- Maximum yields on the better zone will not be realised unless inputs in these areas are greater than those in poorer areas.
- Total paddock inputs often remain similar.
- Easy savings can be made by applying less on lower yielding areas.
- Yield data and sometimes protein data are a reliable way to establish zones within a paddock. This is best done over several seasons, with knowledge of rainfall and other influences that most growers will know (heat events, rainfall, etc.).

Pinkawillinie

The importance of understanding stored soil moisture

At Pinkawillinie, a barley yield of 2.93 t/ha was achieved in 2021. Growing season rainfall at this site was 162 mm (with 18 mm falling in October when the crop was largely mature). Sixty mm of PAW was measured (to 1m depth) at the start of the season in April. This provided an invaluable reserve during the growing season, particularly during September when only 4 mm of rain was recorded.

In this instance, the ability to measure stored soil moisture at the beginning of a season helped give the grower confidence that despite below average rainfall profitable yields were still possible and could assist his decisions regarding fertiliser purchase and grain marketing. The information didn't change the grower's decisions in the way he managed this crop, but it gave confidence and peace of mind.

What does this mean?

At Lock in 2021 we learnt to utilise knowledge of plant available water and yield potential to realise the full economic capabilities of your crop.

Pinkawillinie taught us the importance of preserving stored soil moisture to minimise risk in a low rainfall environment on a soil type with a high plant available water capacity.

Understanding patterns in stored soil moisture and crops to help predict end yield and therefore required inputs was shown at Cockaleechie where yield potential seen in prior years meant a high target could be set for 2021.

Both Minnipa and Cootra demonstrated the importance of understanding variability within paddock and utilising this knowledge to maximise profitability through use of variable rate applications.

Acknowledgements

Funding through the Australian Government's National Landcare Program. Much appreciation to all the growers who host and maintain a soil moisture probe on their properties and freely provide information on crop type, inputs and yield maps. The eight growers and their families that hosted the focus paddocks and provided a great level of transparency to their operations and provided answers to questions throughout the year are appreciated. The research and extension partners that all contribute to the Resilient EP project: SARDI (MAC) and SARDI (Climate Applications), Square V, CSIRO (Agriculture and Food), Regional Connections, AIR EP and the farmers and consultants that participate in the regional innovators group.

Section 4

Section Editor:
Kaye Fergsuson
SARDI Port Lincoln

Break Crops

Table 1. Eyre Peninsula 2021 NVT canola trial yields in t/ha and expressed as percentage of site mean.

Nearest town	**Minnipa**		
Variety	**t/ha**	**%**	**Oil (6% moisture)**
Pioneer 43Y92 (CL)	1.50	108	43.58
Site mean (t/ha)	**1.39**		
CV (%)	5.03		
Probability	<0.001		
LSD (t/ha)	*0.10*		
Sowing Date	21/05/2021		
Variety			
ATR Bluefin	0.78	72	42.55
ATR Stingray	0.77	71	41.82
HyTTec Trident	1.28	118	41.17
HyTTec Trophy	1.21	112	40.21
InVigor T 4510	1.20	111	40.63
Site mean (t/ha)	**1.09**		
CV (%)	5.84		
Probability	<0.001		
LSD (t/ha)	*0.11*		
Sowing Date	21/05/2021		

All NVT data sourced from https://app.nvtonline.com.au/lty/table/

Table 2. Eyre Peninsula 2021 NVT field pea trial yields in t/ha and expressed as a percentage of site mean.

Nearest town	**Minnipa**	
Variety	**t/ha**	**%**
GIA Kastar	1.74	82
GIA Ourstar	1.75	82
Kaspa	2.26	106
PBA Butler	2.43	115
PBA Gunyah	2.37	112
PBA Noosa	2.06	97
PBA Oura	1.93	91
PBA Pearl	2.18	103
PBA Percy	2.20	103
PBA Taylor	2.29	108
PBA Wharton	1.86	88
Site mean (t/ha)	**2.12**	
CV (%)	5.29	
Probability	<0.001	
LSD (t/ha)	*0.19*	
Sowing Date	04/06/2021	

All NVT data sourced from https://app.nvtonline.com.au/lty/table/

Break Crops

Table 3. Eyre Peninsula 2021 NVT lentil trial yields in t/ha and expressed as percentage of site mean.

Nearest town	**Yeelanna**	
Variety	**t/ha**	**%**
GIA Leader	3.51	104
PBA Ace	3.47	103
PBA Bolt	3.05	91
PBA Hallmark XT	3.55	105
PBA HighlandXT	3.32	98
PBA Hurricane XT	3.41	101
PBA Jumbo2	3.11	92
PBA Kelpie XT	3.36	100
Site mean (t/ha)	**3.37**	
CV (%)	3.98	
Probability	<0.001	
LSD (t/ha)	*0.24*	
Sowing Date	02/06/2021	

All NVT data sourced from https://app.nvtonline.com.au/lty/table/

Demonstrating new canola systems

Amanda Cook[1,2], Ian Richter[1] and Craig Standley[1]
[1]SARDI, Minnipa; [2]University of Adelaide Affiliate

Location
Minnipa
Minnipa Agricultural Centre
Rainfall
Av. Annual: 325 mm
Av. GSR: 241 mm
2021 Total: 404 mm
2021 GSR: 248 mm
Paddock history
2021: PBA Butler peas
2020: Scepter wheat
2019: Self-regenerating medic pasture
Soil type
Red loam
Plot size
12 m x 1.7 m x 3 replicates

Key messages

- **Genetically modified (GM) canola varieties are now an option for growers on mainland South Australia.**
- **The 2021 seeding conditions provided ideal conditions for the use of propyzamide.**
- **All applied herbicide treatments reduced barley grass weed numbers compared to the ATR-Bonito untreated control.**
- **Despite the late May seeding opportunity, the average June and July rainfall in 2021 and high canola prices provided the opportunity for good canola gross margins.**
- **Further evaluation of the new canola systems and varieties will need to be undertaken to determine the best management and fit in low rainfall farming systems.**
- **New canola systems and varieties are now available which perform well in low rainfall environments compared to Stingray, despite the lower seed input costs for Stingray.**

Why do the trial?

GM canola varieties are now an option for growers on mainland SA. A demonstration trial was established at MAC in 2021 to compare control of annual ryegrass (*Lolium rigidum*) and barley grass (*Hordeum leporinum*) in different canola systems.

How was it done?

TruFlex® variety Hyola 410XX and Roundup Ready® variety 43Y29 RR were sown along with triazine tolerant varieties ATR-Bonito and Stingray in a replicated trial. All canola varieties were sown using a knife point press wheel system into existing stubble residues with no cultivation. The seeding rate was 2.5 kg/ha of all varieties except Stingray which was sown at 3 kg/ha. Sowing occurred on 24 May 2021, within 4 hours of IBS herbicide application. Various herbicide regimes and rates were applied at pre-emergent or post-emergent at the 2-4 leaf (21 June), 6 leaf (28 July) or first flower stage (13 August) (Table 1). Canola establishment and grass weed numbers were assessed eight weeks after sowing.

What happened?

The trial was dry sown on the 24 May ahead of a predicted opening season rainfall event. The seeding conditions and rainfall events provided ideal conditions for the use of propyzamide, which needs moisture to prevent weed seed germination in the inter row. Germination and canola establishment were successful with greater than 20 plants/m^2 being achieved for hybrid varieties and greater than 30 plants/m^2 for open pollinated varieties (Table 2). Stingray sown at the 3 kg/ha sowing rate and with a smaller seed size had a much higher plant population (Table 2).

The trial site chosen had very little ryegrass present with the main weed being barley grass. Barley grass weed numbers were high in the ATR-Bonito untreated control which impacted on the overall canola yield (Table 2). All herbicide treatments applied reduced barley grass weed numbers compared to the untreated control (Table 2).

The early application of propyzamide and Roundup Ready PL® herbicide at the higher rate performed well in 2021. Visually the Overwatch treatment caused some bleaching of the crop, but the canola plants recovered after a few weeks.

Table 1. Canola varieties, herbicide treatments, timing and rates applied at Minnipa Agricultural Centre N4, 2021. UTC = untreated control

Treatment	Variety	Rate (per ha)			
		Pre- Emergent (A) 24 May	2-4 Leaf (B) 21 June	6 Leaf (C) 28 July	1st flower (E) 13 August
1	ATR-Bonito UTC (Untreated control)	Nil	Nil	Nil	Nil
2	ART-Bonito Prop+Atraz (IBS), 6 L grass weed	Propyzamide @ 1 L + Atrazine @ 1.1 kg	Nil	Atrazine @ 1.1 L + Clethodim @ 500 mL + Hasten1%	Nil
3	410 XX - Prop (IBS) Rup 2-4 L	Propyzamide@ 1 L	Roundup PL (granular) @ 1.3 L	Nil	Nil
4	410 XX - Prop (IBS) Rup 2-4 L (low rate)	Propyzamide@ 1 L	Roundup PL (granular) @ 0.9 L	Nil	Roundup PL (granular) @ 0.9 L
5	410 XX - Prop (IBS) Rup 2-4 L, 1st flower	Propyzamide@ 1 L	Roundup PL (granular) @ 1.3 L	Nil	Roundup PL (granular) @ 1.3 L
6	410 XX - Prop (IBS), Rup 2-4 L+ grass weed, 6 L, 1st flower	Propyzamide@ 1 L	Roundup PL (granular) @ 0.9 L + Clethodim @ 500 mL + Hasten 1%	Roundup PL @ 0.9 L	Roundup PL @ 0.9 L
7	410 XX - Overwatch (IBS) Rup 2-4 L+ grass weed, 6 L, 1st flower	Overwatch @ 1.25 L	Roundup PL (granular) @ 0.9 L + Clethodim @ 500 mL + Hasten 1%	Roundup PL @ 0.9 L	Roundup PL @ 0.9 L
8	43Y29 RR Prop (IBS), Rup 2-4 L+ grass weed, 6 L	Propyzamide@ 1 L	Roundup PL (granular) @ 0.9 L	Roundup PL @ 0.9 L	Nil
9	ATR-Stingray Prop (IBS), 6 L Gp A grass weed	Propyzamide@ 1 L	Nil	Clethodim @ 500 mL + Hasten 1%	Nil

Table 2. Canola varieties and herbicide treatments on canola establishment, barley grass weed numbers and yield at Minnipa Agricultural Centre N4, 2021.

Treatment	Herbicide Treatment	Canola Establishment (plants/m^2) 30 July	Barley grass (weeds/m^2) 30 July	Grain Yield (t/ha) 1 Nov
1	ATR-Bonito UTC	34.2 abc	23.3 a	0.42
2	ATR-Bonito Prop+Atraz (IBS), 6 L grass weed	45.8 cd	0.8 c	0.70
3	410 XX - Prop (IBS) Rup 2-4 L	38.3 bc	0 c	1.14
4	410 XX - Prop (IBS) Rup 2-4 L (low rate)	28.3 ab	0.8 c	0.77
5	410 XX - Prop (IBS) Rup 2-4 L, 1st flower	33.3 abc	0.8 c	0.61
6	410 XX - Prop (IBS), Rup 2-4 L+grass weed, 6 L, 1st flower	36.7 abc	0 c	0.77
7	410 XX - Overwatch (IBS) Rup 2-4 L+grass weed, 6 L, 1st flower	38.3 bc	8.3 b	0.92
8	43Y29 RR Prop (IBS), Rup 2-4 L+grass weed, 6 L	23.3 a	2.5 c	1.04
9	Stingray Prop (IBS), 6 L Gp 1 (A) grass weed	60 d	1.7 c	0.54
LSD (P=0.05)		*14.8*	*4.8*	*ns*

What does this mean?

The moist conditions at seeding with adequate rainfall events allowed the early application of propyzamide to work well, which is not always possible in this environment. All canola lines achieved good plant establishment. The new canola systems will allow another option for grass weed management in problem paddocks with multiple applications being able to be undertaken within the season to control different timings of weed germination.

Despite the lower input costs for Stingray seed there are now new canola varieties and systems which perform well in the low rainfall environment compared to Stingray.

Despite the late seeding opportunity and little subsoil moisture, the average June and July rainfall in 2021 and the high canola prices provided the opportunity for canola gross margins to generate good positive returns. Further evaluation of the new canola systems and lines will need to be undertaken to determine the best management and fit in low rainfall farming systems.

Acknowledgements

SARDI would like to thank Tim Murphy of Bayer for providing Roundup Ready® and TruFlex® seed for the trial. Thanks to Marina Mudge and Katrina Brands for helping with the field work.

Canola at Minnipa Agricultural Centre, 2021.

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SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE

Taking South Australian canola profitability to the next level

Andrew Ware
EPAG Research

Location
Yeltukka (15 km NW Cummins)
Michael Treloar
Rainfall
Av. Annual: 396 mm
Av. GSR: 315 mm
2020 Total: 431 mm
2020 GSR: 365 mm
2021 Total: 421 mm
2021 GSR: 377 mm
Yield
Potential: Canola 5.3 t/ha (Modified French/Schultz, 14 kg/mm)
Actual: 3.5 t/ha
Paddock history
2021: Canola
2020: Wheat
2019: Lupins
Soil type
Sand over clay loam with some calcrete in sub-soil
Soil test
Yeltukka 0-10 cm pH 6.25

Location
Coomunga (15 km NW Port Lincoln)
Peter Russell
Rainfall
Av. Annual: 616 mm
Av. GSR: 499 mm
2020 Total: 881 mm
2020 GSR: 563 mm
2021 Total: 700 mm
2021 GSR: 554 mm
Yield
Potential: Canola 7.7 t/ha (Modified French/Schultz, 14 kg/mm)
Actual: 3.9 t/ha
Paddock history
2021: Canola
2020: Lupins
2019: Wheat
Soil type
Sand loam over ironstone clay loam
Soil test
Coomunga 0-10 cm pH 5.3

Plot size
10 m x 2 m x 4 reps
Split plot x completely randomised block
Yield limiting factors
Some broadleaf weeds in Yeltukka trial

Key messages

- **High canola yields (3.5 t/ha+) were achieved at two sites on the lower EP in 2021.**
- **Canola yields were not improved by applying higher rates of nitrogen, phosphorous, or trace elements than considered "district practice".**
- **At the two 2021 sites canola yields were similar following a 2020 wheat crop as they were for a 2020 lupin or faba bean crop.**

Why do the trial?

Practices such as early sowing, matching cultivar phenology and sowing time to critical flowering period, the use of higher rates of nitrogen fertiliser, the development of high yielding hybrid varieties and fungicide use to control blackleg have improved canola yield in recent years.

To gain insight to where the next advance in canola yield may come from and to determine if profitability can also be improved, a series of trials were commenced in a set-up phase in 2020 and then were planted to canola in 2021.

How was it done?

The trials are being run over two growing seasons at two sites on the lower Eyre Peninsula.

- Site 1: Coomunga (15 km NW Port Lincoln) on an ironstone duplex loamy sand soil.
- Site 2: Yeltukka (15 km NW Cummins) on a sand over clay loam soil.

In 2020 blocks of wheat and lupins (Coomunga) and wheat and faba beans (Yeltukka) were grown in preparation for canola in 2021. On each block separate treatments of high rates of nitrogen, phosphorous, sulphur, and trace elements were applied to create differences for the canola to be grown into in 2021.

In 2021 Pioneer 44Y94CL canola treated with Saltro® seed dressing was seeded dry (16 May Coomunga, 19 May Yeltukka) at both sites, targeting establishment of 45 plants/m^2. Germinating rains fell on 24 May.

In 2021 each site was sown with 100 kg/ha MAP + 200 mL/ha flutriafol 500. A total of 148 kg/ha N (district practice) was applied to the sites before early flowering. Weeds were controlled with 1 L/ha propyzamide, 500 mL/ha of clethodim, and 50 mL/ha Lontrel Advance. 600 mL/ha Aviator Xpro was applied at 30% bloom to control upper canopy blackleg. 500 mL/ha Pyrinex Super was applied post-sowing and 100 mL/ha alpha-cypermethrin applied during grain fill to prevent insect damage.

Additional nutrition was applied as detailed in Table 1 to raise levels of individual nutrients.

Harvest was conducted on 2 November at Yeltukka and 11 November at Coomunga.

Phosphorous was applied at high rate during seeding 2020, nitrogen was applied as urea during stem elongation 2020.

Table 1. Rates (kg/ha) of nitrogen, phosphorous and sulphur applied to each treatment in 2020 and 2021 at both Coomunga and Yeltukka.

		District Practice	P high	N High	TE High	Everything high
Nitrogen (N)	2020	9 (+125)*	9 (+125)	159 (+125)	9 (+125)	159 (+125)
	2021	148	148	148	148	148
	Total	157 (+125)	157 (+125)	307 (+125)	157 (+125)	307 (+125)
Phosphorus (P)	2020	18	36	18	18	36
	2021	22	22	22	22	22
	Total	40	58	40	40	58

*****() figure = extra nitrogen (kg/ha) applied to all wheat plots in 2020. Lupin/ faba bean plots did not receive this.

Table 2. Results of pre-seeding soil tests taken at Coomunga 2021.

2020 Treatment	Total Mineral N (kg/ha) Depth 0-100cm	Total PAW (mm) Depth 0-100cm	S (kg/ha) Depth 0-100 cm	Colwell P (mg/kg) Depth 0-10cm
Wheat - Everything	156	53	89	23
Wheat - District Practice	91	22	94	26
Lupins - Everything	158	25	76	21
Lupins - District Practice	101	44	82	26

Table 3. Grain yield of canola 2021 at Coomunga following the different 2020 crops.

2020 Crop	Yield (t/ha)
Lupin	3.88
Wheat	3.82
LSD (P=0.05)	*ns*

Table 4. Grain yield and oil content of canola 2021 at Coomunga as a result of treatments applied in both 2020 and 2021.

Treatment	Yield (t/ha)	Oil (%)
District Practice	3.75	44.4
P High	3.82	44.9
N High	3.82	44.4
TE High	3.91	45.3
Everything High	3.98	45.0
CV	*9.80*	
LSD (P=0.05)	*ns*	*ns*

Table 5. Results of pre-seeding soil tests taken at Yeltukka 2021.

2020 Treatment	Total Mineral N (kg/ha) Depth 0-100 cm	Total PAW (mm) Depth 0-100 cm	S (kg/ha) Depth 0-100 cm	Colwell P (mg/kg) Depth 0-10 cm
Wheat - Everything	142	82	112	25
Wheat - District Practice	46	108	183	24
Lupins - Everything	128	178	417	27
Lupins - District Practice	80	168	390	36

Table 6. Grain yield of canola 2021 at Yeltukka following the different 2020 crops.

2020 Crop	Yield (t/ha)
Faba Bean	3.53
Wheat	3.55
LSD (P=0.05)	*ns*

Table 7. Grain yield and oil content of canola 2021 at Coomunga as a result of treatments applied in both 2020 and 2021.

Treatment	Yield (t/ha)	Oil (%)
District Practice	3.45	43.4
P High	3.49	42.8
N High	3.58	43.0
TE High	3.58	43.1
Everything High	3.58	42.8
CV	*8.8*	
LSD (P=0.05)	*ns*	*ns*

The "Trace Element (TE) High" and "Everything High" treatments also received 1.7 kg/ha Zn, 5 kg/ha Ca, 2.6 kg/ha Mn, 1 kg/ha Cu, 40 g/ha B, 2 g/ha Mo, and 1.35 kg/ha Fe in 2020, through streaming nozzles. This treatment also received 120 g/ha Zn, 150 g/ha Mn, 40 g/ha Cu, 50 g/ha Ca and 6 g/ha Mo applied as a foliar spray at early bloom in 2021.

Yields presented are hand cut yields, collected at 60% seed colour, as this represents the most accurate method of determining canola yield in small plot trials (John Kirkegaard, pers. comm.).

What happened?

Site 1: Coomunga

2020 Results: Sown 12 May. Wheat (cv Scepter) yielded 5.0 t/ha, lupins (cv Wonga) yielded 1.8 t/ha.

Site 2: Yeltukka

2020 Results: Sown 13 May. Wheat (cv Scepter) yielded 5.3 t/ha, Faba beans (cv Fiesta) yielded 3.1 t/ha.

What does this mean?

Immediately following harvest in 2020, plant available soil moisture levels were 20 mm higher following lupins than wheat at Coomunga. These differences had eroded by April 2021 (where 150 mm of rain fell between December and April).

At Yeltukka differences in plant available water following faba beans compared to wheat found at harvest remained at seeding, with soil moisture levels 80 mm higher to a depth of one metre where faba beans had been grown compared to wheat (84 mm of rain was recorded between December and April at Yeltukka).

This indicates that pulse crops may leave potentially valuable soil water for the next crop to utilise. However, with 170 mm falling during June and July 2021 at Yeltukka and 310 mm falling in the same period at Coomunga, soil moisture profiles filled to capacity at both sites by the end of July, before the crop was able to utilise any stored water (a soil moisture probe is located in the same paddock as the Yeltukka trial).

The faba bean crop at Yeltukka left higher (40 kg/ha) mineral nitrogen levels prior to seeding 2021 than wheat. There was no difference in the amount of mineral nitrogen measured in April 2021 following a lupin crop compared to wheat at Coomunga. The differences didn't realise extra grain grown as a result in 2021.

There was no advantage in growing a pulse crop compared to wheat at either site.

Where 150 kg/ha of extra nitrogen was added (N High and Everything High treatments) during stem elongation in 2020, higher soil mineral N levels were measured prior to seeding at both sites in 2021. This indicates that the concept of nitrogen banking, through banking nitrogen in one year, to be used in subsequent years has some potential. However, in these instances the extra nitrogen provided no increase in canola grain yield at either site.

Canola has been shown to require around 80 kg of nitrogen per tonne of grain removed. To achieve the average yields at each site (3.54 t/ha at Yeltukka and 3.86 t/ha at Coomunga) 283 kg/ha and 309 kg/ha respectively of nitrogen was required at each site.

The treatment starting with the lowest nitrogen levels at Yeltukka (2020 Wheat - District Practice) started the 2021 season with 46 kg/ha nitrogen. 148 kg/ha of nitrogen was added to the canola crop in 2021. The canola grown on the 2020 wheat - district practice treatment realised a yield of 3.45 t/ha which meant the crop required an extra 82 kg/ha of nitrogen to be released from soil mineralisation.

For this amount to be released is historically higher than normal. This may have been due to favourable conditions in October.

Similarly on the higher rainfall, more gravelly type soil at Coomunga, where nitrogen is thought to leech and denitrify in wet conditions an extra 61 kg/ha of nitrogen may have been mineralised for the canola grown on 2020 wheat - district practice treatment to yield 3.75 t/ha.

Higher nitrogen rates applied in the year prior did not affect canola oil percentages at Yeltukka and Coomunga.

Adding higher levels of phosphorous (P) to each site in the year prior to growing canola was thought to boost levels of P sufficiently so it is not limiting when aiming to grow a canola high yielding crop. Canola typically removes 7 kg/t of grain, with many Eyre Peninsula soils (such as the ironstone and calcareous soil these trials were conducted on) also tying P up in insoluble compounds. If targeted yields of canola are higher than 3 t/ha then 100 kg/ha of MAP or DAP are not going to satisfy the total P requirement. Canola is also very sensitive to having high rates of fertiliser close to seed, where germination may be affected. As such, applying all of a crop's requirements in the year it is grown may not be possible.

In both 2021 trials there was no response to adding higher (38 kg/ha of P) the year prior to grain yield.

Canola is typically more efficient at finding sufficient trace elements in soils than cereal crops, however some anecdotal evidence suggests applying trace elements, not only to vegetative crops, but also to crops starting flowering may improve yields in some situations. To investigate this, high rates of trace elements were applied in 2020 including zinc, calcium, manganese, copper, boron, molybdenum and iron. These plots also received zinc, manganese, copper, calcium, boron and molybdenum as a foliar application during early bloom 2021. These treatments did not improve canola grain yield in 2021.

While the treatments used in these trials did not have any influence on canola grain yield in 2021, the trial has given insights into the amount of soil water left by different crops in the lower Eyre Peninsula environment, the amount of nitrogen mineralised in 2021 and how that may have had a large influence on grain yield across the region, how loading high rates of P the year prior may not have an effect on the subsequent crop and how the application of trace elements at these two sites did not affect grain yield.

Achieving canola yields in excess of 3.5 t/ha with above average growing season rainfall on the lower Eyre Peninsula is considered reasonable in light of historical yields but this represents a water use efficiency of 9 kg/mm, well short of the 14 kg/mm thought to be the theoretical potential. These trials do not answer how much later than ideal break to the season and the dry September that coincided with the critical period when canola is most prone to heat, frost and drought damage affected canola yield in 2021. However, choosing a high yielding variety, planting as close as possible to the ideal sowing window, having adequate nutrition and managing blackleg were still important in helping to drive high canola yields on the lower Eyre Peninsula in 2021.

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AIR EP Ag Innovation & Research Eyre Peninsula

EPAG RESEARCH

SAGIT

DNA test takes the guess work out of inoculation requirements

Liz Farquharson[1,2], Ross Ballard[1,2], Amanda Cook[2,3] and Lynnette Schubert[1]

[1]SARDI, Waite; [2]University of Adelaide Affiliate; [3]SARDI, Minnipa

Location
Minnipa
Matt Cook
Rainfall
Av. Annual: 325 mm
Av. GSR: 241 mm
2021 Total: 405 mm (105 mm in Nov)
2021 GSR: 248 mm
Yield
Vetch: 0.75 t/ha
Paddock history
2021: Cummins vetch
2021: CL Chief wheat
2019: CL Chief wheat
Soil type
White sand
Nutrition
See Table below
Plot size
12 m x 1.75 m x 3 replicates
Trial design
Plot trial (12 m x 1.75 m) randomised complete block design, 3 reps
Yield limiting factors
Seeder blockages at sowing. In some cases up to 30% of plots missing
Livestock
None

Key messages

- **PREDICTA® rNod is a DNA test which takes the guess work out of inoculation requirements.**
- **PREDICTA® rNod is available for inoculant groups E&F (lentil, pea, faba bean, vetch), N (chickpea), G&S (lupin, serradella).**
- **Where no rhizobia are present they must be delivered in inoculants applied to the seed or soil at sowing.**
- **Increasing inoculant rates can improve nodulation and nitrogen fixation of pulses on responsive sites and under stressful conditions, however this was not observed for the vetch trial reported in this paper.**

Why do the trial?

- Inoculation response trials were established at multiple sites in South Australia and Victoria, including Minnipa, to demonstrate the value of the new rhizobia DNA tests in predicting the requirement for inoculation.
- To determine if increasing the rate of inoculant applied can improve nodulation or nitrogen fixation of vetch.

Rhizobia are bacteria that live in soil and form nodules on legume roots where biological nitrogen (N) fixation occurs. There are many species of rhizobia and those which nodulate agricultural legumes are not native to Australia. Many agricultural soils in southern Australia now support large populations of rhizobia following their introduction to soils (via inoculation) and are supported by inclusion of host legumes in cropping rotations. However, rhizobia numbers in individual paddocks vary greatly and can be affected by soil type, legume history and management practices. Where no rhizobia are present they must be delivered in inoculants applied to the seed or soil at sowing.

Until recently measuring rhizobia in soil was done using a plant bioassay method which was time consuming and labour intensive. SARDI have now developed PREDICTA® rNod, which includes three DNA tests that can accurately and rapidly estimate the number of rhizobia in soil for inoculation groups E & F, N and G & S.

How was it done?

At Minnipa, Timok Vetch was sown at a rate of 40 kg/ha (60 plants/m^2) on the 3 June 2021 into moist soil. MAP was applied at 60 kg/ha at seeding. A knockdown herbicide was applied on the 1 June of Weedmaster (2 L/ha) and LI700 (300 ml/100 L), and grass weeds were sprayed on the 6 July with Clethodim (500 ml/ha) and Hasten (1%). The trial was sprayed with Alpha Duo 300 ml/ha for insects on 1 September and desiccated on the 27 October with Paraquat 2 L/ha.

Table 1. Nutrition

Depth (cm)	pH 1:5 water pH units	pH $CaCl_2$ (following 4A1) pH units	Org. Carbon (W&B) (%)	MIR - Aus Soil Texture	Nitrate - N (2M KCl) (mg/kg)	Ammonium - N (2M KCl) mg/kg	Colwell P mg/kg	PBI + Col P	Colwell K mg/kg	Salinity EC 1:5 dS/m
0-10	8.70	8.04	0.56	Sand	14.3	<1	18	46	190	0.125

Pre-sowing soil testing 2021

Table 2. Treatments applied to Timok vetch seed prior to sowing.

Treatment Name	Treatment description	Inoculants application Rate
Nil	No inoculant applied	-
0.5 RR	*Group F Peat	Half Recommend
1x RR	Group F Peat	Recommended
1 x RR + LC29	Group F Peat + LC29 (non rhizobial co-inoculant)	Recommended
2 x RR	Group F Peat	Double Recommended
4 x RR	Group F Peat	Four Times Recommended
*Group F is rhizobia strain WSM1455		

Treatments

Inoculant treatments (Table 2) were applied to seed as a peat slurry. Seed was sown within 24 hours of application.

Measurements

Pre-sowing: rNod to establish rhizobia numbers

Plant establishment densities

10-12 weeks post emergence: nodulation (10 plants per plot); nodule number per plant

30 September: Maximum shoot biomass (2 linear m per plot)

PENDING: %N and Estimated Nitrogen Fixed (kg/ha)

Data was analysed (ANOVA) with GenStat 20th Edition.

What happened?

Predicta rNod testing did not detect rhizobia for Groups E&F (vetch, lentil, pea, faba bean), Group N (chickpea) and Groups G&S (lupin, serradella) in pre-season soil samples. This result was consistent with the paddock history which was pasture and cereals for the cereals for the past three years.

Plant establishment density averaged 40 plants/m^2, below the sowing target of 60 plants/m^2. This was a result of the seeding tubes becoming blocked with wet soil during sowing. Affected rows were avoided when conducting emergence counts.

All inoculated treatments had significantly more nodules than the Nil control treatment (Figure 1). However, only the standard rate of inoculant with the non rhizobial co-inoculant achieved close to the target of 50 nodules/plant for adequate nodulation of vetch at 10 weeks post emergence. This result demonstrated that indeed the site was responsive to inoculation. It is worth noting there was a low amount of nodulation in the Nil treatments. This may have been the result of a low residual background of rhizobia in the soil (below rNod detection) or due to contamination of seed with rhizobia from the seeding equipment.

With the exception of the 2RR treatment, there were no significant effects of treatment on the peak biomass of vetch (Figure 2). Similarly yield was not significantly affected by treatment (mean= 0.75 t/ha, data not shown). We are unable to explain the reduced biomass of the 2RR treatment, other than due to a combination of the variable germination within the plots and sample error.

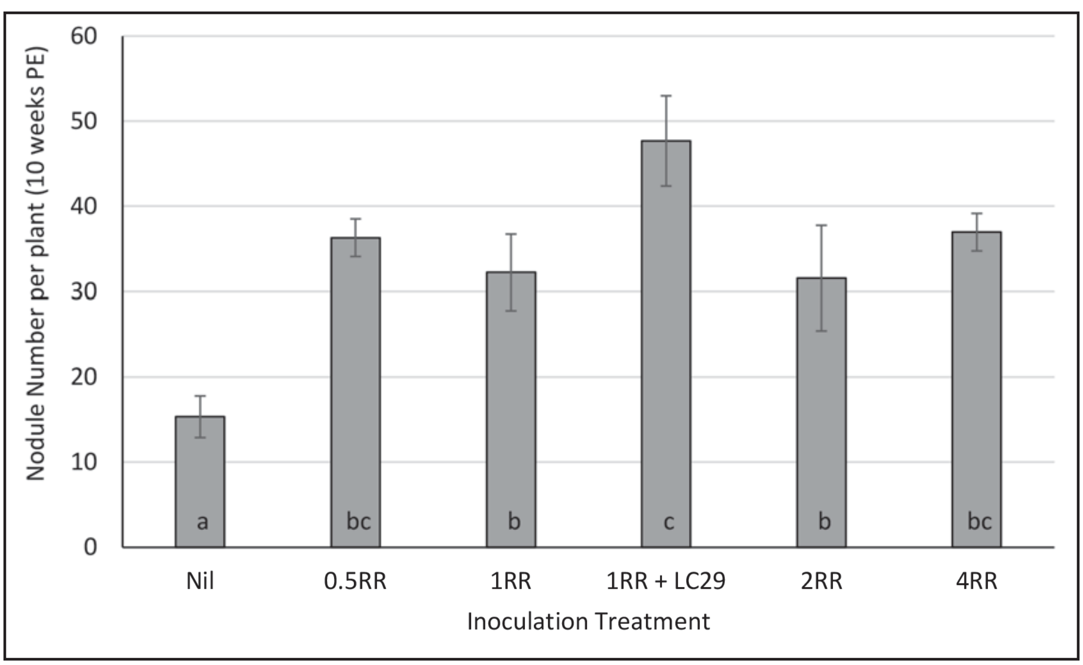

Figure 1. The effect of inoculation rate on the nodulation of vetch at Minnipa in 2021, where pre-sowing rhizobia numbers were below detection using Predicta® rNod. Letters which differ between columns indicate significance (P<0.05). Bars show standard error of the mean.

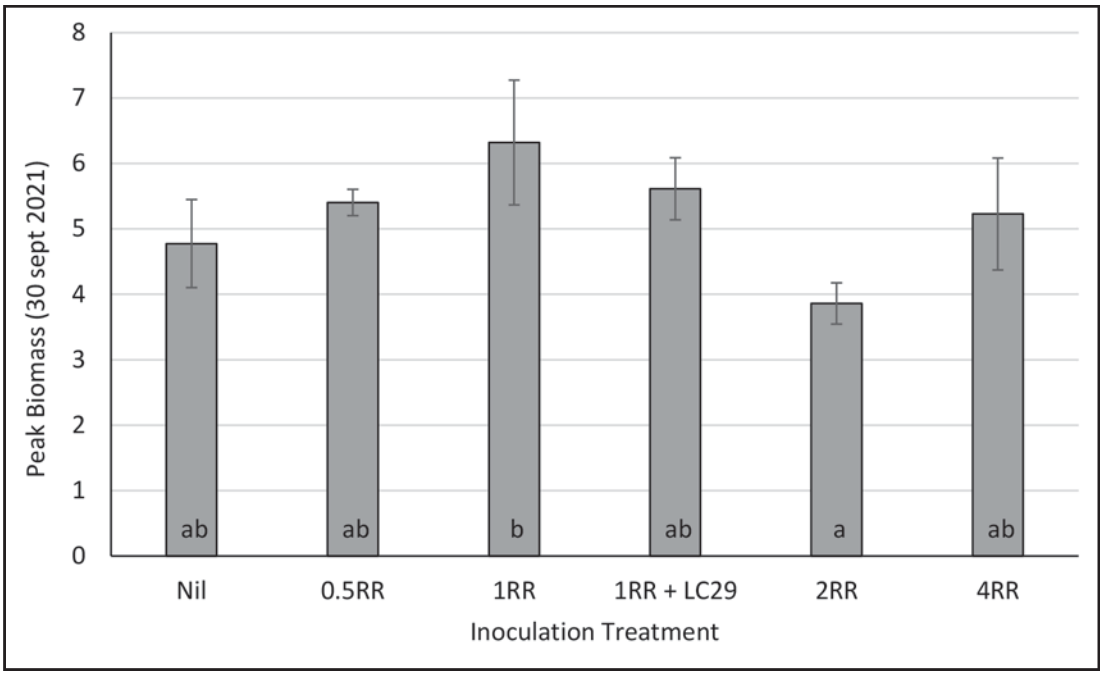

Figure 2. The effect of inoculation rate on the biomass production of vetch at Minnipa in 2021. Letters which differ between columns indicate significance (P<0.05). Bars show standard error of the mean.

What does this mean?

The pre-sowing PREDICTA® rNod tests did not detect any rhizobia from the E & F inoculant groups, which nodulate vetch, and predicted the site would be responsive to inoculation. This result was confirmed by the early crop data for nodulation, where there were significantly more nodules on plants in the inoculated plots. This improvement in nodulation was not realised in biomass production, with no-significant difference between the Nil and the inoculated treatments (except for 2RR, for unknown reasons). It is possible that the crop was not N limited; peak biomass samples are currently undergoing further analysis to determine the amount of N in the biomass and the proportion of N from biological fixation.

Seven similar inoculation response trials have been completed in SA and Victoria for field pea, vetch, faba bean and chickpea. For each of these trials PREDICTA® rNod was successfully used to predict the responsiveness of the sites to inoculation (nodule number per plant). At some sites crop biomass and yield were significantly increased in inoculated treatments relative to Nil treatments, for example faba bean at Cockaleechie on the lower EP yielded 2.45 t/ha in the 1RR treatment compared to 1.45 t/ha for the Nil.

Inoculation at greater than the recommended rate did not significantly increase nodule number or production in the vetch trial at Minnipa, however trials at other sites, including chickpea and vetch trials at Nhill showed significantly higher nodulation and yield at the higher rates (2RR, 4RR). While applying very high rates of peat inoculant to seed is not always practical and can cause seeder blockages, it indicates that there are many cases where nodulation and production can be improved by increasing the number of rhizobia applied at sowing. The non rhizobial co-inoculant (LC-29) has also had positive impacts on nodulation and biomass production and other sites; research continues in this area to better understand where higher application rates or co-inoculants are beneficial and how best to increase inoculant rates with minimal cost and logistical effort.

PREDICTA® rNod is available through PREDICTA®B accredited agronomists. Sampling is recommended between Nov and March to estimate inoculant requirements for the following pulse crops.

Acknowledgements

The research undertaken as part of GRDC project UOA1805-017RTX. The authors wish to thank Matt Cook (Condada) for hosting this trial as well as our other growers and collaborators without whom this work would not be possible.

Special thanks to the team at the Minnipa Agricultural Centre for implementing and maintaining this trial.

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SARDI SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE

Maximising grain legume production and closing the yield gap

Amy Keeley[1], Sarah Day[2,3] and Penny Roberts[2,3]
[1]SARDI, Port Lincoln; [2]SARDI, Clare; [3]University of Adelaide Affiliate

Key message

- **The GRDC funded SA Grain Legume Project will provide development and extension strategies to close the economic yield gap and maximise farming systems benefits from grain legume production in South Australia.**

Why do the trial?

The GRDC funded Southern Pulse Agronomy project (DAV00150) funded a large portion of pulse research on the Eyre Peninsula over the past 8 years and concluded in early 2021 (Bruce *et al*. 2020, Day *et al*. 2021, Gutsche *et al*. 2021, Roberts *et al*. 2021). An increase in pulse production over the past decade and a shift to novel pulse species and management strategies has demonstrated the pulse investment to be well received on the Eyre Peninsula, providing support and drive for the GRDC to invest further in pulses. In 2021, the GRDC funded SA Grain Legume Project commenced. This project will run for four years in South Australia, with Eyre Peninsula components managed by SARDI Port Lincoln, EPAG Research and AIR EP. Contributors in other regions include SARDI Clare, Trengove Consulting, FAR Australia, Frontier Farming Systems and Ag Communicators, as well as local grower groups.

The project will follow a model of hub and spoke sites to deliver grower-driven grain legume validation and demonstration trials across South Australian sub-regions to address economic yield gaps. Hub sites will deliver a focus on a combination of sub-regional development and extension priorities and extension of new research learnings. Spoke sites will be focused on-farm with one to two simple trials at each site. More specifically, trials undertaken will address economic impacts of grain legumes on farm profitability, disease management and integrated weed management strategies.

What happened?

In 2021, SARDI managed a spoke site at Kimba and a hub site at Tooligie. The Tooligie hub encompassed four trials investigating pod shatter and pod loss in lentil; economic disease management in lentil (Figure 1); integrated management of annual ryegrass in lentil (Aggarwal et al. 2022); and ground cover and legacies of pulses in rotation, including some intercropping treatments (Figure 2). At the Kimba spoke site, pulse end uses in vetch and lentil were evaluated, looking specifically at the success of varieties and plant densities for either grazing, hay or grain production, (Day *et al*. 2022). Individual trial results will be published on Online Farm Trials following each season, while key trials and results will be published in EPFS Summaries each year.

Although not directly funded by the GRDC SA Grain Legume project, a lentil variety trial was co-located at the Kimba spoke site to compare variety performance in the low rainfall environment of the Eyre Peninsula. The lentil variety trial was requested by local advisors and growers as a result of the developing interest and uptake of lentil production in marginal areas of the Upper Eyre Peninsula. Lentil varieties evaluated included PBA Hallmark XT, PBA Highland XT, PBA Hurricane XT, GIA Leader, PBA Jumbo2 and PBA Bolt. No significant differences were recorded between lentil varieties and the site average recorded 1.4 t/ha ($P>0.05$).

Communication and extension events attracted approximately 90 participants (growers, reps, advisors & breeders) to the Kimba spoke site in 2021 over three separate crop walk events held by AgSave Kimba and Buckleboo Farm Improvement Group (BFIG). SARDI and AIR EP held a major pulse field day at the Tooligie hub site which had approximately 50 participants attend (Figure 3). Across the state, the project engaged over 500 participants through numerous crop walks and field days hosted at hub and spoke sites. We will continue to communicate research findings and present at crop walks and field days at the spoke and hub sites over the duration of the project. Growers are strongly encouraged to engage in extension activities to learn best practice in legume agronomy and contribute to future trials, project ideas and investments.

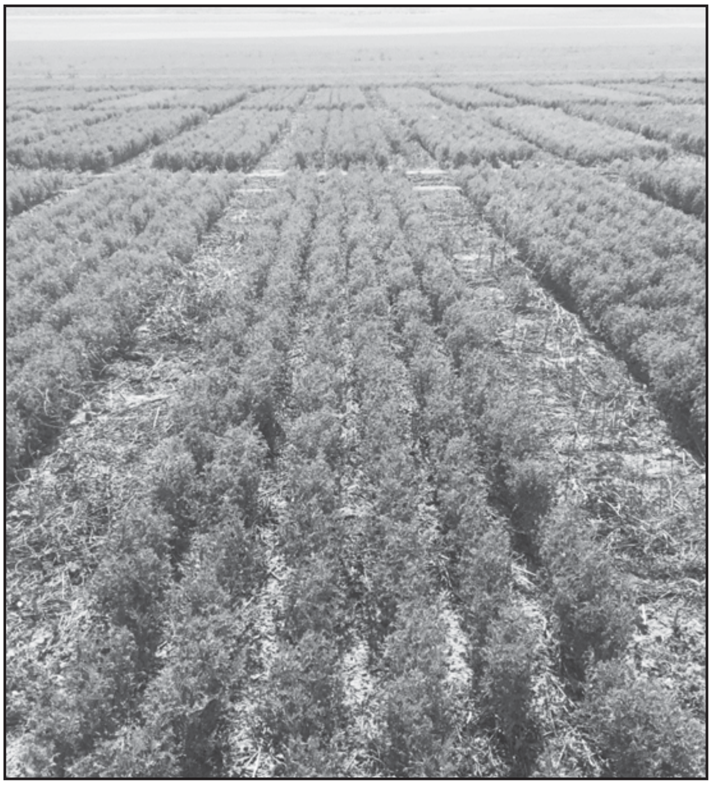

Figure 1. Lentil Disease Management at Tooligie, Eyre Peninsula, 12th October 2021. Canopy closure in lentil did not occur.

Figure 2. Faba Bean mixed with lentil as an intercropping treatment in Ground Cover and Legacies of Pulses trial at Tooligie, Eyre Peninsula 2021.

Figure 3. SARDI Senior Research Agronomist in weed ecology, Navneet Aggarwal, presenting at the Tooligie Pulse Field Day in October 2021.

What does this mean?

At the conclusion of the four year project, the investment will have minimised the current yield gap in grain legumes through supporting increased technical efficiency of growers with extension of best practice grain legume agronomy. System profitability and sustainable expansion of grain legumes will be maximised by supporting grain growers and advisors to incorporate grain legumes into paddock rotations and farming systems. The project aims to target 45% of growers to adopt or have the intention to adopt new practices emerging from achievable research findings.

Acknowledgements

Funding for this work is provided through GRDC project U0A2105-013RTX (Development and extension to close the economic yield gap and maximise farming system benefits from grain legume production in South Australia), and their continued support is gratefully acknowledged. The continued assistance from SARDI Agronomy groups at Clare and Port Lincoln is gratefully acknowledged and appreciated. The authors would also like to acknowledge continued support from AIR EP, EPAG Research, local growers and property owners involved in this project.

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Amy Keeley, SARDI Port Lincoln speaking at NVT pea trial at Minnipa Agricultural Field Day, September 2021.

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Improving lentil and vetch management and mitigating risk in the low rainfall zone

Sarah Day[1,2] and Amy Keeley[3]

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Break Crops

Key messages

- **Variety selection should be based on target end-use, paddock constraints and matching phenology to environment.**
- **Do not increase seeding rates unnecessarily, as this can lead to higher disease and lodging risk.**
- **Herbicide choice, rate and application timing are critical in reducing risk of crop injury.**
- **Experimental use of gibberellic acid in vetch to date has not proven to be beneficial to increasing hay production or delaying phenology, despite anecdotal evidence.**

Why do the trial?

Lentil and vetch production area has increased by over 7,700 hectares in the last decade across the western and eastern Eyre Peninsula regions (PIRSA 2021). 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 majority of pulse management research is conducted in medium and high rainfall zones, and strategies developed in these environments are often not viable or economical for growers in low rainfall regions. To improve grower confidence in pulse production there is a need for the development of pulse management strategies specifically for low rainfall environments. This article reviews recent research conducted under GRDC-funded projects on lentil and vetch production, with a focus on novel management and diversifying risk.

How was it done and what happened?

Variety selection and seeding rate

Research trials to compare biomass and grain production of vetch and lentil sown at recommended and reduced seeding rates (Table 1) were initiated in 2020 (Day, Roberts *et al*. 2021) and further validated in 2021 at three low rainfall sites, including Kimba. Three varieties each of vetch and lentil with varying phenology characteristics (Table 2) were included to refine variety selection depending on target end use. Biomass measurements were taken at late vegetative and early podding growth stages to identify production potential for grazing or hay production, and grain was harvested at crop maturity. Biomass and grain yield data was analysed using a split plot ANOVA model in Genstat 21st Edition. The trial aim is to identify optimum seeding rate and variety selection depending on target crop end use for both vetch and lentil.

Biomass production between lentil and vetch varieties was similar in both seasons, with no differences observed for late vegetative or early podding biomass ($P>0.05$, data not shown). Average biomass production at late vegetative and early podding was, respectively, 1.4 t/ha and 3.4 t/ha in 2020, and 0.69 t/ha and 1.6 t/ha in 2021. Variety selection for biomass production will depend on fit in the system, with a greater range in phenology between vetch varieties offering a unique fit in the system.

Morava is a late maturing vetch variety, suited to early sowing and spring fodder production. Studenica is a white flowering, very early maturing variety that has been bred for low rainfall areas, is particularly well suited to short seasons, and if sown early has a key role in filling the winter feed gap (Nagel, Kirby *et al*. 2021).

PBA Highland XT lentil had the highest grain yield at Kimba in 2021, equivalent to Volga vetch, and in 2020 was equal highest yielding lentil variety to PBA Jumbo2 (Table 2). PBA Highland XT is a medium seed size red lentil with improved herbicide tolerance and is showing adaptation to drier lentil-growing regions of South Australia. Morava vetch had the highest grain yield at Kimba in 2020, and equivalent grain yield to Studenica and Volga vetch in 2021.

Reducing the seeding rate of lentil and vetch didn't reduce production potential for biomass or grain at Kimba, in 2020 or 2021 ($P>0.05$, data not shown). In other environments, vegetative biomass was reduced where crops were sown at half the recommended seeding rate. However, early podding biomass and grain production was not compromised (Day, Roberts *et al*. 2021).

Table 1. Target plant density (plants/m²) and seeding rate (kg/ha) of lentil and vetch sown at Kimba, 2020 and 2021.

Seeding Rate	Lentil		Vetch	
	Plants/m²	kg/ha*	Plants/m²	kg/ha*
Recommended	120	50-70	60	45-60
Three-quarter	90	35-50	45	30-45
Half	60	25-35	30	20-30

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

Table 2. Grain yield of lentil and vetch varieties sown at Kimba 2020 (P=0.004) and 2021 (P<0.001). Different letters in the same column indicate a significant difference in grain yield between varieties in that environment.

Crop	Variety	Maturity	Grain yield (t/ha)	
			Kimba 2020	Kimba 2021
Lentil	PBA Blitz	Early	0.51 c	1.24 c
	PBA Highland XT	Early-Mid	0.89 b	1.71 a
	PBA Jumbo2	Mid	0.79 b	1.43 bc
Vetch	Studenica	Very early	N/A	1.43 bc
	Volga	Early	0.52 c	1.52 ab
	Timok	Mid	0.56 c	N/A
	Morava	Late	1.10 c	1.42 bc
LSD (P<0.05)			*0.15*	*0.108*

Key: N/A = variety was not included in the trial, LSD = least significant difference

Herbicide in lentil

Group 5 (previously group C) lentil herbicide trials have been conducted across the low rainfall zone in 2017-2020 to assess the risk of crop damage from different Group C products, rates and application timing (Day, Roberts *et al*. 2021, Day, Roberts *et al*. 2021). To determine the genotype (G) main effect and genotype by environment (GE) interactions of these trials, a GGE biplot was used to understand mean grain yield performance and stability of treatments across the environments (Figure 1) (VSNi 2018). A GGE biplot was not generated for herbicide crop injury, as this was minimal across all environments. Metribuzin applied incorporated by sowing (IBS) resulted in lower lentil yield stability, compared to applying Metribuzin post-sowing pre-emergent (PSPE), hence this is on label to apply PSPE only. Terbuthylazine label instructs IBS use only, and the GGE biplot shows that lentil with Terbuthylazine applied PSPE has lower mean yield, compared to this product applied IBS as per label instructions. Diuron applied IBS provides higher yield stability and performance than Diuron applied PSPE, with similar yield performance to lentil where Terbuthylazine was applied IBS. Herbicide choice, rate and application timing is important to reduce risk associated with lentil production, as lentil is extremely sensitive to herbicide use in dry conditions. Herbicide crop injury can result in reduced grain yield, nitrogen fixation and weed competition, and can increase the risk of soil erosion over the summer. Decisions around herbicide use in lentil will differ depending on an individual grower's attitude toward risk, soil type, target weed populations and herbicide characteristics (Table 3). A combination of herbicide products with different solubility and leaching rates may be used to reduce risk of damage while targeting a wider spectrum of weeds. Herbicides with low solubility require good soil moisture and rainfall to achieve incorporation and are less available in the soil moisture than herbicide with high solubility, reducing their damage risk. Herbicides with high solubility, such as metribuzin, are available to move more readily within the soil and more likely to achieve off-target damage.

Gibberellic acid use in vetch

Research focused on strategic application timings of gibberellic acid (GA) in vetch production was explored at Booleroo and Kimba in 2020, with the aim of quantifying the effects of GA on phenology, plant height and dry matter production (Day, Roberts *et al*. 2021). This research compared the application of GA at maximum label rate at two growth stages compared to an untreated Nil. Additional research has also been conducted at the Hart Field Day Site (Allen, Noack *et al*. 2021) and Pyramid Hill, Victoria (Bennett 2021). Anecdotal evidence suggests that the use of GA delays flowering in vetch, however, this was not observed at Booleroo, Kimba or Pyramid Hill. A vegetative application of GA did increase plant height by 3.8-5.4 cm through stem elongation, providing improved cutting or grazing ability. Despite this increase in plant height, an increase in biomass production from a vegetative or late flowering application of GA was not observed at Kimba, Booleroo or Pyramid Hill. A biomass increase of 0.27 t/ha was observed at Hart in July, indicating the early use of GA may benefit early grazing opportunities. Grain yield has been reduced from the use of GA in some environments (data not shown).

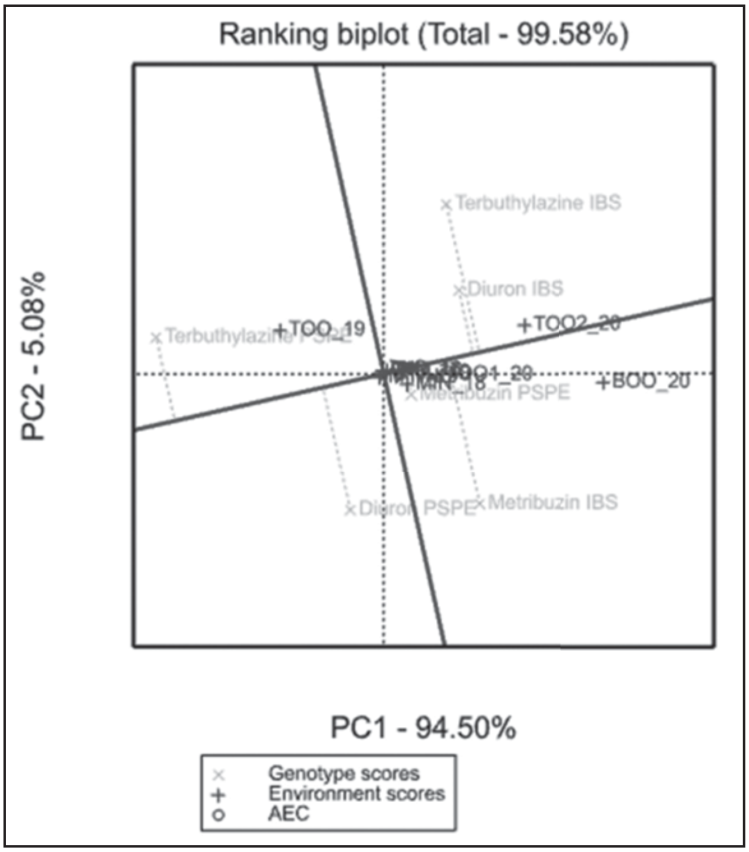

Figure 1. GGE biplot showing yield performance and stability ranking of herbicide treatments applied to lentil at multiple low rainfall environments, 2017-2020.

Table 3. Herbicide label instructions and characteristics, such as solubility rate and binding ability, of herbicide products registered for pre-emergent use in lentil.

Herbicide	Diuron	Metribuzin	Terbuthylazine
Product cost*	$14 per kg	$50 per kg	$21 per kg
Label rate	IBS: 0.83-1.1 kg/ha PSPE: 0.55-0.83 kg/ha	Light sandy soils: 180 g/ha Medium soils: 280 g/ha Heavy soils: 380 g/ha	0.86-1.2 kg/ha
Label instructions	Apply the lower rate on light sandy soil	Only apply post-sowing pre-emergent to a crop sown at least 5 cm deep.	Apply IBS only. Do not use on light soil types. Do not use rates higher than 0.86 kg/ha on soils with pH 8.0 and above.
Solubility	Low	High	Low
Binding	Slightly mobile	Mobile	Moderately mobile
Target weeds (not all weed species listed)	Capeweed, crassula, double gee, erodium, toad rush, wild radish, wild turnip	Capeweed, charlock, chickweed, creeping speedwell, deadnettle, horehound, stinging nettle, wild turnip, wild radish, winter grass, fumitory, fat hen, heliotrope, hogweed, Indian hedge mustard, rough poppy, shepherd's purse, toad rush, sowthistle, three-cornered jack(s)	Burr medic, dead nettle, Indian hedge mustard, prickly lettuce, shepherd's purse, sowthistle, toad rush, turnip weed, wild turnip, wireweed

KEY: IBS + incorporated by sowing, PSPE = post-sowing pre-emergent.
**Source: PIRSA Gross Margin Guide 2021.*

What does this mean?

While pulse and grain legume production continue to expand in the low rainfall zone, research and validation of current and novel management strategies will need to continue to develop management strategies specific to low rainfall zones that focus on improving production and profit.

A review of recent lentil and vetch research has determined variety selection can be complex and final choice will depend on grower's attitude toward risk, target end use, time of sowing, and paddock constraints (e.g., herbicide residues, salinity). Lentil varieties with improved herbicide or salt tolerance are available to growers and have a unique fit in farming systems to address herbicide residues or soil constraints. A broad range of phenology in vetch provides varieties suited to a range of sowing times and target end uses. Seeding rate of lentil and vetch can be reduced without compromising on production potential, particularly early podding biomass production and grain production. It is important to not reduce rates too low as this can reduce production and will leave crops exposed to weed and aphid infestations, while increasing seeding rates can increase risk of foliar disease and lodging.

Lentil is extremely sensitive to Group 5 (previously Group C) herbicide in dry conditions, and herbicide choice is important in reducing risk of crop injury. Herbicide choice will differ depending on an individual grower's attitude towards risk and experience with products, soil type, target weed populations, environmental conditions, herbicide solubility and leaching rate. It is important to remember that product label rates, plant-back periods and directions for use must be adhered to.

Anecdotal evidence suggests that GA can be used to delay phenology or increase hay yield potential in vetch. However, this has not been observed in field-based trials. GA has potential to be utilised early in the season to boost plant height and potentially biomass production, to provide easier grazing for livestock. Late season applications of GA during reproductive growth stages are unlikely to benefit the crop and may have a negative effect on growth and grain production.

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 (DAV00150 – Southern Pulse Agronomy, DAS00162A – Low rainfall break crop validation, UOA2105-013RTX – SA Grain Legume Validation), 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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Critical period for lentil yield determination and grain protein formation

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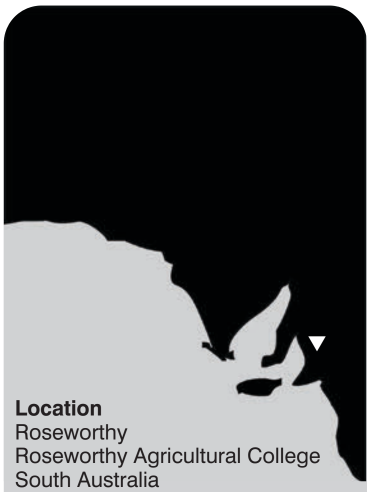

Location
Roseworthy
Roseworthy Agricultural College
South Australia

Rainfall
Av. GSR: 400 mm
Av. GSR: 315 mm
2019 Total: 246 mm
2019 GSR: 110 mm

Yield
Potential: Long term trials 4 t/ha
Actual: 1 t/ha

Paddock history
2018: Wheat
2017: Barley
2016: Canola

Soil type
Calcic luvisol

Plot size
5 m x 1.45 m

Trial design
Split plot design with variety allocated to main plot and shading allocated to subplot

Yield limiting factors
Low rainfall significantly impacted yield

Key messages

- **Grain yield is tightly linked with crop growth rate in species - specific critical developmental periods.**
- **Minimising stress to maximise growth within this period maximises yield.**
- **Irrespective of growing conditions, we found the critical period for yield in lentil was at 50 - 126 °Cd after flowering, around pod emergence.**
- **The critical period for grain protein yield tracked grain yield. However, the increased grain protein concentration that was associated with lower yield partially buffered the effect of stress after flowering.**
- **Grain protein ranged from 22% at Valdivia to 28% at the lower yielding Roseworthy site.**

Why do the trial?

Grain yield is tightly linked with crop growth rate in species-specific critical developmental periods. This has management and breeding implications. The critical period of cereals spans from 2-3 weeks before to 1 week after flowering. The peak critical period when many pulses (e.g. chickpea, faba bean, lupin and field pea) are more sensitive to stress is pod set. The critical period for yield has not been established for lentil. The critical period for protein formation has not been determined in any pulse crop. This study aims to determine the critical period of yield determination and grain protein in lentil in field experiments at two environments that have a 7-fold variation in yield.

How was it done?

At Roseworthy (34° 52' S, 138° 69' E, 70 masl) two small-grained (~35 mg) locally adapted lines, PBA HurricaneXT and CIPAL 901, were sown at 120 seeds/m^2 on 24 June 2019, inoculated with commercial granular inoculum and fertilised with 80 kg/ha mono ammonium phosphate at sowing. In Valdivia (39° 47' S, 73° 14' W, 19 masl) two large-grained (~80 mg), locally adapted cultivars, Calpún and Super Araucana, were sown at 167 seeds/m^2 on 3 September 2019. Seed was not inoculated with Rhizobium; crops relied on fertiliser (298 kg N/ha) and mineralisation estimated at 153 kg N/ha.

We applied sequential shading treatments to the crop every 10-14 days across the growth cycle. Shades were constructed with black shade cloth that intercepted 50 or 90 % of solar radiation at Valdivia and 90 % of radiation at Roseworthy. The shade cloth was attached to a metal frame 1.5 × 2.4 × 1.2 m at Valdivia and 1.0 × 1.2 × 1.0 m at Roseworthy. The roof of the shading system was lifted regularly to ensure a 0.1 m gap above the canopy. The shade cloth covered three sides, with the south side left open to allow for regular air movement to avoid large variation in temperature and vapour pressure deficit.

We measured phenology, yield and its components: biomass and harvest index, grain number and grain size. To calculate grain protein, grain samples (≈40 g) were dried at 80°C, finely ground and analysed for nitrogen concentration with Kjeldahl method. Nitrogen was converted to protein with the factor 6.25.

Yield and yield components in shaded treatments were normalised as a fraction of the unshaded control, and the trajectory of normalised traits was plotted against the phenology of controls on thermal time scale (°Cd) centred at flowering. Thermal time was calculated as the cumulative average daily temperature from sowing. Polynomials were fitted to the data. The timing of minimum yield (and other traits) on the phenological scale was calculated from the first derivative of the fitted curves, and the critical period was defined as two standard errors centred at the minimum.

What happened?

Yield of unshaded controls was ~7 t/ha at Valdivia and ~1 t/ha at Roseworthy. Figure 1AB shows the response of yield to time of shading. At Valdivia, a single curve relating relative yield and time of shading fitted both varieties and reductions in yield were larger with more intense shade. Hence, separate curves were fitted for each shade intensity (Figure. 1A). At Roseworthy, CIPAL0901 was 5% less sensitive to shading than PBA HurricaneXT; this was a small difference and we thus fitted a single curve. All three curves in Fig. 1AB showed a common pattern. At Valdivia for 50% shade the maximum yield loss was at 50°Cd after flowering and for 90% shade at 141 °Cd after flowering. At Roseworthy, maximum yield loss was at 126 °Cd after flowering. The timing of maximum vulnerability corresponded to pod set. Grain number fully accounted for the response of yield (Fig. 1CD); grain weight was largely unresponsive to shading (Figure. 1EF).

Figure 2 shows the effect of time of shading on grain protein concentration and grain protein yield. Grain protein concentration responded nonlinearly to shading. Before a threshold, 40 ± 204 °Cd after flowering at Valdivia and 188 ± 71 °Cd after flowering at Roseworthy, shading slightly reduced (less than 10 %) protein concentration. Grain protein concentration increased linearly with shading after these thresholds. At Valdivia, grain protein of Super Araucana was more sensitive to shade than Calpún with no effect of shade intensity. At Roseworthy, the response of grain protein concentration to shade was similar for the two varieties. The increases in grain protein concentration after flowering was insufficient to overcome the loss in protein yield except in the last 50% shading treatment at Valdivia (Figure. 2CD).

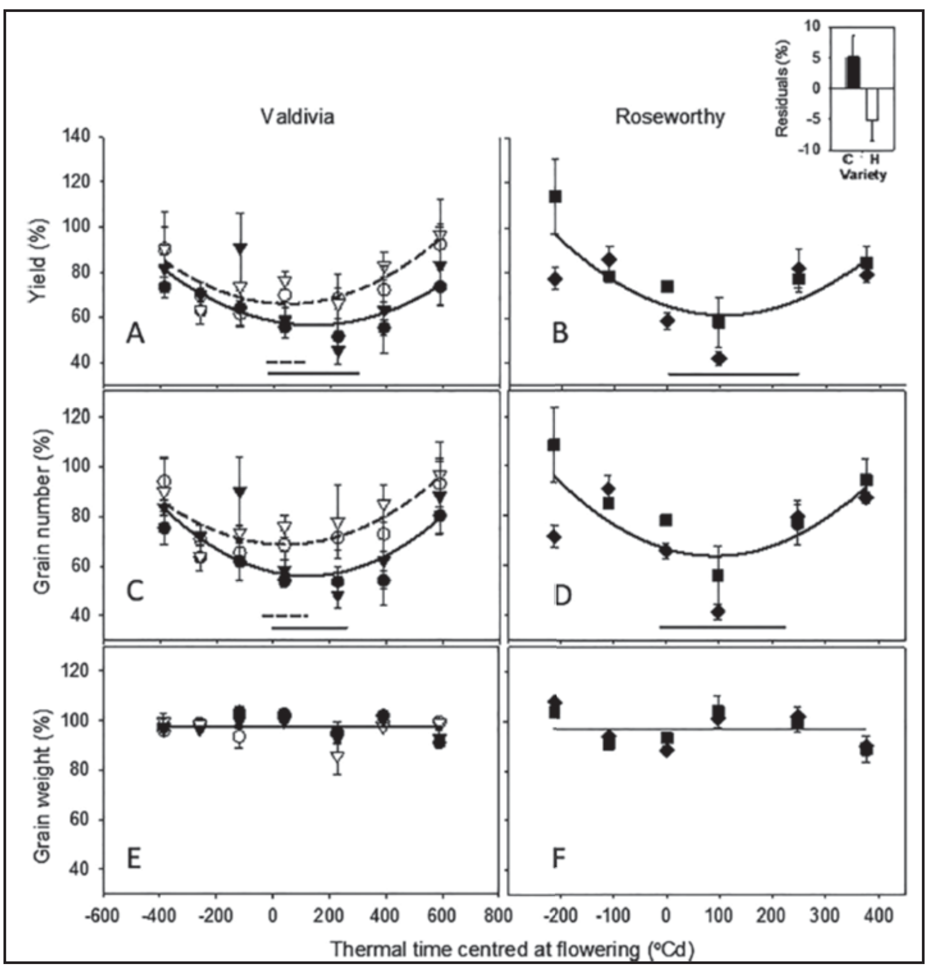

Figure 1. Effect of timing of shade on (A,B) yield, (C,D) grain number and (E,F) grain weight for lentil crops at Valdivia and Roseworthy. Traits are plotted against the phenology of controls on thermal time scale (°Cd) centred at flowering. Thermal time is calculated as the cumulative average daily temperature from sowing. For Valdivia, circles are Calpún and triangles are Super Araucana; open symbols are 50% shade and closed symbols are 90%. For Roseworthy, squares are CIPAL0901 and diamonds are PBA HurricaneXT. The curves in A-D are polynomials, and average across treatments in E, F. Error bars are ± S.E. The phenological scale is for the unshaded controls with data points at the mid-point of the shade period. Horizontal lines in A-D represent two standard errors centred at the minimum for 50% (dashed) and 90% (solid) shade intensity. The inset in B shows the distribution of residuals of CIPAL0901 (C) and PBA HurricaneXT (H) from the fitted polynomial.

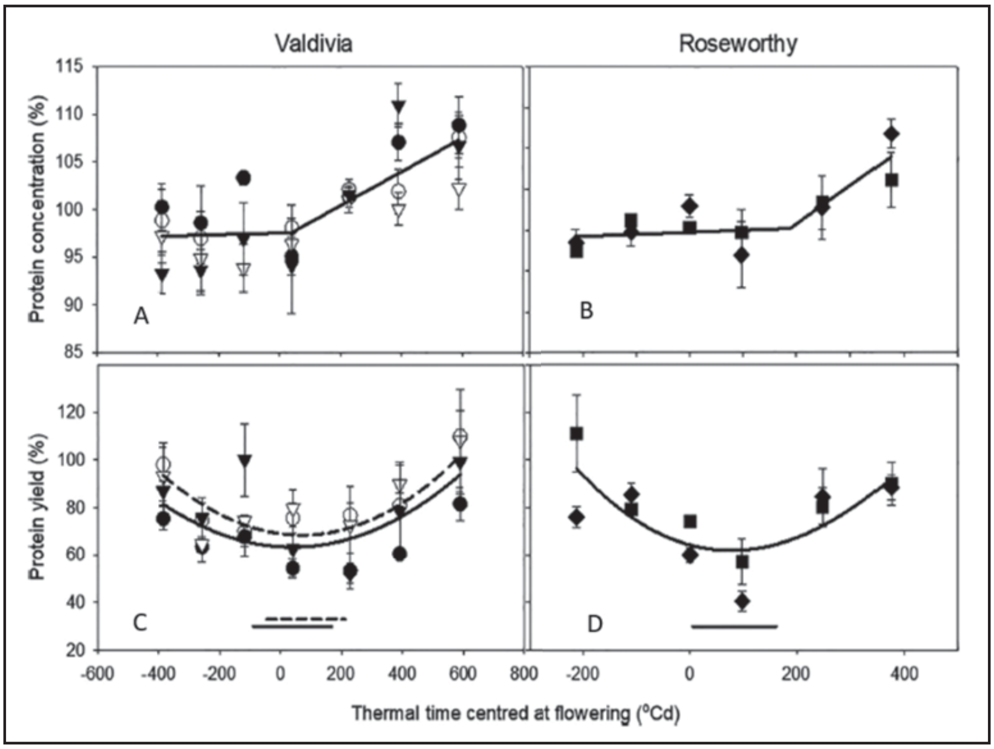

Figure 2. Effect of shade on (A,B) grain protein concentration and (C,D) protein yield for lentil crops at Valdivia and Roseworthy. Traits are plotted against the phenology of controls on thermal time scale (°Cd) centred at flowering. Thermal time is calculated as the cumulative average daily temperature from sowing. For Valdivia, circles are Calpún and triangles are Super Araucana; closed symbols are 50% shade and open symbols are 90%. For Roseworthy, closed squares are CIPAL0901 and open squares are PBA HurricaneXT. The lines are bi-lineal regressions in A, B, and polynomials in C, D. Error bars are ± S.E. The phenological scale is for the unshaded controls, with data points at the mid-point of the shade period. Horizontal lines in G, H represent two standard errors centred at the minimum for 50% (dashed) and 90% (solid) shade intensity.

What does this mean?

In two contrasting environments with a 7-fold variation in yield, the most critical period for lentil yield was between 50 and 126 °Cd after flowering, corresponding to pod emergence. This reinforces the species-specific nature of the critical period and fits with other Australian grain legumes. Grain protein concentration responded bi-linearly to timing of shading, with a slight decrease before an environment specific threshold close to flowering and a linear increase after this threshold. Protein yield tracked grain yield but increased grain protein concentration partially buffered stress after flowering. Site-specific combinations of sowing date and phenology are necessary to reduce the likelihood of stress in the critical period.

Acknowledgements

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Measuring genetic gain in yield of lentil to identify traits associated with improvement

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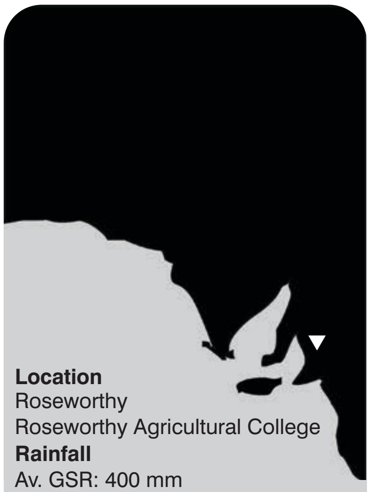

Location
Roseworthy
Roseworthy Agricultural College
Rainfall
Av. GSR: 400 mm
Av. GSR: 315 mm
2019 Total: 246 mm
2019 GSR: 110 mm
Yield
Potential: Long term trials 4 t/ha
Actual: 2.2 t/ha
Paddock history
2018: Wheat
2017: Barley
2016: Canola
Soil type
Calcic luvisol
Plot size
5 m x 1.45 m
Trial design
Factorial with a combination of 19 varieties, two sowing dates, two water regimes and two seasons
Yield limiting factors
Botrytis grey mould (*Botrytis cinerea* and *B. fabae*) affected early sown irrigated crops in 2018 due to humid conditions and heavy canopies. Infection differentially affected plots. Affected areas of the plots were excluded from measurements.

Key messages

- **The rate of genetic gain in Australian lentil from 1988 to 2019 averaged 20 kg/ha/year or 1.23%/year.**
- **The rate of yield increase was greater in lower yielding environments.**
- **The yield increase was associated with substantial shifts in phenology, grain number, crop growth rate and harvest index.**
- **Newer varieties had shorter time to flowering and pod emergence, and the rate of change in these traits was more pronounced in slow-developing environments (e.g. earlier sowing).**
- **Despite their shorter time to maturity, newer varieties had similar or slightly higher biomass than their older counterparts because crop growth rate during the critical period increased with year of release.**

Why do the trial?

Using a historic set of Australian lentil lines released from 1988 to 2019 we determined the rate of genetic gain of yield and the associated phenotypic drivers.

The contemporary lentil industry in Australia started in the late 1980s. Yield in farmers' fields averages 1.2 t/ha nationally and has not increased over three decades. Lack of yield progress can be related to several non-mutually exclusive reasons: expansion of lentil to low-yielding environments, lack of genetic gain in yield, lack of progress in agronomic practices, and lack of adoption of superior technologies. The aims of this study were to (i) quantify the genetic gain in lentil yield since 1988, (ii) explore the variation in the expression of genetic gain with the environment, and (iii) identify shifts in crop phenotype associated with selection for yield and agronomic adaptation.

How was it done?

Lines included in the field trials and their year of release are presented in Table 1. Seeding rate was 120 plants/m^2 on 25.5 cm row spacing; 80 kg/ha MAP was added at sowing. Crops were sown into eight environments resulting from the combination of two seasons (2018, 2019), two sowing dates and two water regimes. Early sowings were on 24 April 2018 and 29 April 2019, and the late sowings on 6 June 2018 and 24 June 2019. Early sown crops were irrigated or rainfed until 26 June 2018 and 1 August 2019, when rainout shelters were deployed to exclude rainfall until harvest, while late-sown crops were irrigated or rainfed.

We performed a quantitative environmental characterisation for water, temperature and radiation and crops were phenotyped for phenology, crop growth rate, yield and its components: biomass and harvest index, grain number and grain size.

We tested trait response to variety, environment and the interaction using ANOVA with Genstat (20th edition). Best Linear Unbiased Predictors (BLUPs) were calculated with META-R (Multi Environment Trial Analysis with R for Windows) Version 6.0. We calculated genetic rate of change as the slope of the least-square regression between trait and year of release.

We calculated actual rates, e.g. kg/ha/year for yield, and rates relative to the newest variety. Rates were calculated for data pooled across all environments and for each environment separately.

What happened?

Yield varied 9-fold with variety (Table 1) and ~10-fold with environment (21 to 220 g/m^2), with no interaction between environment and variety. Across environments, yield increased with year of release at 20 kg/ha/year or 1.23%/ year (Table 2). The rate of genetic gain in yield declined linearly with increasing environmental mean yield (Figure. 1a).

Across environments, thermal time from sowing to flowering, pod emergence, end of flowering and maturity all were shortened with year of release (Table 2). In contrast, thermal time between pod emergence and maturity and the proportion of the season between pod emergence and maturity both increased with year of release (Table 2).

Grain number varied 4-fold with variety and 10-fold with environment. Across environments grain number increased with year of release at 34 seed/m^2/year or 0.92%/y (Table 2). The rate of change in grain number with year of release was higher in low yielding environments (Fig. 1b). Grain size varied with variety (2-fold) and with the interaction between environment and variety. Across environments grain size increased by 0.4 mg seed/year or 0.96%/year (Table 2). The rate of genetic change in grain size was unrelated to environmental mean yield (Figure. 1c).

Shoot biomass at maturity varied little between varieties (< 1.5-fold) and varied ~5-fold with environment, with no interaction between environment and variety. Across environments, the absolute rate of change in biomass with year of release was close to zero and the relative rate was 0.38%/year (Table 2). The association between relative rate of change in biomass and environmental mean yield was weak and negative (Figure. 1d). Crop growth rate in the critical period varied 2.5-fold with variety and 4-fold with environment, with no interaction between environment and variety. Across environments, crop growth rate increased with year of release at 0.07 kg/ha °Cd^{-1} y^{-1} or 1.46%/year. The rate of change in crop growth rate with year of release was higher in more stressful environments (Figure. 1e).

Harvest index varied 6-fold with variety and 3.5-fold with environment, and also varied with the interaction between environment and variety. Across environments harvest index increased 0.0042/year or 1.25%/year (Table 2). The rate of increase in harvest index with year of release almost halved between the lowest and highest yielding environments (Figure. 1f).

Table 1. Seed type, phenology and yield of lentil varieties released between 1988 and 2019. Values are BLUPs ± standard error across eight environments.

Variety or breeding line	Type	Year of release	Thermal time from sowing to (°Cd)				Yield (g/m^2)
			Flowering	Pod Emergence	End of flowering	Maturity	
Indianhead	Red	1988	1546±81.0	1679±56.8	1940±70.5	2193±73.8	19±6.9
Matilda	Green	1993	1273±64.2	1374±38.5	1706±72.5	2034±87.0	120±17.1
Aldinga	Red	1995	1315±68.7	1451±42.0	1761±68.0	2094±76.4	129±16.8
Northfield	Red	1995	1368±80.9	1515±51.9	1751±64.9	2080±78.6	129±23.7
Nugget	Red	2000	1296±70.0	1431±45.3	1726±67.0	2033±84.4	99±13.9
Boomer	Green	2008	1251±53.3	1360±34.8	1736±68.3	2046±78.9	101±10.4
Nipper	Red	2008	1346±78.9	1469±46.6	1746±68.7	2045±82.0	128±18.7
PBA Flash	Red	2009	1272±58.3	1371±36.9	1728±66.2	2041±76.3	140±19.5
PBA Blitz	Red	2010	1096±31.9	1236±23.8	1602±44.3	1969±82.7	131±14.5
PBA Jumbo	Red	2010	1275±64.2	1396±39.7	1722±64.2	2022±78.2	146±22.7
PBA Ace	Red	2011	1208±45.7	1321±27.8	1717±68.6	2008±80.9	116±14.2
PBA Bolt	Red	2011	1191±44.3	1320±27.6	1693±61.3	2028±80.3	141±14.7
CIPAL0901	Red	2013	1130±38.5	1258±26.7	1637±55.1	1983±85.6	153±15.2
PBA HurricaneXT	Red	2013	1225±45.6	1337±32.8	1679±59.7	2028±77.0	124±16.3
PBA Giant	Green	2014	1168±42.5	1289±28.2	1706±66.7	2025±77.7	97±11.5
PBA Greenfield	Green	2014	1249±49.9	1375±33.0	1742±64.7	2046±76.1	110±20.4
PBA Jumbo2	Red	2014	1216±57.0	1344±32.0	1734±67.0	2013±78.5	121±13.6
CIPAL1504	Red	2018	1239±51.8	1369±37.7	1753±68.5	2056±79.0	141±25.8
CIPAL1701	Red	2019	1106±41.0	1238±23.8	1676±72.5	1963±87.5	180±22.5

Table 2. Absolute and relative rate of change in yield and related traits in Australian lentil over three decades between 1988 and 2019.

Trait	Absolute	Relative (% $year^{-1}$)
Yield	20 ± 6.9 kg ha^{-1} $year^{-1}$	1.23 ± 0.28
Thermal time sowing to flowering	-9 ± 1.6°Cd $year^{-1}$	-0.78 ± 0.08
Thermal time sowing to pod emergence	-4.9 ± 1.7°Cd $year^{-1}$	-0.72 ± 0.08
Thermal time sowing to end of flowering	-4.9 ± 2.9°Cd $year^{-1}$	-0.27 ± 0.05
Thermal time sowing to maturity	-4.5 ± 3.6°Cd $year^{-1}$	-0.22 ± 0.04
Thermal time pod emergence to maturity	-4.9 ± 2.6°Cd $year^{-1}$	0.56 ± 0.13
Radio thermal time pod emergence-maturity/sowing-maturity	0.003 ± 0.0007 $year^{-1}$	0.73 ± 0.11
Crop growth rate	0.07 ± 0.02 kg ha^{-1}°Cd^{-1} $year^{-1}$	1.46 ± 0.35
Biomass	16 ± 21 kg ha^{-1} $year^{-1}$	0.38 ± 0.15
Harvest index	0.004 ± 0.001 $year^{-1}$	1.25 ± 0.25
Grain number	34 ± 18 seeds m^2 $year^{-1}$	0.92 ± 0.31
Grain size	0.40 ± 0.08 mg $seed^{-1}$ $year^{-1}$	0.96 ± 0.20

Rates are the slope of least-square regressions between trait and year of release for data pooled across eight environments. Relative rate is percentage of the latest variety.

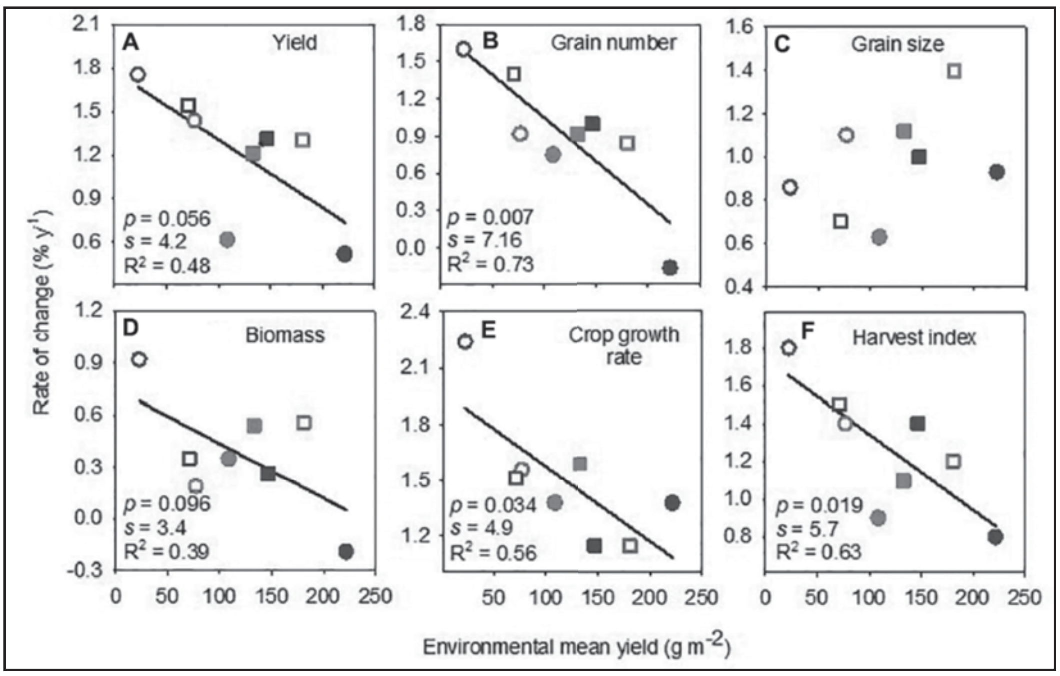

Figure 1. Rate of change of yield (A), grain number (B), grain size (C), biomass (D), crop growth rate (E), and harvest index (F) against environmental mean yield. Lines are least-square regressions. Rates are relative to the newest variety. Symbols: black are 2018, grey are 2019, circles (early sowing), square (late sowing), open (rainfed), closed (irrigated).

What does this mean?

Over the three decades of Australian lentil breeding and for our sample of varieties and environments, improvements in phenology, crop growth rate and harvest index have driven genetic gain in yield at 20 kg/ha/year or 1.23%/year. The estimated genetic gain in yield was larger in lower yielding environments. This genetic gain combined with improved agronomy has allowed the spread of lentil into lower rainfall regions of Australia, increasing rotational options and allowing more diverse cropping systems. Further improvements in lentil production require adoption of improved practices to close the gap between water-limited and actual yield, and a stronger focus in breeding for high yield potential.

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THE UNIVERSITY of ADELAIDE

Management of grass weeds in lentils

Navneet Aggarwal[1,3], Amy Keeley[2] and Penny Roberts[1,3]

[1]SARDI, Clare; [2]SARDI, Port Lincoln; [3]University of Adelaide Affiliate

Location
Tooligie
Long's family
Rainfall
Av. Annual: 329 mm
Av. GSR: 267 mm
2021 Total: 333 mm
2021 GSR: 272 mm
Soil type
Brown grey clay loam
Soil test
pH $CaCl_2$: 7.3
Ammonium N: 1 mg/kg
Nitrate N: 20 mg/kg
Phosphorus: 30 mg/kg
Potassium: 571 mg/kg
Organic carbon: 1.62%
Plot Size
1.35 m x 10 m

Key messages

- **Ultro® (a new Group 23 herbicide with active carbetamide) and Group 3 propyzamide proved equally effective for ryegrass and barley grass control in lentil.**
- **Boxer Gold® and Sakura® herbicides need to be rotated with Ultro® and propyzamide in the pulse crop phase to delay the resistance build up in grass weeds to a single mode of action.**
- **Integrated weed management tactic such as wick wiping should be included to reduce the grass weed seed set of resistant populations.**

Why do the trial?

Over the last decade there has been a rapid uptake of herbicide tolerant break crops including triazine tolerant (TT) canola, imidazolinone (IMI) tolerant Clearfield canola, and IMI tolerant pulses (XT lentil and PBA Bendoc faba bean) in South Australia. This rapid uptake has increased the reliance on Group 1 (previously Group A) chemistry herbicides (fops and dims) to control grass weeds, resulting in resistance build up in both ryegrass (Aggarwal *et al*., 2019) and barley grass (Gill *et al*., 2020) to these herbicides. The use of pre-emergent Group 15 herbicides (previously Group J and K) has also increased to achieve improved grass weed control. Ryegrass has started developing resistance to these alternative Group 15 pre-emergent herbicides (Aggarwal *et al*., 2019). Barley grass is becoming more challenging to control, especially in the low rainfall zone where a survey in the Eyre Peninsula region found 68% of the respondents identify this weed as having medium to high impact in their cropping systems (Cook, 2020). In addition to barley grass developing resistance to Group 1 herbicides, the biological traits of this weed make it difficult to control. These traits include the level of seed dormancy that reduces the control achieved with knockdown herbicides due to delayed emergence in season, early seed set that limits the effectiveness of crop topping, and early seed shedding prior to crop harvest that decreases the efficiency of harvest weed seed control measures. This makes effective control of grass weeds with pre-emergent herbicides crucial for achieving desired grain yield in pulse crops. This trial aims to evaluate the effect of new Group 23 (previously Group E) pre-emergent herbicide Ultro® (active ingredient, carbetamide) alone or in combination with post-emergent herbicides, compared to existing pre-emergent herbicides on annual ryegrass and barley grass control. Additional integrated weed management treatments of wick wiping and clipping + wick wiping have reduced annual ryegrass seed set (Aggarwal and Roberts, 2020; EPFSS 2020, p 135-139). This study also explored the potential benefits of wick wiping in reducing barley grass seed set in lentil when used in conjunction with pre- and post-emergent herbicides.

How it was done?

Fertiliser: 80 kg/ha MAP

Seeding date: 10 June 2021

The field experiment was sown at Tooligie (Lower Eyre Peninsula) with PBA Hurricane XT. The pre-emergent herbicide Ultro® (active carbetamide, Group 23) was included for controlling grass weeds applied as incorporated by sowing (IBS). Ultro (IBS) + clethodim post-emergence (POST) at 5-node growth stage was compared to grower practice of propyzamide (IBS) + clethodim (POST), Boxer Gold® (IBS) + clethodim (POST), and Sakura® (IBS) + clethodim (POST) in lentil (Table 1). Integrated weed management tactics such as wick wiping grass weeds at embryo development stage in conjunction with pre- and post-emergent herbicide treatments was explored in lentil.

A gravity-based wick wiper was used with Glyphosate + LVE MCPA + water, mixed 1:1:1. All herbicide doses are mentioned in terms of the commercial product (Table 1). The background population of ryegrass and barley grass in the paddock was used for this study. Ryegrass and barley grass spike density was assessed near crop harvest from three randomly selected spots using a quadrant of 50 cm × 50 cm. Harvesting of lentil was completed on 25 November 2021. The statistical analysis was done with ANOVA through GENSTAT version 20.

What happened?

Effect on grass weeds

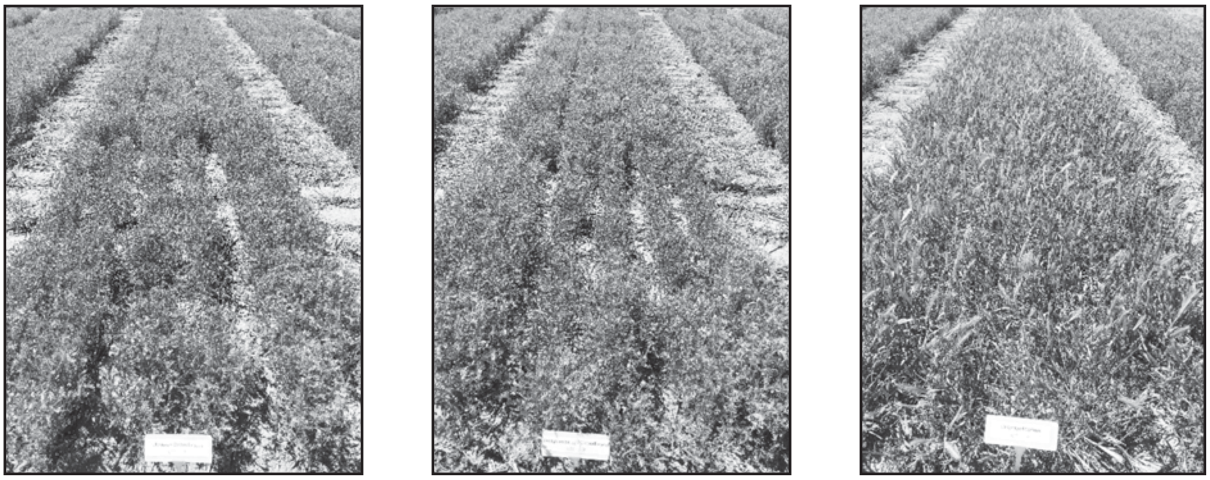
New pre-emergent herbicide, T1: Ultro® (IBS) applied alone reduced ryegrass spike density by 78% compared to the unsprayed control (Table 1). This was equal to the level of ryegrass control achieved with T4: propyzamide (IBS). Most of the surviving ryegrass plants in Ultro® and propyzamide applied alone plots were late emerging populations. This highlights the importance of having an effective post-emergent herbicide option to achieve superior weed control throughout the season. The ryegrass population at the experimental site was susceptible to Group 1 herbicides where the application of T2: Ultro® (IBS) + clethodim (POST) and T5: propyzamide (IBS) + clethodim (POST) recorded increased ryegrass control (>99%) compared to unsprayed control (figure 1). Similarly, pre-emergent Group 15 herbicides Sakura® and Boxer Gold® coupled with post emergent application of clethodim reduced ryegrass spike density by 94-99% compared to the unsprayed control. Previous studies on Group 1 and Group 15 resistant ryegrass population recorded only 60-88% reduced weed seed set with Sakura®/ Boxer Gold® coupled with post-emergent application of clethodim, whereas combinations of Ultro®/ propyzamide with clethodim reduced seed set of this resistant ryegrass population by 98-99.5% (Aggarwal and Roberts, EPFSS 2020, p 135-139).

Similar results were observed for barley grass control with pre- and post-emergent herbicides in this experiment. T1: Ultro® (IBS) and T4: propyzamide (IBS) proved equally effective when applied on their own, reducing barley grass head density compared to the unsprayed control by >98% (Table 1). Combinations of either of pre-emergent Group 3 (propyzamide), Group 15 (Ultro®) or Group 23 (Sakura®/ Boxer Gold®) herbicide, followed by post-emergent application of Group 1 clethodim were found equally effective, reducing barley grass head density by >99%.

Pre- and post-emergent herbicide combinations effectively controlled both ryegrass and barley grass populations at Tooligie. Therefore, the additional application of wick wiping at embryo development stage did not record significant improvement for weed control. However, previous studies on Group 1 and Group 15 resistant ryegrass have found wick wiping to reduce weed seed set by up to 69% (Aggarwal and Roberts, EPFSS 2020, p. 135-139).

Table 1. Ryegrass and barley grass management in lentil at Tooligie, 2021.

	Herbicide (dose in terms of commercial product)	Emergence (plant/m^2)	Ryegrass (spikes /m^2)	Barley grass (heads /m^2)	Grain yield (t/ha)	100-seed weight (g)
T_1	Ultro® 1700 g/ha (IBS)	106 a	19.4 b	4.4 b	1.46 a	3.77 b
T_2	Ultro® 1700 g/ha (IBS) + clethodim 500 ml/ha (POST)	113 a	2.3 cd	0 c	1.62 a	3.89 a
T_3	Ultro® 1700 g/ha (IBS) + clethodim 500 ml/ha (POST) + wick wiping at reproductive stage	113 a	1.7 cd	0 c	1.59 a	3.81 ab
T_4	Propyzamide 1000 ml/ha (IBS)	116 a	13.0 bc	1.2 bc	1.48 a	3.78 b
T_5	Propyzamide 1000 ml/ha (IBS) + clethodim 500 ml/ha (POST)	113 a	0.8 d	0 c	1.61 a	3.84 ab
T_6	Propyzamide 1000 ml/ha (IBS) + clethodim 500 ml/ha (POST) + wick wiping at reproductive stage	118 a	0.6 d	0 c	1.55 a	3.81 ab
T_7	Boxer Gold® 2500 ml/ha (IBS) + Clethodim 500 ml/ha (POST)	107 a	5.3 bcd	0 c	1.63 a	3.84 ab
T_8	Boxer Gold® 2500 ml/ha (IBS) + Clethodim 500 ml/ha (POST) + wick wiping at reproductive stage	99 a	6.8 bcd	0.2 bc	1.59 a	3.88 a
T_9	Sakura® 118 g/ha (IBS) + clethodim 500 ml/ha (POST)	102 a	0.8 d	0 c	1.54 a	3.80 ab
T_{10}	Sakura® 118 g/ha (IBS) + clethodim 500 ml/ha (POST) + wick wiping at reproductive stage	106 a	0.2 d	0 c	1.48 a	3.80 ab
T_{11}	Unsprayed control	116 a	88.4 a	252.8 a	0.36 b	3.66 c



Ultro (IBS) + Clethodim (POST) | *Propyzamide (IBS) + clethodim (POST)* | *Unsprayed control*

Figure 1. Ryegrass and barley grass control achieved with pre- and post-emergent herbicides at Tooligie, 2021.

Effect on crop

All pre-emergent herbicides were safe on PBA Hurricane XT and no decline in lentil emergence was recorded at Tooligie (Table 1). A significant increase in lentil grain weight and grain yield was recorded in all herbicide treatments compared to the unsprayed control. Failure to control grass weeds resulted in dense weed populations outcompeting lentil (Figure 1). This reduced grain yield by 76-78% compared to combinations of pre-emergent herbicides from Group 3 (propyzamide), Group 23 (Ultro) and Group 15 (Sakura/Boxer Gold) followed by post-emergent application of Group 1 clethodim.

What does this mean?

Previous studies have found developing resistance to Group 15 herbicides (Sakura and Boxer Gold) in annual ryegrass, including populations collected from the Eyre Peninsula region (Aggarwal *et al*, EPFSS 2019, p 146-148). Ultro will be an important tool along with propyzamide to achieve effective control of grass weeds in the pulse phase of a crop rotation. Rotating these modes of action with Group 15 herbicides will diversify the selection pressure and delay resistance build up in grass weeds. Opportunistic use of late weed seed control strategies such as wick wiping has the potential to reduce seed set of grass weeds that survive pre- and post-emergent herbicides.

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Crop safety and broadleaf weed control implications for various herbicides and combinations in lentils

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Key messages

- **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.**
- **Crop damage with Reflex herbicide on alkaline sands was rate responsive, with yield loss in a trial at Bute increasing from 17% when applied at 0.5 L/ha to 54% when applied at 1 L/ha.**
- **Crop damage on alkaline sands was cumulative where Reflex was applied in combination with a group 5 herbicide, such as diuron. In a trial at Alford on an alkaline sand, yield loss to either diuron or Reflex was 20%, increasing to 52% yield loss when applied in combination.**
- **Seasonal variation, including higher rainfall post-seeding in 2021 may have been a contributing factor in higher level of crop damage in alkaline sandy soils.**
- **Effective control of broadleaf weeds such as bifora, common sow thistle, Indian hedge mustard, wild turnip and capeweed, including populations resistant to Group 2 imidazolinone herbicides, was achieved with Reflex (Group 14 herbicide).**
- **Control of various broadleaf weeds was achieved in lentil using Reflex in combination with other registered herbicides including Group 2, 5 and 12 herbicides. However, crop safety to these combinations varied between herbicides and their doses, and soil type.**
- **Herbicide strategies on high-risk alkaline sandy soil types needs careful planning to balance avoiding crop damage and achieving adequate weed control. Rate of Reflex may need to be adjusted near the middle of the rate range in some soil types to find the right balance of crop safety and weed control.**

Why do the trial?

Reflex (fomesafen 240 g/L) herbicide has been recently registered for use in chickpea, narrow leaf lupin, lentil, field pea, faba bean and vetch. Of all the pulse species with a Reflex registration, lentil is the most sensitive, with a maximum rate of 1 L/ha incorporated by sowing (IBS) only, whilst other legume species have a maximum rate of 1.25 L/ha post-sowing and pre-emergence (PSPE) (except vetch, maximum 0.9 L/ha PSPE) or 1.5 L/ha IBS. Reflex is registered for control of broadleaf weeds, including wild radish, Indian hedge mustard, sow thistle, prickly lettuce and bifora when used at 0.75-1 L/ha in lentils. A new mode of action registered in lentils will provide herbicide rotation options and will be particularly useful where herbicide resistance is developing.

Effective broadleaf weed management is a major constraint to achieving yield potential in pulse crops. The adoption of herbicide tolerant pulse crops has improved broadleaf weed control options. However, it has resulted in over-reliance on a few modes of action, particularly Group 2 (previously B). The increased reliance on Group 2 imidazolinone (IMI) herbicides carries the risk of the development of herbicide resistant weeds, and therefore raises concerns for the long-term efficacy of this mode of action. The availability of a new mode of action herbicide in Reflex (Group 14, previously Group G) has increased the broadleaf weed control options for both conventional and herbicide tolerant cultivars of pulse crops.

Previous SAGIT projects (TC116, TC119) have investigated crop safety and weed control on sandy soils of the northern Yorke Peninsula for Group 2, Group 5 (previously C) and Group 12 (previously F) herbicides. This work highlighted the heightened risk of crop damage from soil residual herbicides on these soil types, in particular the Group 2 and 5 herbicides (Trengove *et al*. 2021). SAGIT project TC121 has continued this work, including Reflex, investigating herbicide crop safety on a range of soil types, including differences in soil texture and pH, with 2021 results presented here.

How was it done?

A total of four trial sites were established in 2021 to assess herbicide tolerance and weed control on imidazolinone (IMI) tolerant lentils.

Two of these four trials were established at Alford and Bute (1) (northern Yorke Peninsula) on sandy soils with either high or low soil pH to assess crop safety when using Group 2, 5, 12 and 14 pre-emergent and/or post-emergent herbicides (Table 1). Weeds were removed by hand from all plots in these trials to determine herbicide effects in the absence of weeds.

The remaining two trials were established at Bute (2 & 3) to develop strategies for controlling broadleaf weeds (including bifora, Indian hedge mustard and common sow thistle) on loamy soil, and sandy alkaline soils (Table 1). The treatments comprised of herbicide combinations from Group 2, 5 and 14 in a randomised complete block design with three replicates. The background population of broadleaf weeds in the paddock was used for this study.

Rainfall conditions in 2021

Two major rainfall events occurred after seeding, with 27.6 mm and 24.0 mm of rainfall received within the first and second week, respectively (Table 4). A total of 278 mm was received between seeding and harvest (Figure 4).

Trial establishment

Trials were sown using knife points and press wheels between 26 May and 4 June and were sown to PBA Hurricane XT[A]. Herbicides were applied using hand boom equipment delivering 100 L/ha water volume at a pressure of 200 kPa. Plots at the herbicide tolerance sites were rolled post-emergent compared to the weed control trials which were rolled immediately post-seeding.

Herbicide properties and application details

The herbicides used in the trials are described in Tables 2 and 3.

Break Crops

Table 1: Descriptions for the four trial sites established in 2021.

Location	Site	0-10 pH ($CaCl_2$)	0-10 pH (H_2O)	ECEC Cmol/kg	OC (%)	Texture	Weeds assessed
Alford	Alkaline herbicide tolerance	7.7	8.4	11.7	0.94	Sand	Indian hedge mustard (*Sisymbrium orientale*), burr medic (*Medicago polymorpha*), common sow thistle (*Sonchus oleraceus*), and wild turnip (*Brassica tournefortii*)
Bute 1	Acidic herbicide tolerance	4.7	5.8	3.09	0.76	Sand	As above + Cape weed (*Arctotheca calendula*)
Bute 2	Loam weed control	7.5	8.1	N/A	1.33	Loam	Bifora (*Bifora testiculata*), Indian hedge mustard and common sow thistle
Bute 3	Sand weed control	6.8	8.1	N/A	0.82	Loamy sand	Indian hedge mustard

Table 2: Pre-emergent herbicide properties for products used in the herbicide tolerance trials in 2021(source: GRDC pre-emergent herbicide fact sheet).

Herbicide (Group)	Solubility (mg/L @ 20°C)		Adsorption coefficient, Koc value	
Diuron (5)	36	Low solubility	813	Slightly mobile
Terbuthylazine (5)	7	Low solubility	230	Moderately mobile
Metribuzin (5)	1165	High solubility	60	Mobile
Reflex® (14)	50	Moderate solubility	228	Moderately mobile

Table 3: Herbicide products and application timing/method for the alkaline (Alford) and acidic sand (Bute 1) herbicide tolerance trials in 2021.

Herbicide product	Trial application	Trial rate (product)	Registered use pattern
Diuron (900 g/kg)	IBS	830 g/ha	830 g – 1100 g/ha PSPE
Metribuzin (750 g/kg)	IBS	180 g/ha	180 g PSPE
Terbyne® (terbuthylazine 750 g/kg)	IBS	750 g/ha	1.0 – 1.4 kg/ha IBS
Reflex® (fomesafen 240 g/L)	IBS	1000 mL/ha	500 – 1000 mL/ha IBS
Intercept® (imazamox 33 g/L + imazapyr 15 g/L)	Post-emergent	500 mL/ha	500 – 750 mL/ha Post
Diflufenican (500 g/L)	Post-emergent	150 mL/ha	100 – 200 mL/ha Post

What happened?

Crop safety

Early season herbicide damage scores indicate there were differences between the two herbicide tolerance sites at Alford and Bute 1 (Figure 1). At the alkaline site (Alford), the group 5 herbicides diuron and terbuthylazine caused significant herbicide damage with scores for necrosis reaching 6.2 out of 9 from the application of Terbyne. Reflex caused significant damage at this site but in the form of leaf chlorosis rather than necrosis. The combination of the Group 5 and 14 herbicides at these sites did not lead to increased damage at this time. In contrast, at the acidic site (Bute 1), there were only minor symptoms evident in association with the application of diuron and no other herbicide was significantly different from the control treatment. Reflex also caused stunting in lentil as the rate increased from 500 to 1000 mL/ha in weed control trials (Bute 2 & 3) (data not shown) and the effect was more pronounced in alkaline sands than in loamy soils.

At both sites, there was a reduction in leaf necrosis associated with combining diuron and Reflex compared with diuron alone, this requires further investigation.

Previous trial work has shown that on these sandy soil types, there is a strong relationship between NDVI (where NDVI is correlated to biomass) and yield for lentil, and this is also the case for the 2021 alkaline sand herbicide tolerance trial (Figure 2). Herbicide damage on this sandy soil resulted in growth and biomass reduction (Figure 1) and led to decreased yields (Figure 2).

Grain yield was significantly reduced in response to the application of some herbicide treatments at the alkaline sand trial site, consistent with earlier herbicide damage scores (Figure 3). Diuron and Reflex® treatments both reduced grain yields by 20% when applied alone, and Terbyne reduced yield by 51%. This contrasts with the acidic sand site where no significant yield differences occurred in response to the application of any individual herbicide.

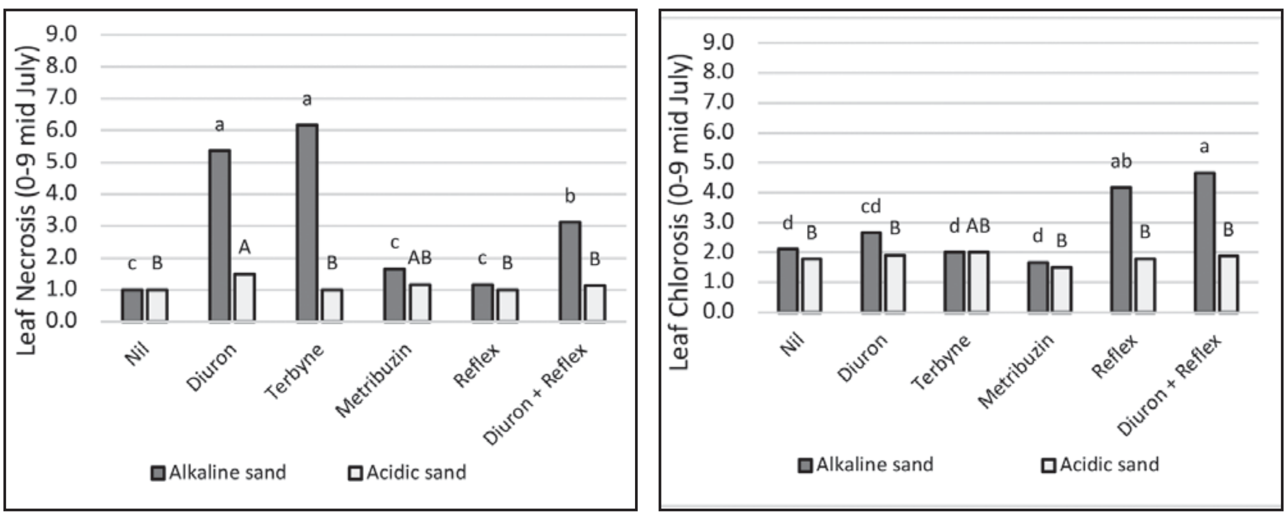

Figure 1. Early season leaf necrosis (left) and chlorosis (right), scored 13 July at Alford (alkaline sand) and 20 July at Bute (acidic sand) (0 = no chlorosis, 9 = death) of PBA Hurricane XT^A for the herbicide tolerance trials in 2021. Lower case letters and upper-case letters denote significant differences for each site, P values = <0.001.

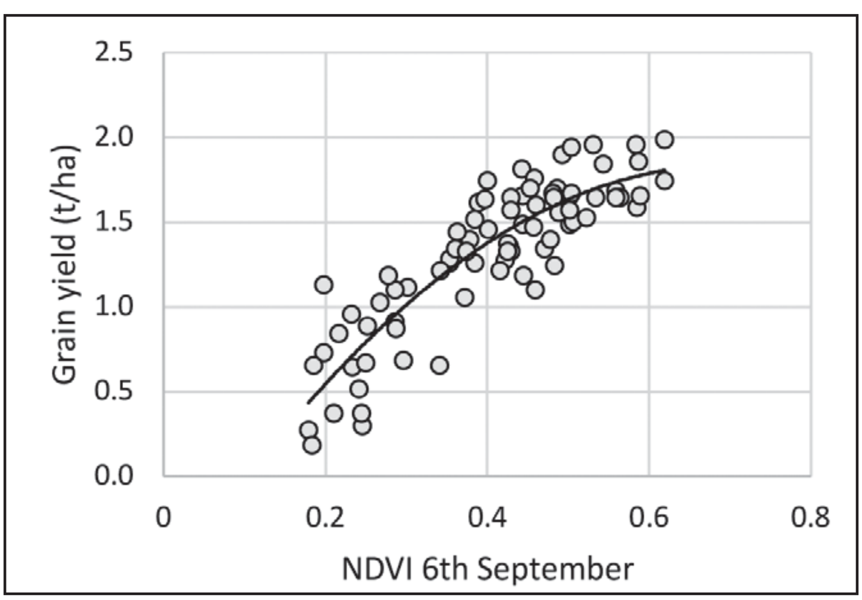

Figure 2. Relationship for Greenseeker NDVI of PBA Hurricane XT^A (recorded on 06-09-2021) and grain yield for the alkaline sand herbicide tolerance trial at Alford in 2021 ($y = -5.2444x^2 + 7.3026x - 0.706$, $R^2 = 0.77$).

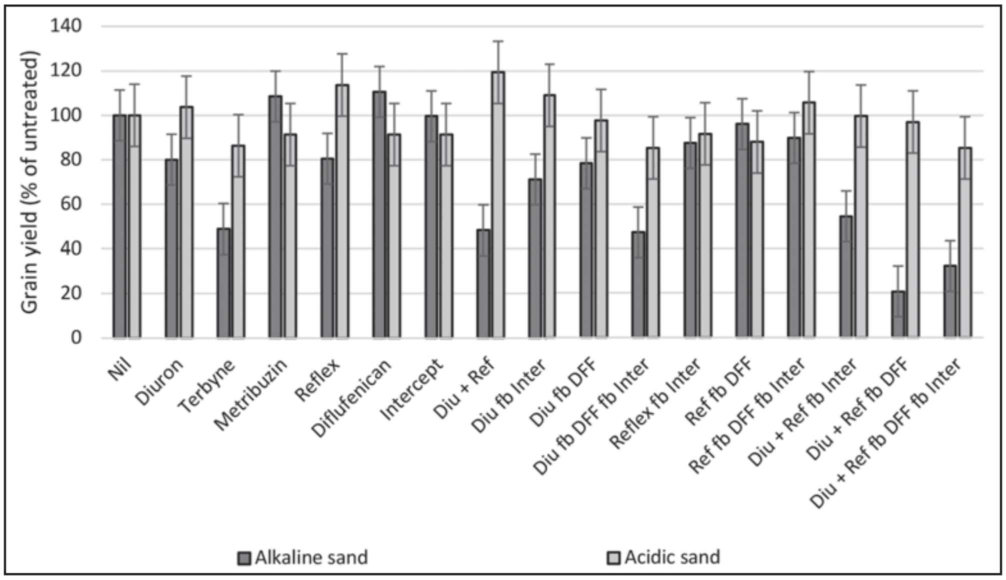

Figure 3. Grain yield presented as per cent of untreated for individual herbicide treatments at the acidic (Bute 1) and alkaline sand (Alford) herbicide tolerance sites in 2021, Diu = diuron, Ref = Reflex®, DFF = diflufenican, Inter = Intercept®, fb = followed by. Bars represent LSD (P=0.05).

Where diuron and Reflex were applied in combination, yield loss increased to a 52% reduction in grain yield compared to the untreated control.

Post-emergent herbicides Intercept and diflufenican (DFF) did not cause yield loss at either site, which is consistent with results of Trengove et al. (2021) for similar soil types. Generally, DFF and Intercept were also safe to apply following application of either diuron or Reflex IBS. Where these had caused damage at the alkaline sand site, the post-emergent applied herbicides did not exacerbate the damage. However, the most damaging combination of herbicide at the alkaline sand site was the combination of diuron plus Reflex applied IBS followed by DFF post-emergent. This treatment resulted in a grain yield reduction of 79%. The addition of Intercept to this treatment did not increase the level of damage further.

Reflex application rates in the herbicide tolerance trials (Alford, Bute 1) were set at 1000 mL/ha for all treatments. However, in the weed control trials (Bute 2 & 3), rates of 500 mL/ha, 750 mL/ha and 1000 mL/ha were applied. Grain yield loss at the alkaline sand trial (Bute 3) varied depending on the rate applied with the 500, 750 and 1000 mL/ha rates yielding 83%, 76% and 46% of the untreated, respectively (Pr(>F)=<0.001). This indicates that if rates can be reduced and weed control is still maintained, the crop safety margin can be improved.

Seasonal effect of crop safety

It is important to note that season and rainfall patterns are likely to influence herbicide movement and activity in soil and the effect this has on the crop. All the above crop safety data is from the 2021 season. Reflex was also included in 2020 trials and, whilst similar herbicide damage symptoms were present on an alkaline sand, this did not translate into any yield loss in 2020. There were no herbicide damage symptoms or yield loss at the acidic sand site in 2020. A reason for the increased herbicide damage in the 2021 season may be due to more rainfall in the weeks following sowing, which may have moved the herbicide further into the soil profile, with June 2021 receiving 56 mm of rainfall compared to 19 mm in June 2020 (Figure 4). Bute sites received 63 mm rainfall in June 2021 (Table 4). Greater spring rainfall in 2020 is also likely to have contributed to better crop recovery.

Broadleaf weed control

Reflex was effective in controlling 94-98% of bifora at rates of between 500 and 1000 mL/ha (Table 5). Application of Intercept, on its own or in combination with Reflex, provided excellent control of bifora, reducing seed set to <1 bifora seed/m^2 compared to existing pre-emergent herbicide options metribuzin and Terbyne with 323 and 1672 bifora seeds/m^2, respectively. Similarly, the combination of Reflex + Intercept provided high levels of common sow thistle control at all sites where it was present (Tables 5 and 6).

Intercept did not provide adequate control of Indian hedge mustard (IHM) and was not significantly different to the untreated control at the clay loam site (Bute 2) (Table 5). Similar results for poor IHM control with Intercept occurred at the other three sites (Tables 6 and 7). However, wild turnip was effectively controlled with Intercept. This poor control of IHM may be explained by the increase of IHM populations resistant to imidazolinone herbicides in this area. This suggests that strategic use of IMI herbicides in combination with alternative modes of action is needed to delay the increase of resistant broadleaf weeds or to manage already resistant populations.

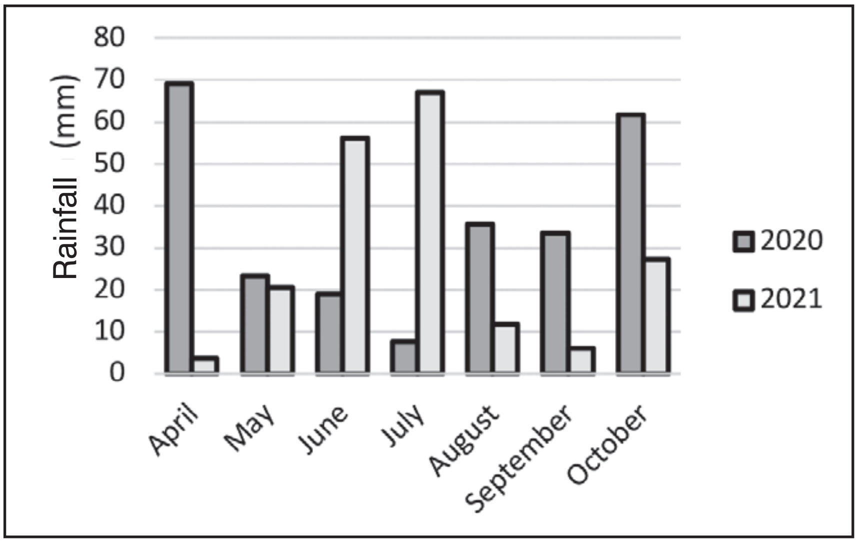

Figure 4. Growing season rainfall recorded at the Alford community weather station.

Table 4. Daily rainfall received at Bute sites after sowing till June 30, 2021.

Date	Rainfall received (mm)	Date	Rainfall received (mm)
7/06/2021	3.3	18/06/2021	1.8
8/06/2021	19.5	19/06/2021	1.1
9/06/2021	3.3	20/06/2021	0.1
10/06/2021	0.3	23/06/2021	1.0
11/06/2021	1.2	24/06/2021	3.9
13/06/2021	0.7	25/06/2021	4.7
15/06/2021	5.4	26/06/2021	0.2
16/06/2021	0.8	27/06/2021	0.3
17/06/2021	15.3	28/06/2021	0.1

Table 5. Effect of herbicides on broadleaf weeds and their seed set on clay loam soils at Bute 2, 2021.

Herbicide treatment (commercial product rate)	Seed bearing bifora (plants/m^2)	Bifora (seeds set/m^2)	IHM (pod set/m^2)	Common sow thistle (plants/m^2)	Common sow thistle (pod set/m^2)
Intercept 600 mL/ha (POST)	0.1 de	0.4 c	731 a	1.4 bc	4 de
Metribuzin 200 g/ha (PSPE)	14.3 c	323 b	1 de	0 d	0 f
Reflex 500 mL/ha (IBS)	5.9 cd	35 c	217 bc	2.6 b	12 bcd
Reflex 500 mL/ha (IBS) + Intercept 600 mL/ha (POST)	0 e	0 c	409 ab	0.4 cd	1 ef
Reflex 500 mL/ha (IBS) + Metribuzin 200 g/ha (PSPE) + Intercept 600 mL/ha (POST)	0 e	0 c	24 de	0 d	0 f
Reflex 500 mL/ha (IBS) + Terbyne 1000 g/ha (IBS) + Intercept 600 mL/ha (POST)	0.1 de	0.4 c	0 e	0 d	0 f
Reflex 750 mL/ha (IBS)	2.0 de	7 c	64 cde	3.1 b	15 abc
Reflex 750 mL/ha (IBS) + Intercept 600 mL/ha (POST)	0 e	0 c	81 cde	0.2 cd	1 ef
Reflex 750 mL/ha (IBS) + Metribuzin 200 g/ha (PSPE) + Intercept 600 mL/ha (POST)	0 e	0 c	0 e	0 d	0 f
Reflex 750 mL/ha (IBS) + Terbyne 1000 g/ha (IBS) + Intercept 600 mL/ha (POST)	0 e	0 c	10 de	0 d	0 f
Reflex 1000 mL/ha (IBS)	5.4 cd	21 c	24 de	2.6 b	21 ab
Terbyne 1000 g/ha (IBS)	52.7 b	1672 a	105 cd	1.2 bc	5 cde
Unweeded control	97.2 a	1987 a	836 a	7.3 a	29 a

**IHM - Indian Hedge Mustard*

Table 6. Broadleaf weed control with herbicide treatments on an alkaline and acidic sandy soil at Alford and Bute 1, respectively, in 2021.

Herbicide treatment (commercial product rate)	Alkaline sand				Acidic sand				
	Medic control (%)	IHM* control (%)	Wild turnip control (%)	Common sow thistle control (%)	Medic control (%)	IHM* control (%)	Wild turnip control (%)	Common sow thistle control (%)	Capeweed control (%)
Nil	0 a	0 a	0 a	0 a	0 a	0 a	0 a	0 a	0a
Diuron 830 g/ha (IBS)	63 b	93 cd	100 c	96 b	38 abc	80 b	82 b	84 cd	76 bcde
Terbyne 750 g/ha (IBS)	78 bc	96 cde	100 c	96 b	30 abc	87 bc	78 b	90 cd	87 defg
Metribuzin 180 g/ha (IBS)	53 ab	74 ab	98 b	48 a	4 ab	73 b	76 b	57 b	62 abc
Intercept 500 mL/ha (POST)	93 d	70 ab	98 b	85 b	80 ef	0 a	100 d	84 c	48 ab
Diuron 830 g/ha (IBS) + Intercept 500 mL/ha (POST)	89 cd	96 de	100 c	96 b	70 bcde	70 b	99 d	97 ef	74 abcd
Diflufenican 150 mL/ha (POST)	53 ab	100 g	100 c	93 b	42 abcd	100 e	100 d	90 cd	90 cdef
Diuron 830 g/ha (IBS) + Diflufenican 150 mL/ha (POST)	58 b	100 g	99 c	100 b	90 efg	100 e	100 d	100 f	99 gh
Diuron 830 g/ha (IBS) + Diflufenican 150 mL/ha (POST) + Intercept® 500 mL/ha (POST)	91 d	100 g	100 c	96 b	98 fg	100 e	100 d	100 f	99 gh
Reflex 1000 mL/ha (IBS)	54 ab	96 de	99 c	93 b	0 a	93 cd	94 c	94 de	93 efgh
Reflex 1000 mL/ha (IBS) + Intercept 500 mL/ha (POST)	88 cd	96 efg	100 c	100 b	80 cde	97 d	100 d	100 f	91 efgh
Reflex 1000 mL/ha (IBS) + Diflufenican 150 (POST)	57 b	100 g	100 c	100 b	78 def	100 e	100 d	100 f	98 fgh
Reflex 1000 mL/ha (IBS) + Diflufenican 150 mL/ha (POST) + Intercept 500 mL/ha (POST)	93 d	100 g	100 c	100 b	100 g	100 e	100 d	100 f	100 h
Diuron 830 g/ha (IBS) + Reflex 1000 mL/ha (IBS)	72 bc	97 def	99 c	93 b	18 ab	96 d	97 c	91 cd	95 efgh
Diuron 830 g/ha (IBS) + Reflex 1000 mL/ha (IBS) + Intercept 500 mL/ha (POST)	87 cd	96 de	100 c	96 b	88 efg	97 d	100 d	100 f	91 defg
Diuron 830 g/ha (IBS)+ Reflex 1000 mL/ha (IBS) + Diflufenican 150 mL/ha (POST)	75 bc	100 g	100 c	100 b	66 cde	100 e	100 d	100 f	99 gh
Diuron 830 g/ha (IBS) + Reflex 1000 mL/ha (IBS) + Diflufenican 150 mL/ha (POST) + Intercept 500 mL/ha (POST)	93 d	100 fg	100 c	100 b	86 efg	100 e	100 d	100 f	100 h
Weed density in nil (weeds/plot)	159	91	56	9	16	119	87	22	39
Weed density in nil (weeds/m^2)	10.6	6.1	3.7	0.6	1.1	7.9	5.8	1.5	2.6

**IHM - Indian Hedge Mustard*

Table 7. Effect of herbicides on Indian hedge mustard (IHM) and their seed set on sandy alkaline soils at Bute 3, 2021.

Herbicide treatment (commercial product rate)	IHM/m^2 (120 DAS)	IHM pods/m^2 (135 DAS)
Diuron 550 g/ha (PSPE)	0.2 bc	1 b
Intercept 600 mL/ha (POST)	5.6 a	118 a
Metribuzin 180 g/ha (PSPE)	0.6 b	13 b
Reflex 500 mL/ha (IBS)	0.6 b	5 b
Reflex 500 mL/ha (IBS) + Diuron 550 g/ha (PSPE)	0 c	0 b
Reflex 500 mL/ha (IBS) + Diuron 550 g/ha (PSPE) + Intercept 600 mL/ha (POST)	0 c	0 b
Reflex 500 mL/ha (IBS) + Metribuzin 180 g/ha (PSPE)	0 c	0 b
Reflex 500 mL/ha (IBS) + Metribuzin 180 g/ha (PSPE) + Intercept 600 mL/ha (POST)	0.2 bc	5 b
Reflex 750 mL/ha (IBS)	0 c	0 b
Reflex 1000 mL/ha (IBS)	0 c	0 b
Unweeded control	6.3 a	154 a

Reflex applied at 1000 mL/ha IBS was effective at controlling IMI resistant IHM populations at this location. The level of weed control improved with increasing Reflex rates from 500 mL/ha (217 IHM pods/m^2) to 1000 mL/ha (24 IHM pods/m^2) (Table 5). Most of the surviving IHM plants in Reflex treated plots were found in the in-row spaces, from where the applied herbicide was likely moved out by the seeding operation. Where Reflex was applied IBS and followed by a Group 5 herbicide, metribuzin or Terbyne as a PSPE application, the surviving weeds in the in-row area were mostly controlled. Reflex also proved more effective against capeweed (93% control) compared to Intercept (48% control) (Table 6).

Intercept application was the stand-out herbicide for achieving medic control in these trials, particularly at the acidic site where the next best treatment only achieved 38% control. Therefore, to achieve the desired level of broadleaf weed control in lentil, it is important to know the likely weed types, population, and resistance status prior to deciding on herbicide treatment.

What does this mean?

The availability of the new Group 14 herbicide Reflex has increased the options for achieving improved broadleaf weed control in lentil, including weeds resistant to IMI herbicides. Careful decisions regarding safe dosage rates of Reflex, governed by the soil type, and a follow-up application of Group 5 and Group 12 herbicides provide broad-spectrum broadleaf weed control in lentil. Group 2 IMI herbicides will continue to be a valuable tool for broadleaf weed control in lentil, especially for weeds that have not evolved resistance to this mode of action, and the weeds such as medics that are not effectively controlled with other herbicides. Using Reflex in conjunction with IMI herbicides, metribuzin, Terbyne or diuron, will diversify the selection pressure for broadleaf weed control in lentil and delay the resistance build up to a specific mode of action.

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Understanding environmental and agronomic influences on pulse protein

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Key messages

- **South Australia is engaging with the global interest in plant protein by investigating the impact of common farming practices on pulse grain protein and conducting research on sustainable methods of protein fractionation.**
- **Development of a pulse protein industry in South Australia will provide new market opportunities for pulses that are not reliant on visual grain classifications.**
- **Preliminary results demonstrate both genetic and environmental factors influence protein content in pulse grain in South Australian farming systems.**

Why do the trial?

In Australia, pulses are typically grown in rotation with higher-value cereal crops and are often sold at lower prices per tonne for use in stockfeed or exported in bulk to countries such as India or Egypt, where they are a staple food source. Rising consumer awareness of the environmental consequences, health implications and animal welfare issues associated with increasing levels of meat consumption has led to substantial growth in demand for foods that are sustainably produced and promote health and wellness. This demand has resulted in pulse crops becoming one of the world's fastest growing agricultural sectors. Indeed, Australia's plant protein market is forecast to be worth AU$4.03 billion a year by 2030.

Globally, grain legumes including yellow peas and soybeans are the most popular for making plant protein powders and isolates. Locally, lupin, chickpea, lentil, faba bean and field pea contain high levels of protein suitable for extraction. The South Australian Government recognises the potential and value of pulse protein and have funded a 3-year project to facilitate the development of plant protein fractionation and processing capability in South Australia.

Processing plant protein

At present, the Australian Plant Proteins (APP) plant, based in Horsham Victoria, is the only commercial fractionation facility in the country producing plant proteins. The APP process is based on wet extraction which uses (and re-uses) water to separate protein from the other grain constituents - mostly starch and fibre. The components are separated from the water using a significant power input and the resulting outputs are high purity protein, starch and fibre powders. The alternative to wet extraction is dry fractionation (also referred to as air classification) which uses no water and much less power but with less efficiency in separating protein from starch and fibre. The low water and power requirements of dry fractionation make it more suitable for South Australian conditions. In practice, dry fractionation can enrich the protein content of a pulse flour from 20% to around 50%, but the yield of the protein enriched fraction will only be about 25-30% of the input. The remaining 70-75% will be a starch-enriched fraction.

Dry fractionation works by separating particles from a mixture on the basis of physical properties including mass and density. Essentially, the process involves milling grain to a fine flour which is then drawn through an air classifying machine containing a very fast spinning slotted rotor that acts as a gate to create a fine and coarse fraction based on particle density. The fine fraction is enriched with smaller, lighter protein particles, which can be used in products like artificial meat and protein powders, while the coarse fraction contains larger, heavier starch granules which can be used as thickeners and fillers in food manufacturing.

In 2020, the Waite Research Institute pulse protein group purchased a pilot scale dry fractionation unit and are working on refining the process of dry fractionating for locally grown pulses to define the milling and dry classifier settings that balance the goal of achieving the highest possible level of protein enrichment and yield of that fraction. Results indicate initial grain protein content largely determines the level of protein enrichment that is possible following dry fractionation, so making sure the most suitable feedstock is used for dry classification is critical to the process and this is why the work on understanding the effects of variety, environment and management is essential.

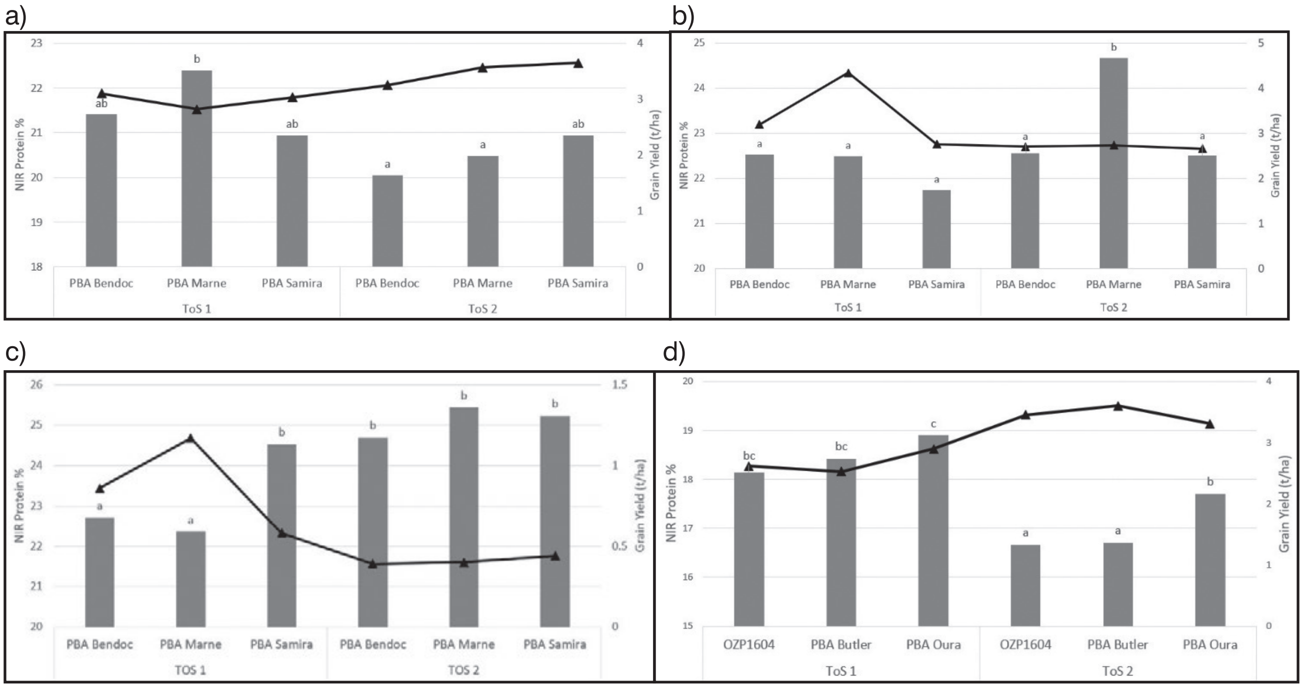

Figure 1. Grain yield t/ha (line graph) and NIR protein % (column graph) for faba bean and field pea time of sowing trials (ToS) in 2020: a) Farrell Flat faba bean; b) Warnertown faba bean; c) Wudinna faba bean; d) Eudunda field pea. ToS 1- early April. ToS 2- early May. Bars labelled with the same letter are not significantly different (P<0.05).

Preliminary work

A large range of pulse agronomy trials from 2020 were tested for protein using a near-infrared (NIR) grain analyser. Preliminary results suggest there are differences in grain protein content between varieties for both faba bean and field pea, with a protein response to sowing time (Figure 1).

The results from 2020 show that there is a difference in protein level between varieties and across times of sowing (ToS), particularly for PBA Marne. PBA Samira had more consistent yield and protein content across ToS, while this was more variable for PBA Marne. Protein levels in PBA Marne were higher at ToS 2 (early May sowing) compared to ToS 1 (early April sowing) at both Warnertown and Wudinna, however, the opposite occurred at Farrell Flat. Farrell Flat had multiple frost events throughout the flowering and podding growth stages, which resulted in lower yield and higher protein for ToS 1. Eudunda also experienced a major frost event during early podding, which resulted in similarly lower yield but increased protein content in field pea for ToS 1. PBA Oura (dun type pea) looks promising as it had high yield and high protein for both times of sowing.

How was it done?

In 2021, SARDI had four trial sites and ten focus paddocks across the Mid-North and Eyre Peninsula to determine how protein levels in field pea and faba bean grain was affected by agronomic management practices. There were two trials at Tooligie. The first included commercial and advanced breeding lines and was designed to investigate the difference in protein levels between varieties. The second experiment assessed the protein response to nitrogen management by applying urea at different growth stages with the aim of manipulating the conversion of nitrogen to grain protein. In addition, ten faba bean and field pea focus paddocks were used to assess how different environments including soil limitations, temperature, frost, and rainfall affect the protein levels at a paddock scale.

What happened and what does this mean?

Grain samples from 2021 field trials are being processed in the SARDI lab at the Clare Research Centre for protein content - results are being compiled at the time of writing to be communicated in subsequent publications.

These results will be very useful for understanding the influence of changing genotypic and agronomic management practices on grain protein levels. Results from 2020 and the 2021 larger scale trial will guide the 2022 research plan to further understand how pulse grain protein content can be improved through different agronomic practices in variable environmental conditions across the state, along with the most efficient method of protein extraction.

Acknowledgements

The continued assistance with trial management by the SARDI Agronomy groups at Clare and Pt Lincoln is gratefully acknowledged and appreciated. The continued support and guidance from the SARDI pulse protein group at the Waite Research Precinct is recognised and greatly valued.

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Growing pulse crops on sandy soils on lower Eyre Peninsula

Andrew Ware
EPAG Research

Location
Mount Hope
Billy Pedler
Rainfall
Av. Annual: 420 mm
Av. GSR: 346 mm
2021 Total: 491 mm
2021 GSR: 434 mm
Yield
Grower yield 1.7 t/ha lupin
Paddock history
2020: Wheat
Soil type
Sandy loam
Plot test
0-10 cm pH: 7.12 ($CaCl_2$), P (Colwell) 26 mg/kg, Org. C 0.76 %, Nitrate N 9.4 mg/kg
Paddock scale demonstration
Yield limiting factors
Sowing rate, broadleaf weeds

Location
Yeltukka (NW Cummins)
Michael Treloar
Rainfall
Av. Annual: 396 mm
Av. GSR: 315 mm
2021 Total: 421 mm
2021 GSR: 377 mm
Yield
Potential: Faba beans 6.0 t/ha (Modified French/Schultz, 16 kg/mm)
Actual: 2.0 t/ha
Paddock history
2020: Barley
2019: Wheat
2018: Wheat
Soil type
Sand over clay loam with some calcrete in sub-soil
Plot test
0-10 cm pH: 6.92 ($CaCl_2$), P (Colwell) 23 mg/kg, Org. C 1.42 %, Nitrate N 15 mg/kg
Plot size
10 m x 2 m x 4 reps
Yield limiting factors
Broadleaf weeds

Key messages

- **Soil amelioration has the potential to allow profitable production of high value pulse crops on sandy soils on Lower Eyre Peninsula, however yields may not match lupins.**
- **Using 2021 prices gross margins of crops such as lentils are comparable to canola, however, yields of lentils on sandy soils at the demonstration site and field trials were only around 1 t/ha, much lower than was observed on heavier soils.**

Why do the trial?

This article will report on findings from work conducted at two locations on the lower Eyre Peninsula in 2021 as part of the GRDC's investment "Development and extension to close the economic yield gap and maximise faming systems benefits from grain legume production in South Australia."

Following consultation with the AIR EP Medium Rainfall RD&E Committee, large scale demonstrations and trials in 2021 were designed to answer two questions:

1. Can soils be ameliorated to increase the area that high value pulses are able to be grown on?
2. What is the value of pulse crops, in terms of direct profitability and value to the rotation, compared to other break crops such as canola?

To answer these questions in the 2021 season a demonstration was monitored and and field trials were undertaken.

1. Demonstration Paddock:
Growing high value pulse crops on soil that's been ameliorated.

Background
Around a third of the arable area on the lower Eyre Peninsula consists of acidic sandy - sandy loam topsoils (B. Masters pers. comm.) that have traditionally only been suitable for the production of lupins as a grain legume crop. In recent years pH mapping, coupled with variable rate lime application and an improved understanding of how to implement soil amelioration strategies has sufficiently changed some soils to the point where growing higher value pulses such as lentils and faba beans is now an option (while the latter is not always higher value). However direct yield comparisons of these crops on ameliorated soil have not yet occurred on the lower Eyre Peninsula.

How was it done?

In 2018 a paddock near Mt Hope was mapped for pH and found top-soil pH to vary between 5.2 and 6.5 ($CaCl_2$). In early 2019 the paddock had variable rates of lime applied, depending on the acidity of the soil, which was then was incorporated with delving, and the surface smoothed and then cropped each year.

In 2021 the paddock was planted on 3 June using the grower's air-seeder to sow zones of lupin (cv PBA Barlock), lentil (cv PBA Kelpie) and faba bean (PBA Samira). All crops were treated with high rates of the appropriate inoculant and broadleaf weeds controlled with label rates of herbicide, appropriate for the crop and the soil type.

Table 1. Nodule scores, biomass and grain yield of pulse crops grown at Mt Hope in 2021.

		Plants/m²	Nodule score 3/8	Nodule score 6/9	Biomass (t/ha) 11/10	Biomass maturity (t/ha)	Hand cut grain yield (t/ha)	Harvester yield (t/ha)
Lupin	Ripped	48	5.6	7.2	7.66	8.43	3.29	1.79
	unripped	50			3.92	5.47	2.27	
Faba bean	Ripped	28	7	6.4	4.50	5.10	2.60	2.0
	unripped	30			3.15	4.60	2.20	
Lentil	Ripped	92	4.4	4.8	3.00	3.12	1.07	0.8**
	unripped	96			1.85	2.51	0.75	

**Nodule score 0-8 scale where scores of 4-5 (40-50 small or 4-9 large pink nodules) are considered adequate to ample (Yates* et al*, 2016).*
*** some yield loss experienced due to pod drop prior to harvest.*

Table 2. Pulse crop gross margin x grain price sensitivity ($/ha).

Crop	Grain Price ($/t)									
	300	350	400	450	500	600	700	800	900	1000
Lupin	624	789	953	1118	1282	1611	1940	2269	2598	2927
Faba bean	262	392	522	652	782	1042	1302	1562	1822	2082
Lentil	-176	-123	-69	-16	38	145	252	359	466	573

shaded likely price achieved in 2021.

Table 2a. Grain yields and variable costs used in sensitivity analysis ($/ha).

Crop	Hand cut grain yield* (t/ha)	Variable costs** ($/ha)
Lupins	3.29	363
Faba bean	2.60	518
Lentil	1.07	497

**Yields from hand-cuts collected adjacent to each crop (collected 11 November).*
***variable costs derived from PIRSA Farm Gross Margin Guide 2021*

During the season emergence, nodulation scores, biomass and grain yield data were collected using quadrant cuts at multiple locations in each zone.

What happened?

Soil testing conducted in autumn 2021 found that top-soil pH (0-10 cm) to be 7-7.9, the sub-soil was also near-neutral 7.8 ($CaCl_2$) at 60-100 cm.

Nodule scores conducted twice during the growing season found that all crops were able to produce enough nodules to meet industry standards considered for adequate nodulation, however the beans and lupins did appear to have a higher nodulation rate than lentils.

Pulses grown on the deep ripped/delved soil all yielded higher than where the soil wasn't ripped. A 31% advantage from ripping was recorded in lupins, 15% in faba beans, and 30% in lentils.

Whilst the way the paddock was sown doesn't allow for direct statistical analysis to compare yields of each of the crops against each other, the yields obtained do provide a realistic impression of pulse yields achievable on limed and ameliorated soil in this environment. When these yields were used to extrapolate out to a gross margin it showed that lupins were reasonably profitable in 2021 at the grain yields achieved, but faba bean and lentil have the potential to also be profitable in this environment (Table2).

What does this mean?

While adjusting soil pH and ameliorating soil are important steps in growing high value pulse crops, such as lentils, on acidic sandy soils, returns still may be lower or only match that of a productive crop of lupins.

A range of skills and practices not used in cereal, canola or lupin production are also required when growing high value pulse crops for the first time. These include (but are not limited to) matching broadleaf herbicide performance to soil type and harvesting crops vulnerable to pod drop low to the ground.

2. Field experiments

Background:

Over the last 30 years the lower Eyre Peninsula has grown large areas of canola. This is due to its widespread adaptability to the soils and the lower EP environment as well as the high returns it has provided. Pulse crops have been grown in the region but have, by large, been restricted to heavier alkaline soils or lupins on sandier soils, which generally provide lower returns. Increasing the viability of pulse crops on the lower Eyre Peninsula needs to demonstrate their capacity to produce across a range of soil types found in the region and to compare favourably in terms of profitability to canola. To answer the question of how valuable pulse crops are, trials were established on a sandy soil at Yeltukka, 15 km north-west of Cummins. The paddock where the trials were located had no history of ever growing a pulse crop.

Three trials were established on the site. Two examined rates and types of rhizobia when sown into dry and moist soils on both lentil and faba beans. The third trial examined the performance of a range of pulse crops (lentil, faba bean, lupin, and vetch) relative to canola. All trials will be over-sown with wheat in 2022 to assess the residual value of the pulse crops.

What happened?

Sowing occurred at two dates: 18 May (dry sown) and 29 May (wet sown, rain 26 May). All trials received 100 kg/ha MAP fertiliser at seeding and a foliar trace element spray of 3 L/ha Smart Trace Triple®. Weeds were controlled with 1 L/ha propyzamide and 500 mL/ha clethodim across all treatments, 1.1 kg/ha simazine (applied PSPE) on faba beans and lupins, 400 g/ha simizine + 400 g/ha diuron (applied PSPE) to lentils, 400 g/ha diuron (applied PSPE to vetch) and 500 mL/ha Intervix® applied to canola. 60 mL/ha alpha-cypermethrin was applied during grain fill to control insect damage. No seed dressing fungicides were used at this site. 500 mL/ha carbendazim was applied to lentil and faba beans mid-August. Vetch brown manure plots were sprayed with 2 L/ha glyphosate in early October.

Faba bean (cv Bendoc) was sown at 30 plants/m^2, lentil (cv Hurricane XL) was sown at 120 plants/m^2, lupin (cv Wonga) was sown at 55 plants/m^2, vetch (cv Timok) was sown at 50 plants/m^2 and canola (cv Pioneer 44Y94CL) was sown at 45 plants/m^2.

Despite reasonably effective pre-emergent herbicides being applied, the site had some capeweed emerge in plots which may have influenced yield.

Inoculant trials

Inoculants used were in granular and peat form, both Tag Team® products. They were applied at x1 and x2 label rates. Label instructions for application were adhered to for both products. The peat inoculant was applied to seed day of sowing.

Trials were harvested on 17 November.

Pulse Legacy trial

This trial was sown 29 May, to determine the relative value of growing a range of pulse crops compared to canola. Each crop was managed as per best practice for that crop. All pulse crops were inoculated. Grain yields were collected with hand cuts, due to differences in maturity. This trial will be sown with wheat in 2022 to determine legacy effects.

Break Crops

Table 3. Emergence, nodulation, biomass (NDVI and cut) and grain yield of a granular and peat inoculant applied to Hurricane lentils in 2021.

Inoculant form	Time of sowing (TOS)	Label rate	Emergence 5 June (plants/m^2)	Nodulation 5 June	NDVI 5 June	Nodulation 8 Sept	Biomass 11 Oct (t/ha)	Grain yield (t/ha)
Granular	Dry	x1 rate	117	4.5	0.25	4.4	2.2	1.09
		x2 rate	109	4.4	0.26	4.6	2.85	1.05
	Wet	x1 rate	97	3.9	0.21	5.1	2.7	0.98
		x2 rate	105	4.1	0.21	4.7	2.28	1.14
Peat	Dry	x1 rate	113	3.8	0.25	4.1	1.97	0.66
		x2 rate	112	4.2	0.26	4.0	2.28	0.86
	Wet	x1 rate	116	3.6	0.23	4.2	2.55	0.69
		x2 rate	114	4.1	0.22	4.6	2.74	0.80
LSD (P=0.05)		*Rate*	*ns*	*ns*				*ns*
		Product						*0.22*
		TOS	*ns*					*ns*

Table 4. Emergence, nodulation, biomass (NDVI and cut) and grain yield of a granular and peat inoculant applied to Bendoc Faba Beans in 2021.

Inoculant form	Time of sowing (TOS)	Label rate	Emergence (pl/m²)	Nodulation 5 June	NDVI 5 June	Nodulation 8 Sept	Biomass 11 Oct (t/ha)	Grain yield (t/ha)
Granular	Dry	x1 rate	27	3.4	0.35	7.9	4.1	2.21
		x2 rate	30	3.3	0.32	7.8	4.7	2.01
	Wet	x1 rate	29	3.1	0.37	7.7	3.9	1.77
		x2 rate	34	3.4	0.34	7.7	5.0	1.94
Peat	Dry	x1 rate	28	1.7	0.28	7.0	4.4	1.50
		x2 rate	28	1.6	0.29	7.6	3.6	2.19
	Wet	x1 rate	24	1.0	0.29	7.6	4.8	2.12
		x2 rate	29	2.3	0.29	7.6	4.1	1.84
LSD (P=0.05)		*Rate*	*ns*	*ns*				*ns*
		Product						*ns*
		TOS	*ns*					*ns*

Table 5. rNod soil test of rhizobia numbers following 2021 trials at Yeltukka.

Sample	Rhizobia Group E & F kDNA copies/g sample
Bare soil	0
Bean wet sow	1044
Bean dry sow	82
Lentil wet sow	431
Lentil dry sow	550

**nb levels of around 1000 kDNA copies/g are considered adequate.*

Table 6. Biomass (October and harvest), grain yield and gross margin of the pulse and canola crops grown at Yeltukka in 2021.

Crop	October biomass (t/ha)	Harvest biomass (t/ha)	Grain yield (t/ha)	Variable** cost ($/ha)	Grain price **($/t)	Gross margin ($/ha)
Canola	7.14 cd	6.11 c	1.93 b	756	900	980
Faba Bean	2.41 ab	3.01 abc	1.80 b	504	550	484
Lentil	2.52 ab	2.68 a	1.53 b	461	1000	1073
Lupin	4.10 bc	4.32 abc	2.08 b	379	410	472
Vetch	3.90 ab	2.87 ab	1.24 b	361	700	509
VetchBM*	1.46 a	2.36 a	0.00 a	361	0	-361

**BM = brown manure.*
*** source: 2022 Farm Gross Margin and Enterprise Guide (PIRSA)*

What does this mean?

rNod soil testing of the site (to determine the levels of inoculant present) found no strains of the desired group E&F present (Table 5). Testing at the end of the season only found sufficient levels of inoculant present after growing faba beans sown in wet soil, but all other samples collected were lower than desired levels.

In the lentil inoculant trial, the granular inoculant was able to demonstrate a higher yield. There were no differences in rate applied or sowing time (either wet or dry). Nodulation scores of the lentil trial found nodules at a level considered adequate (but not ample) to meet the plant's needs. There were no differences in grain yield from the faba bean trial. Nodulation scores conducted on the faba bean trial found nodules at abundant levels.

While there was no background of the correct rhizobia strains at this site, both the lentil and faba bean trials were able to show there was no effect from applying higher than label rates and that seeding dry eight days before the break of the season did not affect yield or nodulation.

The legacy trial reinforced findings from the demonstration site that even relatively low lentil yields do have the ability to match canola in terms of gross margin. Raising both lentil yield and yield stability in these soil types, where they haven't been traditionally grown will be explored over the next few years.

Reference

Yates, R.J. Abaodoo, R and Howieson, J. (2016) Field experiments with rhizobia. Pages 145-156 in Working with Rhizobia, J Howieson and M. Dilworth, eds. Australian Centre for International Agricultural Research, Canberra.

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GRDC GRAINS RESEARCH & DEVELOPMENT CORPORATION

EPAG RESEARCH

AIR EP Ag Innovation & Research Eyre Peninsula

Brian Dzoma and Brett Masters presenting at the calcareous soils trials site at the Minnipa Field Day, Sept, 2021.

Section 5

Cereals

Section Editor:
Amanda Cook
SARDI, Minnipa Agricultural Centre

Table 1. Upper Eyre Peninsula main season wheat yield performance. NVT data 2016–2020. Long-term yield expressed as a percentage of mean yield.

		Year	2016	2017	2018	2019	2020
		Mean yield (t/ha)	2.39	1.17	1.33	1.30	1.48
Variety	**Classification**	**No. trials**	**7**	**6**	**6**	**7**	**6**
MILLING WHEATS							
Ballista	AH	13	-	-	-	118	115
Beckom	AH	26	109	104	104	105	-
Calibre	AH	6	-	-	-	-	118
Catapult	AH	19	-	-	106	105	113
Corack$_A$	APW	32	101	100	101	90	101
Cutlass$_A$	APW	19	-	108	-	109	111
Emu Rock$_A$	AH	32	100	98	97	111	103
LongReach Arrow	AH	26	105	101	104	100	-
LongReach Cobra	AH	19	102	96	96	-	-
LongReach Scout	AH	32	105	99	94	112	103
LongReach Trojan	APW	32	103	103	102	95	97
Mace	AH	32	99	103	107	101	104
RockStar	AH	19	-	-	108	112	117
Scepter	AH	32	107	110	112	107	116
Vixen	AH	25	-	108	107	122	111
Wyalkatchem	APW	32	102	100	103	98	105
CLEARFIELD PLUS®							
Chief CL Plus	APW	32	99	101	108	85	103
Grenade CL Plus	AH	32	97	96	95	100	101
Hammer CL Plus	AH	13	-	-	-	102	105
Kord CL Plus	AH	32	92	96	97	93	96
Razor CL Plus	ASW	32	103	103	104	110	107
Sheriff CL Plus$_A$	APW	32	105	103	105	100	107

Data sourced from 2022 South Australia Crop Sowing Guide (https://grdc.com.au/resources-and-publications/all-publications/nvt-crop-sowing-guides/sa-crop-sowing-guide)
- denotes no data available

Table 2. Upper Eyre Peninsula early season wheat yield performance. NVT data 2017 and 2020. Long-term yield expressed as a percentage of mean yield.

Variety	Classification	Year	2017	2018	2019	2020
		Mean yield (t/ha)	1.40	0.00	0.00	2.00
		No. trials	1	0	0	1
MILLING WHEATS						
Cutlass	APW	2	105	-	-	101
Denison	APW	1	-	-	-	106
DS Bennett	ASW	2	119	-	-	114
DS Pascal	APW	2	104	-	-	103
Illabo	AH	2	114	-	-	109
LongReach Nighthawk	APW	1	-	-	-	108
LongReach Trojan	APW	2	97	-	-	96
RockStar	AH	1	-	-	-	98
Sheriff CL Plus	APW	1	-	-	-	93
FEED WHEAT						
Longsword	FEED	2	119	-	-	111

Data sourced from 2022 South Australia Crop Sowing Guide (https://grdc.com.au/resources-and-publications/all-publications/nvt-crop-sowing-guides/sa-crop-sowing-guide)
- denotes no data available

Table 3. Upper Eyre Peninsula barley yield performance. NVT data 2016–2020. Long-term yield expressed as a percentage of mean yield.

	Year	2016	2017	2018	2019	2020
	Mean yield (t/ha)	4.01	2.13	2.17	2.55	2.21
Variety	**No. trials**	**4**	**2**	**4**	**4**	**3**
MALTING						
LG Alestar	17	94	92	86	88	90
Commander	17	100	100	103	101	101
Compass	17	101	118	121	117	117
La Trobe	17	100	111	110	110	109
Leabrook	17	104	115	119	117	117
Maximus CL	11	-	-	112	114	114
RGT Planet	17	109	94	94	99	99
Scope CL	17	96	99	99	96	96
Spartacus CL	17	100	110	111	111	109
FEED						
Fathom	17	109	109	116	114	110
Rosalind	17	106	110	110	113	112
PENDING MALT ACCREDITATION						
Beast	7	-	-	-	123	122
Buff	11	-	-	108	106	102
Commodus CL	3	-	-	-	-	116
Cyclops	3	-	-	-	-	117
Laperouse	11	-	-	112	113	113
Minotaur	3	-	-	-	-	110

Data sourced from 2022 South Australia Crop Sowing Guide (https://grdc.com.au/resources-and-publications/all-publications/nvt-crop-sowing-guides/sa-crop-sowing-guide)
- denotes no data available

New wheat and barley varieties in 2021

Kaye Ferguson[1] and Amanda Cook[2]

[1]SARDI, Port Lincoln; [2]SARDI, Minnipa; [3]University of Adelaide Affiliate

Wheat NVT

The 2022 South Australia Crop Sowing Guide (https://grdc.com.au/resources-and-publications/all-publications/nvt-crop-sowing-guides/sa-crop-sowing-guide) has the current information on all varieties including the 2021 wheat releases Calibre Longreach Dual Longreach Bale and Valiant CL Plus.

New Release Wheat Variety Notes (Compiled from 2022 South Australia Crop Sowing Guide).

Calibre is a new variety released by AGT in spring 2021, with seed available for the 2022 season. It is a quick to mid-maturing variety similar to Mace with an AH classification. Calibre is largely derived from Scepter with improved coleoptile length and good sprouting tolerance. Seed is available from AGT Affiliates.

Longreach Dual was released in spring 2021 from LongReach Plant Breeders (tested as LPB18- 7982). It is a mid to slow variety flowering between LongReach Trojan and Yitpi. LongReach Dual is a long coleoptile variety with an AH classification. It is awnless and can be cut for hay or delivered as grain, offering options in frost-prone areas. Evaluation through NVT is limited. Seed is available for the 2022 season through LongReach seed network.

LongReach Bale was released in spring 2021 from LongReach Plant Breeders (tested as LPB18-7946). It is a slow-maturity awnless variety with a long coleoptile length. LongReach Bale also has an APW classification. Maturing later than Yitpi, its awnless qualities and delayed flowering allow it to be delivered as grain or cut for hay. Evaluation in NVT is limited. Seed is available for the 2022 season through grower-to-grower trade.

Valiant CL Plus is an imidazolinone herbicide tolerant (Clearfield®Plus) AH wheat released by InterGrain in 2021 (tested as IGW4502). It is a mid to slow-maturing wheat, providing the phenology fit for sowing in April. Valiant CL Plus has had limited evaluation in NVT to date but is SVS to powdery mildew, similar to Chief CL Plus. Seed is available for planting in 2022 from local resellers or InterGrain Seedclub Members. EPR $4.35 ex-GST.

Barley NVT

New release barley variety notes (Compiled from 2022 South Australia Crop Sowing Guide)

The 2022 South Australia Crop Sowing Guide (https://grdc.com.au/resources-and-publications/all-publications/nvt-crop-sowing-guides/sa-crop-sowing-guide) has the current information on all varieties including the 2021 barley releases Commodus CL, Cyclops and Minotaur.

Commodus CL is an imidazolinone - tolerant barley released in 2021 by InterGrain (tested as IGB1908). It is closely related to Compass, being similar agronomically, with the addition of the herbicide tolerance. Suited to the low-medium rainfall environments, Commodus CL has a similar head loss and lodging risk to Compass. Commodus CL has been accepted for Barley Australia malt accreditation, starting stage 1 in 2021 with the earliest possible time an accreditation decision can be made in 2023. Seed is available through InterGrain Seedclub Members. EPR $4.25 ex-GST.

Cyclops is a new variety released by AGT in spring 2021, with seed available for the 2022 season. It is a quick-maturing variety with a speed similar to Spartacus CL and is suited to a range of environments. It has an erect Hindmarsh plant type and therefore is less susceptible to lodging. Cyclops has been accepted for Barley Australia malt accreditation with the earliest possible accreditation decision in 2023. Seed is available through AGT Affiliates.

Minotaur is a new variety released by AGT in spring 2021, with seed available for the 2022 season. It is a mid to slow-maturing variety slightly slower than RGT Planet and best suited to medium-high rainfall environments. Minotaur has been accepted for Barley Australia malt accreditation with the earliest possible accreditation decision in 2023. Seed is available through AGT Affiliates.

Figure 1. NVT main season wheat at Kimba 2021.

Figure 2. NVT barley at Elliston September 2021.

Assessment of grain yield and quality of wheat and barley varieties at Penong in 2021

Melissa McCallum[1], Kym Zeppel[2], Kaye Ferguson[3] and Rhiannon Schilling[1,4]

[1]SARDI, Waite; [2]SARDI, Minnipa; [3]SARDI, Port Lincoln; [4]The University of Adelaide Affiliate

Location
Penong
Cade Drummond
Rainfall
2020 Total: 370 mm (excluding Dec)
2020 GSR: 252 mm
Paddock history
2021: Wheat
2020: Legume pasture
2019: Wheat
2018: Wheat
Fertiliser
DAP + Impact 80 kg/ha on 31 May 2021
Urea 58 kg/ha on 8 July 2021
RapiSol ZMC at 1 kg/ha on 29 July 2021
Soil test
Topsoil: 0-10 cm
Texture - sandy loam
Soil Colwell P = 21 mg/kg
Soil Boron = 3.04 mg/kg
Soil Conductivity = 0.51 dS/m
Soil pH (H_20) = 8.4
Soil pH ($CaCl_2$) = 7.8
Subsoil: 10-60 cm
Texture - sandy loam
Soil Boron = 20.69 mg/kg
Soil Conductivity = 1.11 dS/m
Soil pH (H_20) = 9.7
Soil pH ($CaCl_2$) = 8.6
Plot size
10 m x 1.85 m. 6 rows at 0.255 row spacing
Trial design
Experimental: randomised complete block design
Yield limiting factors
Late sowing due to dry start to the season (low), rain events occurred prior to harvest influencing quality (moderate).

Key messages

- **Wheat yields (0.72 t/ha) outperformed barley yields (0.57 t/ha) at Penong, SA in 2021.**
- **Slower maturing varieties including Commodus and RGT Planet (barley) and Valiant and Denison (wheat) had the lowest yields compared to other varieties.**
- **Sprouting occurred in all wheat varieties with falling number tests showing Scepter had the highest falling number compared to all other varieties.**
- **Findings are based on one year and subsequent years are required to evaluate consistency of results across multiple growing seasons.**
- **If using retained seed in 2022, we advise growers to check germination of seed and adjust seeding rates accordingly due to rain damage causing sprouting of harvested grain.**

Why do the trial?

The aim of this trial was to independently assess the grain yield and quality of wheat and barley varieties at Penong, South Australia. Some long-term yield data is available for wheat varieties with growers encouraged to view this through the GRDC-funded National Variety Trials (NVT, see: https://nvt.grdc.com.au). Performance of current barley varieties have not been recently evaluated in the Penong district. This field trial was requested by the local Penong growers and supported by the SARDI Agronomy program. It is known that environmental conditions, including low rainfall, can impact on field trials. Observations of variety performance under environmental extremes can be of value with careful interpretation and awareness of trial limitations. These findings reflect one year of data and subsequent years are required to provide sufficient conclusive outcomes. The findings of the 2021 trial are presented here for interested growers to interpret.

How was it done?

One wheat (6 rows × 3 ranges, GPS: 31.95827, 133.43330) and one barley (6 rows × 3 ranges, GPS: 31.95835, 133.43346) trial were sown at Penong on the 31 May 2021 into good soil moisture shortly after the first opening rain event. The site was prickle chained, the seeding depth was 25 mm with plot size 10 m × 1.85 m and mouse off was applied after sowing. A total of 12 varieties were tested with 3 replicate plots per variety (Table 1). Varieties were selected to have a range of maturity types.

Crop establishment was scored on the 23 June 2021 with uniform germination achieved for all varieties. Other measurements included grain yield (t/ha) and grain quality (1000 grain weight, test weight, moisture content, grain protein, retention >2.5 mm (%), screenings % and falling number).

Table 1. A summary of the wheat and barley varieties tested in the Penong trial in 2021.

Crop	Variety	Year Released	Breeder	Maturity
Wheat	Ballista	2020	AGT	Quick to mid
	Denison	2020	AGT	Slow
	RockStar	2019	InterGrain	Mid to slow
	Scepter	2015	AGT	Mid
	Valiant $^{CL\ Plus}$	2021	InterGrain	Mid to slow
	Vixen	2018	InterGrain	Quick
Barley	Beast	2020	AGT	Very quick
	Commodus	2008	University of Adelaide	Quick to mid
	Compass	2015	University of Adelaide	Very quick
	Maximus ^{CL}	2020	InterGrain	Very quick
	RGT Planet	2017	Seed Force/RAGT	Quick
	Spartacus $^{CL\ Plus}$	2016	InterGrain	Very quick

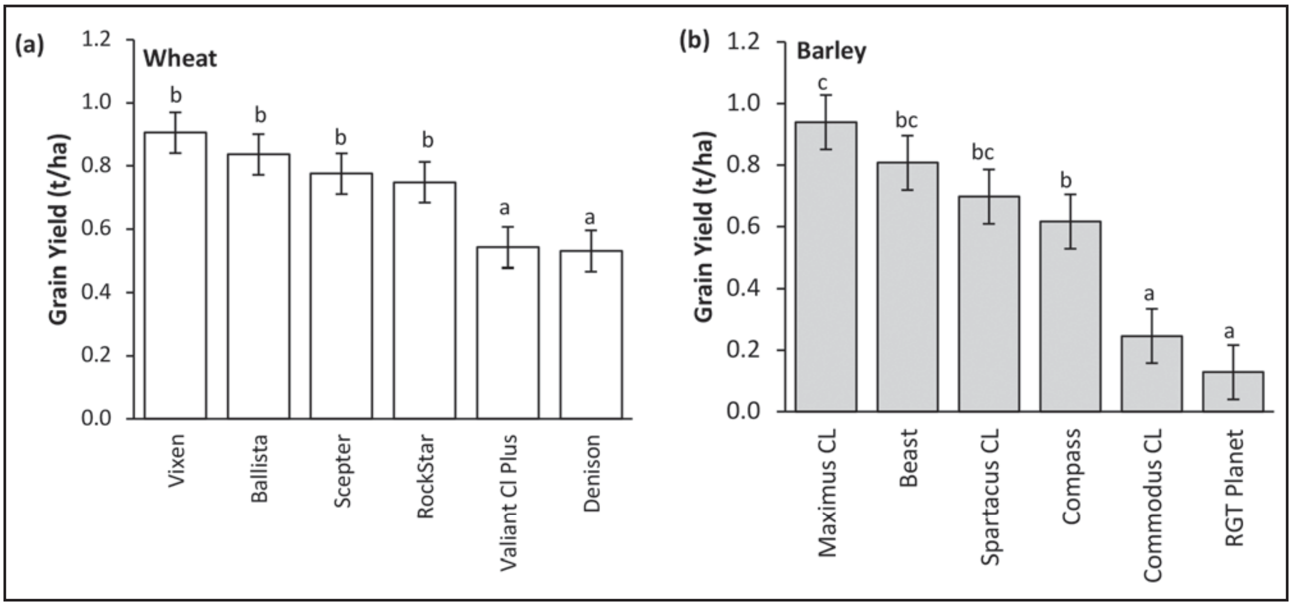

Figure 1. Grain yield of (a) wheat and (b) barley varieties at Penong in 2021. Values are average of 3 replicate plots with SEM error bars shown and a different letter indicating a significant difference at P<0.001.

The following pre- and post-emergent chemicals were used including Triallate (1.5 L/ha), Boxer Gold (1.5 L/ha), Roundup DST (2 L/ha), Carfentrazone-ethyl (240 g/L at 0.04 L/ha), LI 700 (0.26 L/ha) were applied at seeding. Axial 100 EC (0.3 L/ha) was applied on 8 July 2021 and Saracen (0.1 L/ha), LVE MCPA (500 g/L at 0.44 L/ha) and Hasten (1 L/ha) were applied on 29 July 2021 with Congito (0.25 L/ha) applied on 7 September 2021. No other treatments were applied to the trial.

Statistical analysis using GenStat version 21st and a general ANOVA with blocking at P>0.05 was completed.

What happened?

Grain yields were generally low in both trials, with the wheat trial averaging 0.72 t/ha and the barley trial averaging 0.57 t/ha (Table 2). Wheat varieties Vixen, Ballista, Scepter and RockStar were the highest yielding, with the slower maturing varieties Valiant CL Plus and Denison having significantly lower yield (Figure 1a). For barley varieties Maximus CL, Beast and Spartacus CL were the highest yielding, with Compass similar to Beast and Spartacus CL. Commodus CL and RGT Planet had significantly lower yields than other barley varieties (Figure 1b).

For wheat quality, Ballista (35.55 g/1000 seed) and Vixen (33.58 g/1000 seed) had significantly smaller 1000 grain weights than all other wheat varieties (Table 2). Grain protein % was on average 17.3% for wheat with Ballista (15.7%), Vixen (15.97%) and RockStar (16.5%) having lower values compared to other varieties and Valiant CL Plus (19.7%) having the highest protein value (Table 2). No difference in test weight, grain moisture content or screenings was observed between wheat varieties (Table 2).

Table 2. A summary of the grain yield and quality including 1000 grain weight, test weight (kg/hL), grain moisture content, grain protein %, screenings and falling number for wheat varieties at Penong in 2021. ns = not significant at P<0.05.

Crop	Variety	Yield (t/ha)	Grain Weight (g/1000 seeds)	Test Weight (kg/hL)	Grain Moisture Content (%)	Grain Protein (%)	Screenings <2.0 mm (%)	Grain Falling Number (sec)
Wheat	Ballista ⓟ	0.836 b	35.55 a	75.97	12.37	15.70 a	1.52	92.67
	Denison ⓟ	0.531 a	38.86 b	73.94	11.73	18.63 c	1.21	65.33
	RockStar ⓟ	0.748 b	39.66 b	75.86	11.5	16.53 ab	1.10	86.17
	Scepter ⓟ	0.775 b	38.13 b	76.18	11.33	16.97 b	1.45	152.33
	Valiant CL Plus ⓟ	0.542 a	39.85 b	73.88	12.5	19.77 d	1.48	73.50
	Vixen ⓟ	0.905 b	33.58 a	75.58	11.6	15.97 a	0.90	82.83
Site Average		*0.723*	*37.61*	*75.23*	*11.84*	*17.3*	*1.28*	*92.4*
LSD (5%)		*0.1291*	*1.396*	*1.906*	*0.956*	*0.604*	*1.321*	*4.86*
F Prob		*<0.001*	*<0.001*	*0.072 (ns)*	*0.103 (ns)*	*<0.001*	*0.853 (ns)*	*<0.001*

Table 3. A summary of the grain yield and quality including 1000 grain weight, test weight (kg/hL), grain moisture content, grain protein %, retentions and screenings for barley varieties at Penong in 2021. ns = not significant at P<0.05.

Crop	Variety	Yield (t/ha)	Grain Weight (g/1000 seeds)	Test Weight (kg/hL)	Grain Moisture Content (%)	Grain Protein (%)	Retention >2.5 mm (%)	Screenings <2.0 mm (%)
Barley	Beast ⓟ	0.807 bc	36.48 b	64.17	10.27	16.77 abc	78.4 b	1.82 a
	Commodus ⓟ	0.246 a	35.40 b	62.36	10.57	18.50 c	87.4 b	0.86 a
	Compass ⓟ	0.616 b	33.06 ab	62.36	10.27	15.73 ab	90.8 b	0.70a
	Maximus CL ⓟ	0.939 c	28.79 ab	64.87	10.57	15.10 a	81.3 b	1.20 a
	RGT Planet ⓟ	0.128 a	31.29 ab	31.71	10.40	18.83 c	52.9 a	5.58 b
	Spartacus CL Plus ⓟ	0.697 bc	26.3 a	63.75	10.23	17.50 bc	44.8 a	4.43 b
Site Average		*0.572*	*31.89*	*63.79*	*10.38*	*17.07*	*72.6*	*2.43*
LSD (5%)		*0.177*	*5.667*	*1.45*	*0.762*	*1.421*	*9.02*	*1.36*
F Prob		*<0.001*	*0.022*	*0.081 (ns)*	*0.817 (ns)*	*0.002*	*<0.001*	*<0.001*

A rain event prior to grain harvest can cause germination (sprouting) issues. Once germination begins, a decrease in starch will occur in the grain due to an increase in alpha-amylase activity. This decrease in starch can lead to poor quality flour. The falling number measurement assesses this change in grain starch caused by alpha-amylase activity. A low falling number indicates high alpha-amylase activity, whereas a falling number of 300 seconds or more indicates low alpha-amylase activity. All wheat varieties had low falling numbers, below 153 seconds, indicating all were strongly affected by sprouting (Table 2). This sprouting was also observed visually on the grain. Scepter had visible sprouting, but this was less than all other varieties (Table 2) with Denison having a poor falling number of 65.3 seconds.

For barley quality, Beast (36.48 g/1000 seed) and Commodus (35.40 g/1000 seed) had significantly larger 1000 grain weights than Spartacus CL Plus (26.3 g/1000 seed) (Table 3). Grain protein % was on average 17.0% for barley with Maximus (15.1%) having low values compared to Commodus (18.5%) and RGT Planet (18.8%) which recorded the highest values (Table 3). Grain retention and screening % showed that RGT Planet and Spartacus CL Plus had significantly lower retention and higher screenings compared to all other barley varieties (Table 3). No difference in test weight or grain moisture content was observed between barley varieties (Table 3).

What does this mean?

- Slow maturating wheat and barley varieties yielded less compared to other varieties at Penong in 2021.
- There was significant sprouting of wheat grain. If using retained seed in 2022, we advise growers to check germination of seed and adjust seeding rates accordingly due to rain damage causing sprouting of harvested grain.
- Findings are based on one year and subsequent years are required to evaluate consistency of results across multiple growing seasons.

Acknowledgements

We wish to acknowledge and thank the local grower Cade Drummond for his input into this trial and providing access to land. We greatly appreciate and thank the contribution of Australian Grain Technologies (AGT) for conducting the falling testing number of all lines for this study. We also thank Sue Budarick and casual staff at the Minnipa Agricultural Centre. The trials were completed with funding from the SARDI Agronomy program. The GRDC is also acknowledged for the soil test results through the NVT.

Minnipa NVT trial site, 2021.

THE UNIVERSITY of ADELAIDE

Government of South Australia
Department of Primary Industries and Regions

SARDI
SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE

Oaten Hay Agronomy - Wimmera 2021

Alison Frischke and Genevieve Clarke
Birchip Cropping Group (BCG)

Location
Wallup, upper Wimmera
McCrae family
Rainfall
Av. Annual: 370 mm (Nov-Oct)
Av. GSR: 245 mm
2021 Total: 256 mm (Nov-Oct)
2021 GSR: 198 mm
Paddock history
2020: Chickpeas
Soil type
Clay
Soil test
pH: 0-10 cm: 7.8, >10 cm: 8.3-9.3
Deep N (0-100 cm): 71 kg N/ha
PAW at sowing: 56 mm
Plot size
5 m x 6 rows x 3 reps
Trial design
Split Plot
Yield limiting factors
Dry start

Key messages

- **Hay yield was highest for longer season varieties Vasse and Wintaroo in response to above average spring rainfall in the Wimmera in 2021.**
- **Delaying sowing from 30 April to 11 June had no effect on hay yield, due to the dry autumn delaying emergence.**
- **Across nine varieties, hay yield increased by 0.3 t/ha as nitrogen rate increased from 30 to 60 kg N/ha but yielded the same at 90 kg N/ha. There was no variety response to nitrogen.**
- **Comparing increasing nitrogen rates up to 150 kg N/ha for Mulgara, Wintaroo and Yallara, yields plateaued at 90 kg N/ha.**
- **Height was influenced by variety, and N rate for some varieties. Variety affected greenness, as did N rate but was not variety specific. Stem diameter responded to variety and time of sowing for some varieties.**

Why do the trial?

The aim of the trial was to evaluate hay yield and quality of oat varieties at different times of sowing and under different nitrogen (N) nutrition strategies.

Hay exporters take a subjective and objective approach to determining hay quality. Each exporter has a different set of quality parameters and use different testing standards depending on the international market destination and feed type (hay or pellets). Visual indicators are used in the paddock, such as hay colour, stem thickness, texture, and smell. Feed testing is used to measure levels of metabolisable energy, water soluble carbohydrates (WSC), protein, fibre (NDF and ADF) and digestibility. These are combined to determine palatability, animal intake and performance. Generally, exporters are seeking thin stemmed, soft textured hay, with high WSC and low in fibre (require NDF≤50-57% and ADF≤27-35%).

The National Hay Agronomy project is a four-year investment by the AgriFutures Export Fodder Program led by DPIRD with, Agriculture Victoria, NSW DPI and SARDI and grower groups including BCG and Hart. The project, now in its third and final season, aims to improve the understanding of how agronomic practices affect export oaten hay yield and quality.

From the national research, guidelines will be developed to help growers better manage oaten hay crops to meet export market specifications for a competitive advantage in our export fodder markets. Here initial results from 2021 are presented.

How was it done?

A replicated field trial was sown with a split plot trial design at Wallup in the upper Wimmera of Victoria. Target plant density was 320 plants/m^2. Treatments from the 2019 Oaten Hay Agronomy trial were repeated for the third time, except for the variety Forester (very slow maturity) which was replaced for Vasse in 2020; a mid-slow variety more suited to the Wimmera. Treatments are outlined in Table 1.

The trial was sown with knife points + splitter boot (70 mm split) and press wheels at 30 cm row spacing.

Seed was treated with EverGol® @ 260 mL/100kg and Gaucho® @ 240 mL/100kg. All treatments received Granulock® Supreme Z + Flutriafol (200 mL/100kg) @ 60 kg/ha, plus additional N applied as urea to make treatment rate targets (Table 1). The trial was managed as per best practice for herbicides, insecticides, and fungicides.

Table 1. Treatment outline: Oat varieties, time of sowing and N rate, Wallup 2021.

Variety	Variety Characteristics			Time of Sowing	N rate** (kg N/ha)
	End Use	Height	Maturity		
Brusher	Hay/grazing/feed grain	Tall	Quick	(30 April)* 27 May 2020 - TOS1 11 June 2020 - TOS2	10*** 30 60 90 120*** 150***
Carrolup	Milling/hay	Mod tall	Quick		
Durack	Milling/hay	Mod tall	Very quick		
Koorabup	Hay	Mod tall	Mid-quick		
Mulgara	Hay/feed	Tall	Quick		
Vasse	Hay	Mod tall	Mid-slow		
Williams	Milling/hay	Short-tall	Quick		
Wintaroo	Hay/grazing	Tall	Mid		
Yallara	Milling/hay	Mod tall	Quick		

** Treatment sown 30 April, emerged 27 May due to dry sowing conditions*
*** Nitrogen applied as two thirds at sowing and one third at 6 weeks post sowing*
**** Mulgara, Wintaroo and Yallara only*

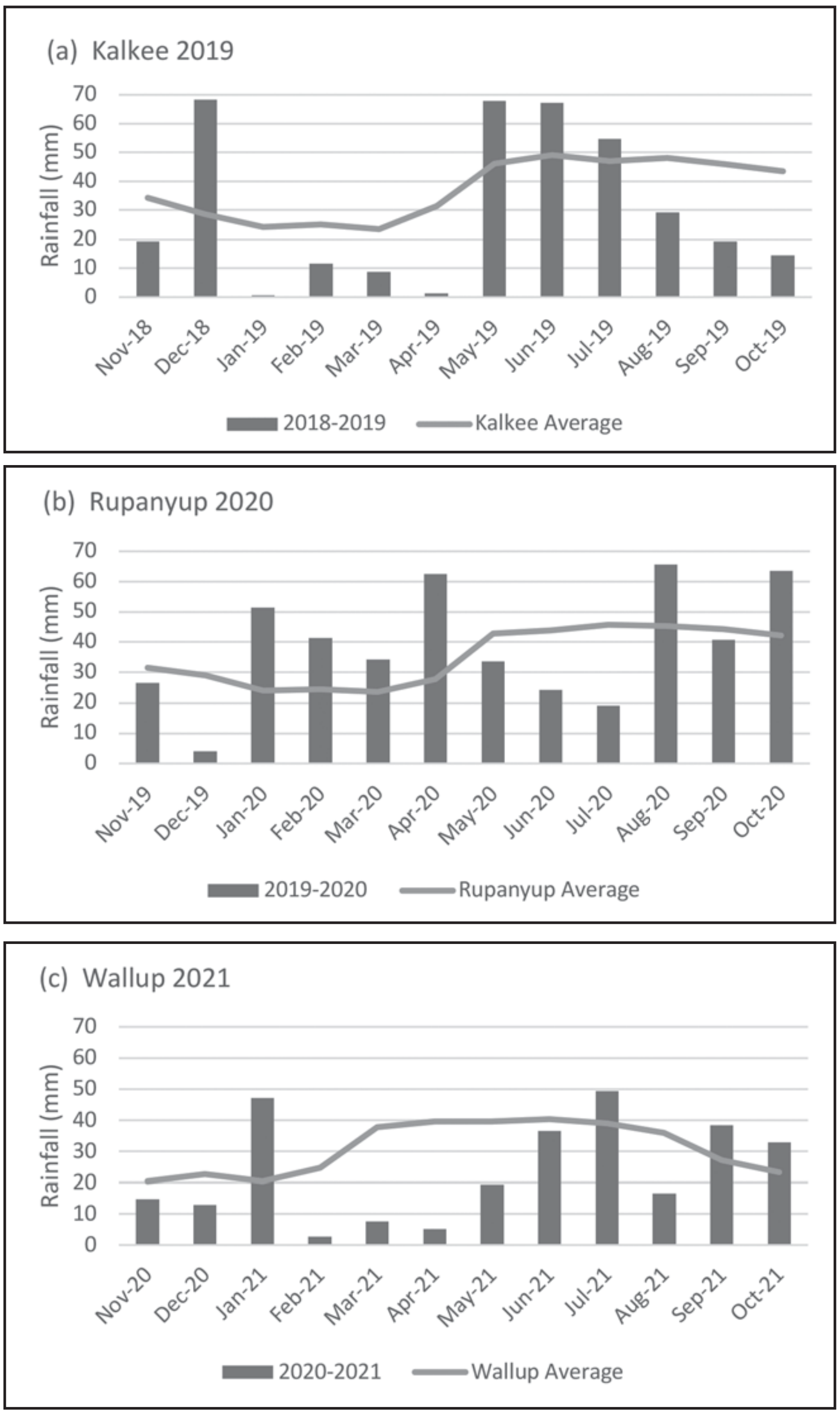

Figure 1. Long term average rainfall and growing season rainfall, Oaten Hay Agronomy sites at (a) Kalkee 2019, (b) Rupanyup 2020 and (c) Wallup 2021.

Assessments included soil analysis and moisture, plant establishment, NDVI, hay biomass at GS71, plant height, lodging, leaf greenness (SPAD chlorophyll measure) and stem diameter. Data was analysed using Genstat® 21st edition. NIR (including DairyOne calibration) was being analysed at the time of writing and will be reported once national results have been collated.

What happened?

Measured in March, plant available water was 56 mm and soil N to 1 m was 71 kg N/ha.

Across 2019 to 2021, combinations of autumn, winter and spring conditions varied for the Oaten Hay Agronomy trials at Kalkee, Rupanyup and Wallup (Figure 1) affecting responses by varieties to time of sowing and N rate between years.

See 2019 and 2020 BCG Season Research Results for previous results.

In 2021, most of autumn was dry at Wallup (Figure 1(c)). The first time of sowing (TOS 1) was dry sown on 30 April. A rain event of 6.6 mm fell on 10 May, but the next rain of 10.4 mm was not until 25 May, pushing emergence of TOS 1 out to 27 May. The second time of sowing (TOS 2) was sown on 11 June, separating sowing dates but keeping the later oaten hay sowing date practical. TOS 2 plots emerged between 7-10 days later, separating emergence dates between treatments by 3-3.5 weeks.

After the dry, slow start, crops established well and received regular winter rainfall until mid-August. The crop then finished with plentiful September rain, continuing into October when plots were cut for hay.

Hay yield and quality parameters were generally influenced by variety selection and rate of applied nitrogen, but not time of sowing. There was no three-way interaction between the factors, but there was a two-way interaction between time of sowing and variety. Across the trial, hay yields averaged 6.8 t/ha.

Time of sowing

Across all varieties, time of sowing had no effect on hay yield in 2021, despite 6 weeks between sowing dates, and 3-3.5 weeks between emergence. Soil temperatures had begun to decline, and while crops emerged evenly, they lacked early vigour during June and into July as they struggled to establish roots and biomass.

On average, highest hay yielding varieties were Vasse and Wintaroo (7.9 t/ha), closely followed by Mulgara (7.2 t/ha) ($P<0.001$).

A significant interaction between sowing date and variety occurred for three oat varieties ($P<0.001$). Mid-slow Vasse and mid-quick Durack benefited from earlier sowing and capitalised on the mild spring, with TOS 1 outyielding TOS 2 by 1.6 t/ha and 1.1 t/ha respectively. It is likely that the TOS 2 date was too late for the faster-maturing variety to capitalise on the mild spring. Mid-quick Koorabup on the other hand yielded 1.7 t/ha higher when sown later. All other varieties yielded similarly at both times of sowing.

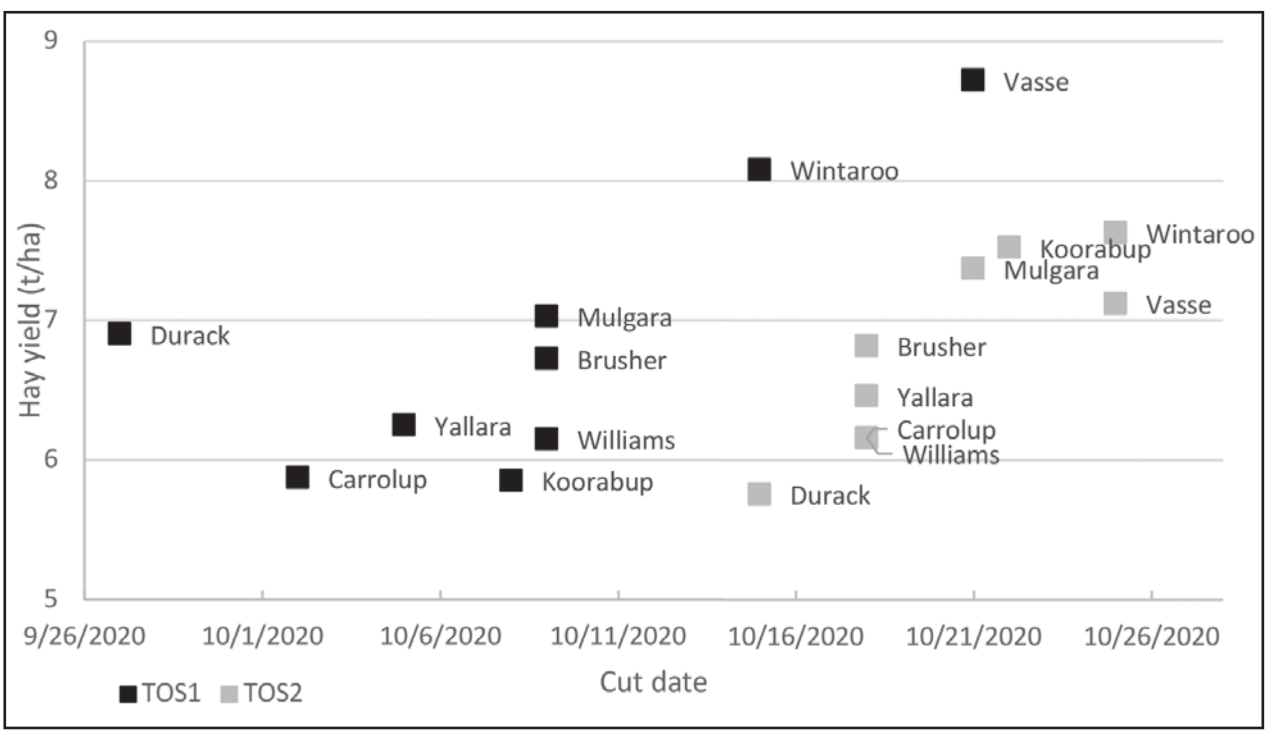

Figure 2. Oaten hay yield response to time of sowing with corresponding cut date, Wallup 2021. Stats TOS x Variety: P<0.001, LSD=0.55 t/ha, CV=7.2%.

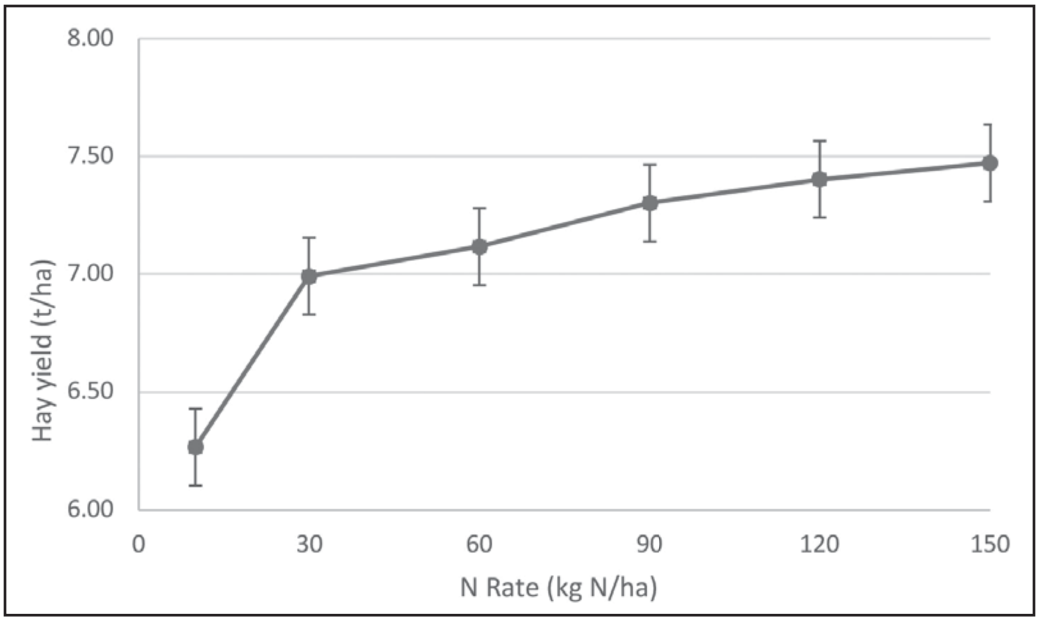

Figure 3. Oaten hay yield response to N rate across varieties, Wallup 2021. Stats: P<0.001, LSD=0.33 t/ha, CV=6.9%.

Table 2. Stem diameter of oaten hay varieties at two times of sowing, Wallup 2021.

TOS	Oaten hay variety								
	Brusher	**Carrolup**	**Durack**	**Koorabup**	**Mulgara**	**Vasse**	**Williams**	**Wintaroo**	**Yallara**
1	4.5 abc	4.4 bcd	4.9 a	3.8 e	4.7 abc	4.5 abc	4.6 abc	4.9 ab	4.3 bcde
2	4.4 bcd	4.2 cde	3.9 de	4.6 abc	4.6 abc	4.5 abc	4.4 abc	4.8 ab	4.4 bcd
Sig. diff.	*P=0.009*								
LSD(P=0.05)	*0.3 mm*								
CV%	*11.9*								

For each time of sowing, the shortest season variety, mid-quick Durack was first to reach GS71, and longest season varieties; mid-maturing Wintaroo and mid-slow Vasse, were last to be cut for hay.

Nitrogen response

Across the nine varieties, hay yield increased by 0.26 t/ha as N rate increased from 30 to 60 N, but there was no further response to 90 N (P<0.001). The response to N rate did not differ between varieties.

There was a weak negative response (P=0.094) between TOS and N rate, but only for the TOS 2 30N treatment which yielded less (0.46 t/ha) than other TOS and N combinations.

For varieties Mulgara, Wintaroo and Yallara that received six rates of N up to 150 kg N/ha, again there was a general overall response to N rate (P<0.001), but there was no difference between varieties. Hay yields increased to 90 N, then plateaued at higher rates (Figure 3).

Across the six N rates for Mulgara, Wintaroo and Yallara, there were no time of sowing and nitrogen rate interactions.

Hay quality

Plant height

Plant height averaged 76 cm and was influenced by variety (P<0.001) and N rate (P<0.001), but not TOS.

Wintaroo was tallest at 89 cm, followed by Brusher and Mulgara at 84 cm and 83 cm respectively (P<0.001). Again, while yielding highest, on average Vasse was one of the shortest varieties at 69 cm, with Durack 70 cm and Williams at 68 cm. While TOS did not affect height on average across varieties, later TOS 2 reduced already shorter Vasse plant height from 72 cm to 67 cm (P=0.001).

Across varieties, increasing N rate from 30-60 N to 90 N increased plant height by 2 cm from 75 cm to 77 cm (P<0.001). By increasing N rate from 30 to 60 N Vasse increased height by 5 cm to 71 cm but height did not increase further when N was raised to 90 kg N/ha (P=0.003). Height increased for other varieties Brusher, Carrolup and Mulgara when N rate was raised from 60 to 90 kg N/ha by 6 cm, 3 cm and 3 cm respectively. N rate did not affect plant height for other varieties.

Lodging

No hay crops lodged in 2021.

Leaf greenness (SPAD chlorophyll measure)

Colour measurements or greenness of hay (SPAD) is a desired quality trait, indicating plant health and conditions for hay during curing and baling. SPAD averaged 50 units. SPAD was affected by variety (P=0.001) and N rate (P<0.001) but was not affected by TOS across varieties.

Highest SPAD readings measured 50-52 for Mulgara, Brusher, Durack, Williams and Wintaroo, while Vasse measured lowest at 48; a contrast to the 2020 season when longer season Vasse was one of the greenest. TOS did affect variety SPAD (P=0.038) but only for Mulgara, which increased greenness by 4 units when later sown in July.

Increasing N rate from 30 to 60 to 90 increased SPAD from 47, to 51 and 52 respectively, but there was no SPAD response interaction between N rate with variety or TOS.

Stem thickness

Thinner stems (<6 mm) with lower fibre and higher water-soluble carbohydrates make better quality hay. Stem diameter for all treatments met this quality target (Table 2), averaging 4.5 mm, ranging from 3.8-5.1 mm, driven by the high target plant density of 320 plants/m^2 (sowing rates ranged from 159 to 197 kg/ha).

Stem diameter responded to TOS by variety (P=0.009). Durack responded strongest to later sowing with reduced stem thickness by 1.0 mm, whereas Koorabup increased stem thickness by 0.8 mm (Table 2). Durack TOS 2 and both TOS for Wintaroo had the thickest stems but were well under 6 mm. There were no differences in stem diameter between sowing times for other varieties.

Although Vasse was below the industry standard of 6 mm, Vasse is not preferred by hay processors as the stems can be too thick when attention to seeding density is not taken.

Stem thickness did not respond to nitrogen rate in 2021.

What does this mean?

For the third season, the trial site received below average rainfall across the growing season. However, like in previous seasons, rainfall exceeded the average for particular months; in 2021 those months were July and September, during plant growth stages that would have set tillers and finished biomass.

Three different seasons in the Wimmera (Kalkee and Rupanyup) with rainfall patterns have produced different oaten hay yield and quality responses to agronomy treatments.

- In 2019, a drier spring meant that crops sown earlier yielded higher, faster varieties generally did better and crop yields were optimised at a lower nitrogen rate of 60 kg/ha.
- 2020 had a favourable start and finish but dry winter, delaying sowing until the end of May grew more hay, longer season varieties Vasse and Wintaroo performed better, and yields were optimised by higher N at 90 kg/ha.
- In 2021, a very dry autumn meant time of sowing had less effect, but good spring rain meant that again longer season varieties Vasse and Wintaroo performed best, and yields responded to increasing N rates to 90 kg/ha.

The challenge is to make sowing decisions with regard to the season forecast that will favour hay production, and then for that forecast to happen. Over the past three seasons, the spring forecast has eventuated, although nerves have been tested along the way. Time of sowing and variety decisions must be made at sowing, and N rate should be decided and applied by GS25 (tillering) to GS31 (stem elongation): about six weeks after sowing.

Production and NIR quality results from similar trials nationally will be collated to produce guidelines for agronomy to optimise hay quality in different seasons and regions across Australia.

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Frischke A., Clarke G. and Troup G., 2021, 2020 BCG Season Research Results, 'Oaten Hay Agronomy - Wimmera' p. 177-184. https://www.bcg.org.au/oaten-hay-agronomy-wimmera/

Acknowledgements

This research is part of the 'National Hay Agronomy project', funded by the AgriFutures™ Export Fodder Program. It is a national collaboration between DPIRD, SARDI, Agriculture Victoria, NSW DPI and grower groups including BCG and Hart.

BCG SHARED SOLUTIONS

Utilising novel genetic diversity to increase barley yields nationally

Anh-Tung Pham, Julian Taylor and Jason Able
University of Adelaide

Location
Roseworthy (RAC)
John Mathieson
Sowing date: 15 May 2020
Harvest date: 25 Nov 2020
Fertiliser:
DAP + 2%Zn (18% Kg/ha N)
Rainfall
2020 Total: 337 mm
2020 GSR: 232 mm
Yield
5.43 t/ha
Soil type
Calcareous loam
Plot size
1.3 m x 5.5 m x 4 reps
Trial design
Randomised complete block
Yield limiting factors
Barley leaf rust: mild-moderately

Location
Tarlee
Tony Clarke
Sowing date: 7 May 2020
Harvest date: 16 Nov 2020
Fertiliser:
DAP + 2%Zn (18% Kg/ha N)
Rainfall
2020 Total: 426 mm
2020 GSR: 279 mm
Yield
6.44 t/ha
Soil type
Calcareous loam
Trial design
Randomised complete block
Plot size
1.3 m x 5.5 m x 4 reps

Key messages

- **Wild barley can provide useful sources of genes to improve yield in Australian barley.**
- **Fourteen lines with genomic regions transferred from wild barley that were associated with either greater drought tolerance or higher grain weight and grain number yielded at least 5% higher than their Australian parents at one or more sites.**
- **Higher yields were associated with more grain per ear and/or thousand grain weight in 10 lines.**
- **Selection using these genomicregionsmayimprove barley yield and grain size and lead to the development of germplasm specifically tailored for Australia's variableenvironment.**

Why do the trial?

A previous GRDC-funded project (UA00148) identified genomic regions in wild barley that were associated with increased biomass, grain number per ear (5-9 grain/ear) and thousand grain weight (up to 13%) under drought in controlled conditions. Eight beneficial genomic regions were incorporated into Compass, LaTrobe, and GrangeR via backcrossing using molecular markers tightly associated with the traits to develop lines yielding higher than the recurrent parents (Compass, LaTrobe, and GrangeR). Field trials were conducted to examine whether the wild barley genes improve the yield in lines with an Australian genetic background, and if there are any unwanted traits associated with them.

The project aims are:

- Field validation of the effect of beneficial genomic regions from the wild barley (in terms of yield and drought tolerance) identified from the GRDC-funded project UA00148 in Australian genetic backgrounds.
- To develop a package of superior germplasm with the genomic regions from the wild barley conditioning enhanced drought tolerance and higher yield than the current best varieties (Compass, LaTrobe, GrangeR, RGT Planet).

How was it done?

In 2020 a set of 119 lines were selected (11 control varieties and 108 experimental lines). The 108 experimental lines consisted of crosses between wild barley derivatives and three Australian varieties: 50 lines were derived from a cross with Compass, 33 lines from a cross with GrangeR, and 25 lines from a cross with LaTrobe. All lines were genotyped to confirm they carried at least each of the eight regions of interest from wild barley. The three chosen sites in 2020 included Bordertown, Roseworthy Agricultural College (RAC), and Tarlee, South Australia.

Location
Bordertown
Ted Ridgeway
Sowing date:
20 May 2020
Harvest date:
1 Dec 2020
Fertiliser:
DAP + 2%Zn (18% Kg/ha N)
Rainfall
2020 Total: 484 mm
2020 GSR: 315 mm
Yield
6.27 t/ha
Soil type
Brown and grey cracking clay
Plot size
1.3 m x 5.5 m x 4 reps
Yield limiting factors
Frost and snail (mild)

The experimental design was a randomised complete block design, with three replicates at each of the three sites. Plot dimensions were 1.3 m x 5.5 m. Eight traits were measured including flowering time (estimated as days from sowing to Zadoks growth stage 49), plant height at maturity (HEI), lodging (LOD), grain number per ear (GPE)), fertile tiller number at harvest (TIN), thousand grain weight (TGW), test weight (TW), harvest index (HI), and final grain yield. Additionally, disease incidence for net form (NFNB), spot form of net blotch (SFNB), and barley leaf rust (BLR) were also recorded.

Statistical analyses were performed with the software Rstudio 1.2.1335. For each trait, the data for each site were analysed using a linear mixed model (LMM) that partitioned and accounted for genetic and non-genetic variation. For each trait, best linear unbiased predictions (BLUPs) were predicted for each of the genotypes at each of the locations.

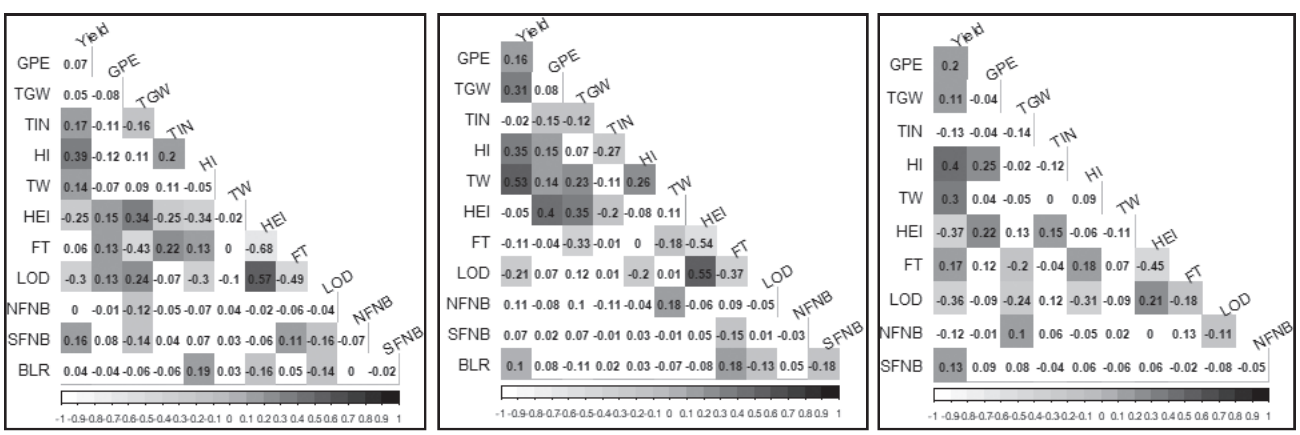
What happened?

1. Overall performance and trait correlation

Overall, Tarlee was the highest yielding site while RAC was the least. Grain yields for Compass at Tarlee, Bordertown, and RAC were 6.44, 6.27, and 5.43 t/ha, respectively. It is noteworthy that both Tarlee and Bordertown had higher total rainfall compared to RAC, and Bordertown was in general a little cooler than RAC and Tarlee.

With respect to trait correlation, overall, yield was positively correlated to GPE, TGW, test weight (TW), harvest index (HI) and negatively correlated to plant height and lodging (Figure 1). Yield correlated with HI and TW at Tarlee and Bordertown, and with TW at RAC. The correlation coefficients of grain yield with TIN is not significant at RAC and Bordertown, and while significant at Tarlee, it was of small magnitude. The correlations of GPE and TGW with grain yield is positive at three sites, but they were only significant at RAC and Bordertown. TIN negatively correlated with both GPE and TGW, and there was no correlation between GPE and TGW. Flowering time negatively correlated with TGW and plant height at all three sites.

The correlations of net form net blotch scores with the remainder of the traits was either not significant or significant but very low. In contrast, spot form net blotch and barley leaf rust positively correlated with grain yield though the correlation coefficient were small and only found at one testing site. It should be noted that during 2020, the incidence of all three scored diseases was mild. Lodging, as expected, strongly and positively correlated with plant height and negatively correlated with harvest index and flowering time.



Tarlee ***RAC*** ***Bordertown***

Figure 1. Correlation matrix of important traits measured in the 2020 trials at three sites. Shades underlying numbers indicate a significant correlation, and the intensity of grey correlated to the magnitude of the correlation coefficients. Numbers in white background indicate nonsignificant correlations at level of P= 0.05. GPE=grain number per ear, TGW=thousand-grain weight, TIN=fertile tiller number, HI=harvest index, TW=test weight, HEI=plant height at maturity, FT=flowering time, Net form net blotch=NFNB, spot form of net blotch=SFNB, and barley leaf rust =BLR, LOD=lodging.

2. Lines that have greater than 5% improvement in grain yield (relative performance >5%) than the backcrossing parents

At Bordertown and RAC, there were lines whose yields were not statistically different from Planet, the control variety with the highest yield, during 2020. At Tarlee, Planet's yield was statistically higher than all of the other lines. Across the three sites, 14 lines produced yields greater than 5 % compared to the corresponding backcrossing parents at one or more sites (Figure 2). There were 10 lines that yielded at least 5% higher than their Australian parent at one site – four at Tarlee, three each at Roseworthy and Bordertown. A smaller number of lines yielded 5% more than their parents at two sites: two lines (Anh_27 and Anh_119) at Bordertown and Tarlee and Anh_93 and Anh_94 at RAC and Tarlee.

Four lines, Anh_143, Anh_145, Anh_63, and Anh_174 performed very well at RAC, an environment with the least amount of rainfall in 2020 across all three sites evaluated. Another line, Anh_125, showed yield improvement at Bordertown and RAC, which were the two environments with the most and the least rainfall, respectively. This genotype, Anh_125, also had the most stable yield across the three sites. Two other lines, Anh_93 and Anh_94, had yield improvement of more than 5% at two locations (RAC and Tarlee).

To uncover the mechanism underlying the significant increase in yield in these 14 lines, the difference in 11 traits of these 14 lines compared to their corresponding parents was calculated. It shows that the high yield in Anh_69, Anh_93, and Anh_94 was the result of increased TGW or test weight. Line Anh_174 flowered much later than LaTrobe, with the range from 14-19 days, and also had elevated TGW compared to LaTrobe. Line Anh_13 also flowered approximated 6 days later than Compass at all three locations and it too tended to have higher test weight and tiller number, although this was quite site-specific. Anh_27 and Anh_63 were late in flowering and had higher GPE (at three sites) compared to Compass. The high yield of Anh_125 at RAC and Bordertown was likely due to an increase in GPE and TGW. Anh_38 and Anh_119 only showed a small delay in flowering compared to their backcrossing parents. There was no significant difference in 11 measured traits for Anh_37, Anh_102, Anh_143, and Anh_145.

3. The effect of genomic regions from wild barley that improved GPE and TGW

Among four genomic regions from wild barleys that enhanced GPE, only one genomic region on chromosome 4H showed to have a strong and consistent effect. Eleven experimental lines were carrying this genomic region and eight showed a GPE improvement effect including Anh_20, Anh_24, Anh_26, Anh_27, Anh_28, Anh_29, Anh_159, and Anh_163. Line Anh_28 showed a GPE improvement effect at all three locations. Among these 11 lines, only Anh_27 exhibited a yield improvement effect but was only found at Bordertown and Tarlee which were two sites where a GPE improvement effect was also found (Figure 3).

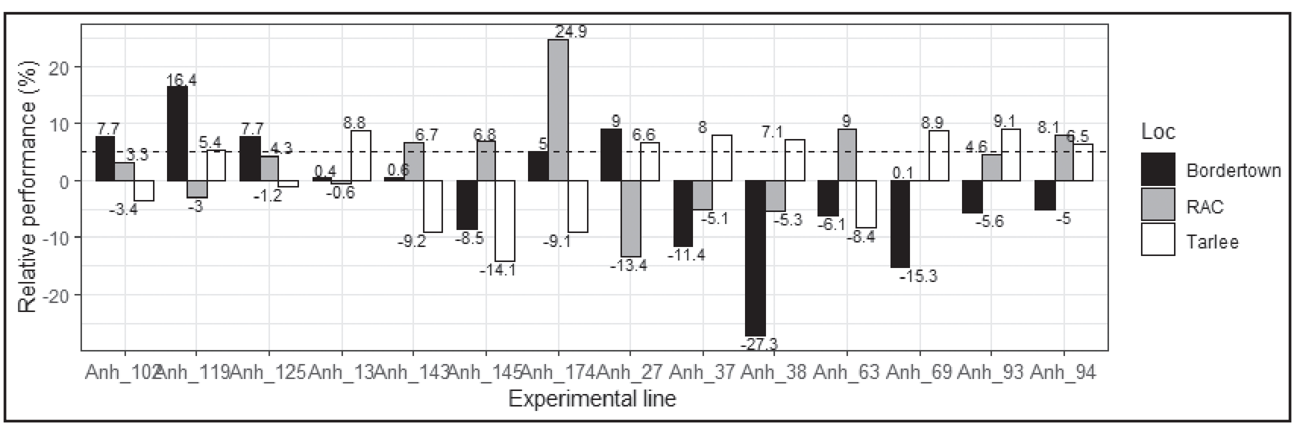


Figure 2. Relative performance of 14 lines with yield higher than 5% compared to the backcrossing parents.

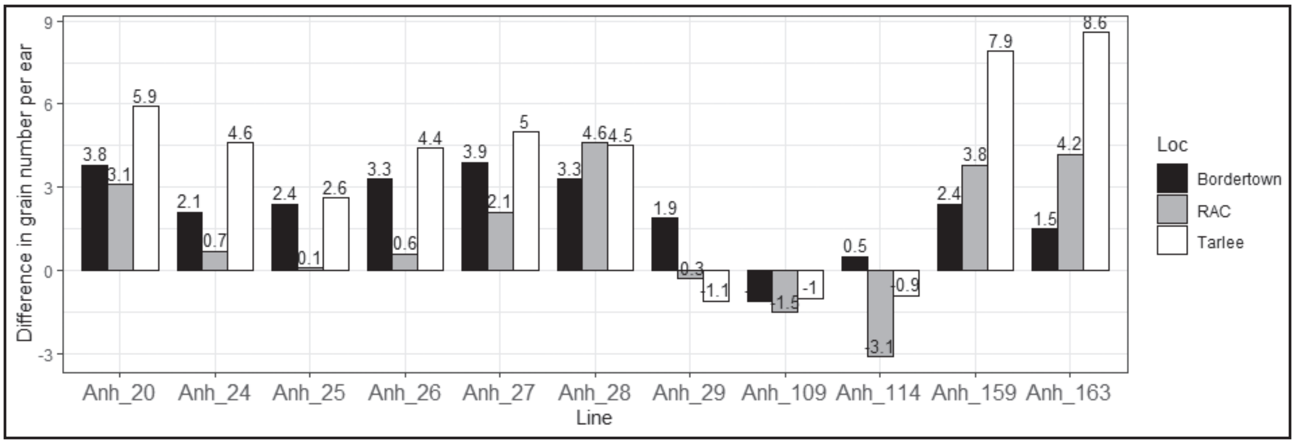


Figure. 3. The difference in grain number per ear (GPE) of lines with GPE-improving genomic region from the wild barley on chromosome 4H and their backcrossing parents at three locations.

There are two genomic regions associated with high TGW. Among 10 lines carrying the region on chromosome 2H, none of them had TGW or test weight higher than those of the corresponding parents although two lines Anh_37 and Anh_38 had a 7% higher yield than Compass at Tarlee (Fig. 2). Among nine lines carrying the region on chromosome 5H, there is one line, Anh_125, which had TGW and test weight higher than GrangeR at all three locations. This line yielded 4.3% and 7.7% higher than GrangeR at RAC and Bordertown, respectively. Its yield was similar to GrangeR at Tarlee, so the yield improvement characteristic in this line was environment-specific although the TGW improvement effect was stable across three environments.

Additionally, line Anh_69 and Anh_129 are two lines that have TGW higher than Fathom, the commercial variety with the highest TGW, at all three locations. At RAC and Tarlee, Anh_69 and Anh_129 had the highest TGW, which was approximately 7% and 5.3% higher than Fathom. The TGW of these two lines were approximately 8% and 11% higher than Compass and GrangeR, respectively, at both RAC and Tarlee. Interestingly, both Anh_69 and Anh_129 have the two genomic regions on chromosome 3H that increased biomass and GPE. However, there are lines that have the exact genetic combination similar to these two lines including Anh_74 (Compass genetic background) and Anh_130 (GrangeR genetic background) but did not show any TGW improvement effect. Altogether, these data suggest that the two regions on chromosome 3H may have a role in the improvement of TGW, but there are other gene(s) that are currently unknown in the background of Anh_69 and Anh_129 that assisted an improved TGW being recorded.

What does this mean?

- 14 barley lines with greater than 5% improvement in yield compared to the three backcrossing parents were identified, however, they are quite environment-specific.
- Lines with significantly higher thousand-grain weight and grain number per ear than all of the commercial varieties were also identified.
- Genomic regions from wild barley have a role in the improvement of traits like yield, thousand-grain weight and grain number per ear, but they must be put in a suitable background to show an effect.

Acknowledgements

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SARDI, Minnipa Agricultural Centre

Section
6

Weeds

Demonstrating integrated weed management strategies to control barley grass in low rainfall zone farming systems

Amanda Cook[1,2], Gurjeet Gill[2], Ian Richter[1], Craig Standley[1], John Kelsh[1] and Wade Shepperd[1]

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Location
Minnipa Agricultural Centre, S3
Rainfall
Av. Annual: 324 mm
Av. GSR: 241 mm
2021 Total: 406 mm
2021 GSR: 248 mm
Soil type
Red sandy loam
Paddock history
2021: Implemented broadacre trial and Wheat.
2020: Implemented broadacre trial and Canola.
2019: Implemented broadacre trial and Compass barley.
2018: Scepter wheat
2017: Volga vetch
Plot size
27 m x 620 m x 3 replicates (3 paddock seeder strips (27 m each) wide)

Key messages

- **The traditional management of pasture systems results in an increase in barley grass weed set.**
- **In 2019 the use of propyzamide in pasture and a desiccated late hay freeze reduced the barley grass weed seed set by 75%.**
- **TT canola systems with simazine reduced barley grass weed seed set.**
- **IMI chemistry worked well in the year of application (2019) but barley grass weed seed set still increased in the sown pasture system in the following season.**
- **There is seasonal variation with the number of seeds set per panicle in a season, with 2020 having a high weed seed set.**
- **Despite getting good control in one season barley grass still has the ability to germinate from the weed seed bank the following season and set high weed seed numbers.**
- **There was no single year elimination strategy identified to control barley grass numbers and weed seed set over the three seasons, which means barley grass management and lowering weed seed set needs to be a focus in all seasons in low rainfall farming systems.**

Why do the trial?

Barley grass possesses several biological traits that make it difficult for growers to manage it in the low rainfall zone, so it is not surprising that it is becoming more prevalent in field crops in SA and WA. A survey by Llewellyn *et al*. (2015) showed that barley grass has now made its way into the top 10 weeds of Australian cropping in terms of area infested, crop yield loss and revenue loss.

The biological traits that make barley grass difficult for growers to manage in low rainfall zones include:

- early onset of seed production, which reduces effectiveness of crop-topping or spray-topping in pastures;
- shedding seeds well before crop harvest, reducing harvest weed seed control effectiveness compared to weeds such as ryegrass which has a much higher seed retention;
- increased seed dormancy, reducing weed control from knockdown herbicides due to delayed emergence

Table 1. The five different management strategies, crops and herbicide treatments for each season (2019-2021) at Minnipa Agricultural Centre, paddock S3.

Treatment	1	2	3	4	5
Rotation Strategy	**District Practice**	**IMI**	**High cost chemical**	**Two year break**	**Cultural**
YEAR 1- 2019	**Compass Barley** 17 May - 68 kg/ha with GranulockZ 65 kg/ha 17 May -1.2 L/ha Glyphosate, 1.5 L/ha Trifluralin, 400 gm/ha Diuron	**CL Scope Barley** 17 May - 68 kg/ha with GranulockZ 65 kg/ha 17 May - 1.2 L/ha Glyphosate, 1.5 L/ha Trifluralin, 400 gm/ha Diuron 16 July - 700 ml/ha Intervix	**Compass Barley for haycut** 17 May - High seeding rate at 95 kg/ha with GranulockZ 65 kg/ha Hay cut on 26 Sept 17 May - 1.2 L/ha Glyphosate, 1.5 L/ha Trifluralin, 400 gm/ha Diuron 3 Sept - Hay freeze 1.8 L/ha Weedmaster DST (Glyphosate)	**Self-Regenerating Grass Free Pasture** 17 May - Propyzamide 1 L/ha 15 mm rainfall after but grass weeds had germinated 2 July Double hit grasses- 190 ml/ha quizalofop Targa Bolt (GpA), Broadstrike (Gp B -SU) 25 gm/ha and Clethodim (Gp A) 250 ml/ha. 3/9/2019 Paraquat 1.2 L/ha	**Compass Barley** 17 May - Double seeding rate (60 kg/ha spread then 60 kg/ ha sown) with GranulockZ 65 kg/ha 17 May - 1.2 L/ha Glyphosate HWS - Chaff lines and burnt
YEAR 2- 2020 All paddock 25 March 1.5 L/ha Glyphosate, 0.45 L/ha 2,4-D LV Ester 680, 50 ml/ha Hammer and 100 ml/ ha LI700	**Self-Regenerating Grass Free Medic Pasture** 3 June - 330 ml/ha Clethodim 4 Sept - Karate Zeon 36 ml/ha (insecticide)	**Sultan Sown Medic** 26 April - 7 kg/ha 25 May - 25 gm/ha Broadstrike, 0.75 L/ha Hasten. 3 June 330 ml/ha Clethodim, 0.75 L/ha Hasten 4 Sept- Karate Zeon 36 ml/ha (insecticide)	**Scepter Wheat** 12 May - 70 kg/ha with GranulockZ 70 kg/ha 1.5 L/ha Trifluralin and 50 ml/ ha Hammer. 28 August - 1 L/ha 625 Amicide	**Trident TT Canola**, 26 April - 1.8 kg/ha with GranulockZ 80 kg/ha 26 April - 1.5 L/ha Glyphosate, 0.8 L/ha Trifluralin, 800 ml/ha Simazine, 50 ml/ha Hammer. 3 June - 330 ml/ha Clethodim, 0.75 L/ha Hasten 11 June 30 ml/ha Lontrel Advance, 800 gm/ha Atrazine.	**Self-Regenerating Grass Free Medic Pasture** . 3 June - 330 ml/ha Clethodim 4 Sept - Karate Zeon 36 ml/ha (insecticide) 6 Sept - Hay freeze - 1.2 L/ha Paraquat
YEAR 3 - 2021 Scepter wheat seeding rate of 75 kg/ha with GranulockZ 75 kg/ha	**Scepter Wheat** 2 June - 1.2 L/ha Glyphosate, 1.5 L/ha Trifluralin, 400 gm/ha Diuron. 3 August - Saracen 100 ml/ha, and LVE Ester 570 @ 400 ml/ ha, Lontrel Advance 40 ml/ha, Topic 85 ml/ha, Zn, Cu, Mn @ 0.5 kg/ha	**Scepter Wheat** 2 June - 1.2 L/ha Glyphosate, 1.5 L/ha Trifluralin, 400 gm/ha Diuron. 3 August - Saracen 100 ml/ha, and LVE Ester 570 @ 400 ml/ ha, Lontrel Advance 40 ml/ha, Topic 85 ml/ha, Zn, Cu, Mn @ 0.5 kg/ha	**CL Spartacus Barley** 10 June - 1.2 L/ha Glyphosate, 1.5 L/ha Trifluralin, 400 gm/ha Diuron. 6 August - 700 ml/ha Intervix and LVE Ester 570 @ 400 ml/ ha, Zn, Cu, Mn @ 0.5 kg/ha	**Scepter Wheat** 2 June - 1.2 L/ha Glyphosate, 1.5 L/ha Trifluralin, 118 gm/ha Sakura. 3 August - Saracen 100 ml/ha, and LVE Ester 570 @ 400 ml/ ha, Lontrel Advance 40 ml/ha, Topic 85 ml/ha, Zn, Cu, Mn @ 0.5 kg/ha	**Scepter Wheat - no row spacing (double sown)** 2 June - 1.2 L/ha Glyphosate, 1.5 L/ha Trifluralin, 400 gm/ha Diuron. 3 August - Saracen 100 ml/ha, and LVE Ester 570 @ 400 ml/ ha, Lontrel Advance 40 ml/ha, Topic 85 ml/ha, Zn, Cu, Mn @ 0.5 kg/ha

- increasing herbicide resistance, especially to Group 1/A herbicides, used to control grass weeds in pasture phase and legume crops.

Barley grass management is likely to be more challenging in the low rainfall zone because the growing seasons tend to be more variable in terms of rainfall, which can affect the performance of the pre-emergent herbicides. Furthermore, many growers in these areas tend to have lower budgets for management tactics, and break crops are generally perceived as a higher risk rotation strategy than cereals. Therefore, wheat and barley tend to be the dominant crops in the low rainfall zone. This project is undertaking coordinated research with farming systems groups across the Southern and Western cropping regions to demonstrate tactics that can be reliably used to improve the management of barley grass.

How was it done?

In early 2019 a meeting was held with growers, MAC staff and Dr. Gurjeet Gill to discuss the issue of barley grass in upper EP farming systems. A three-year broad acre management plan (2019-21) was developed to be implemented with five different strategies to be tested and compared in a replicated broad acre farm trial on the MAC farm (Table 1).

The management strategies were tested over the three year of rotation with the focus on barley grass weed management and weed seed set. For the previous seasons' trial details refer to 'Demonstrating integrated weed management strategies to control barley grass in low rainfall zone farming systems', EPFSS 2019 Summary p. 175, and EPFSS 2020 Summary p. 171.

The trial was composed of three replicated broad acre strips of three seeder widths (27 m wide) of each treatment in MAC paddock S3. The 2019 - 2021 paddock management is listed in Table 1.

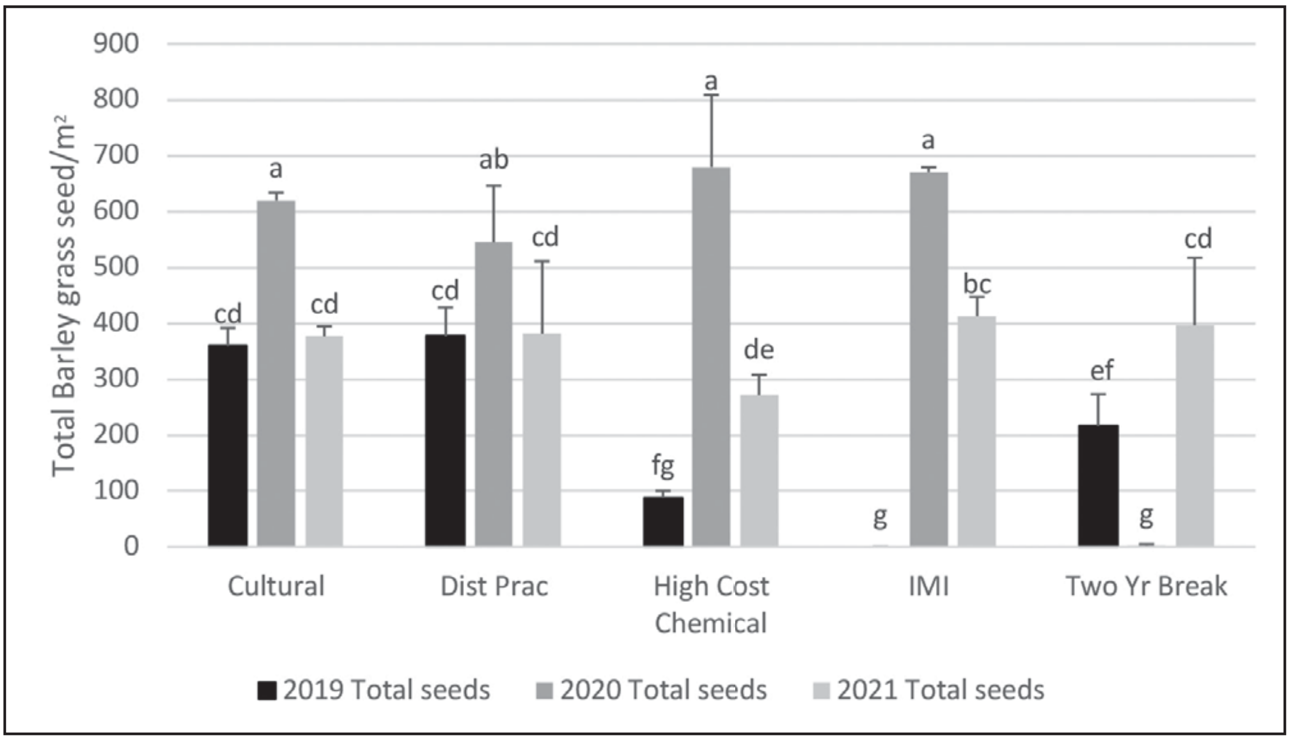

Figure 1. The five different management strategies and total barley grass weed seed set for each season (2019-2021) at Minnipa Agricultural Centre S3, different letters are significantly different LSD=138. Error bars represent standard deviation of the population.

Strategy	2019	2020	2021
Cultural	Double rate Barley (HWSC)	Pasture	Wheat (no row)
District Practice	Barley	Pasture	Wheat
High Cost Chemical	Barley Hay cut	Wheat	Barley
IMI	Barley IMI	Sown Pasture	Wheat
Two Year Break	Pasture (prop)	Canola	Wheat

During 2021 the sampling and timings assessed during the growing season were, pre-sowing barley grass numbers (14 May), crop establishment and early barley grass numbers (6 July), late barley grass number and crop dry matter (26 August), barley grass seed set (12 October), and grain yield (6 December) and quality. Late barley grass samples were taken and panicles sent to Roseworthy for the assessment of barley grass seed set. The 27 m strips were harvested with the plot header (4 times) per treatment on 6 December for wheat and barley, and the grain quality was assessed.

What happened?

In 2019 the IMI system had no barley grass weed seed set at harvest (Figure 1). The Compass barley in 2019 in the District Practice and Cultural Control systems produced similar barley grass weed seed set. The desiccated Compass barley hay cut sown at a higher seeding rate of 95 kg/ha reduced the overall barley grass weed seed set to 88 seeds/m^2 (Figure 1). The Two Year Break self-regenerating pasture system had the higher barley grass numbers during the 2019 season, but the late paraquat application in early September in the pasture phase lowered weed seed set to 216 seeds/m^2 (Figure 1).

In 2020 the majority of the barley grass again germinated later in the season during mid July and August avoiding the early weed control with pre-sowing herbicide applications. The residual carryover in the IMI system resulted in the lowest pre-seeding germination and low barley grass numbers/m^2. The different crops all established well but a lower than average rainfall in May, June and July resulted in very slow crop growth until August and September. The 2020 chemical applications applied in the break crop systems of the canola and medic crops reduced the late barley grass plant numbers, with the TT Canola system giving the best later barley grass weed management. Despite the lower numbers of barley grass there were differences in the number of barley grass seed/m^2 (Figure 1) with the Higher Cost Chemical system sown with Scepter wheat having more seed heads per plant late in the season, but it must be noted this system did not receive the Sakura herbicide as initially planned (Figure 2).

In 2021 there was some germination of barley grass plants by early July but again most barley grass germinated in mid July-August which is reflected in the higher late barley grass numbers counted on September 1 (Table 2). The Higher cost herbicide treatment sown with CL Spartacus Barley had high early barley grass numbers but the Intervix applied in early August reduced the late barley grass population and lowered the overall weed seed set (Figure 1 and Table 2). All other management strategies which were sown to Scepter wheat had a similar barley grass weed seed set of greater than 370 barley grass weed seeds/m^2 (Table 2). There were no differences in yield of the management treatments sown to cereals in 2021.

Table 2. Plant and barley grass weed numbers, dry matter, yield and grain quality in GRDC Low Rainfall Barley Grass Management farm trial, 2021.

2021 Barley grass weed control strategy and crop variety	2020 Pre-harvest barley grass weed seed set/m^2	Pre seeding barley grass numbers (plants/m^2) 14 May	Crop establishment (plants/m^2) 6 July	Early barley grass numbers (plants/m^2) 6 July	Late barley grass (plants/m^2) 1 Sept	Late barley grass (heads/m^2) 1 Sept	Yield (t/ha)	2021 Harvest barley grass weed seed set/m^2
District Practice Scepter Wheat	620	0	142	4.8	6.7	16.4	2.85	382
IMI system Scepter wheat	546	0	136	1.2	2.4	5.1	2.38	413
Cultural Control Scepter wheat	680	0	157	6.3	20.3	55.2	2.09	377
Higher cost herbicide CL Spartacus Barley	671	0.5	112	23.5	1.9	2.7	2.31	272
Two Year Break Scepter Wheat	2	0	133	0.5	1.3	2.7	2.32	397
LSD (P=0.05)	*159*	*ns*	*ns*	*13.7*	*8.9*	*23.5*	*ns*	*ns*

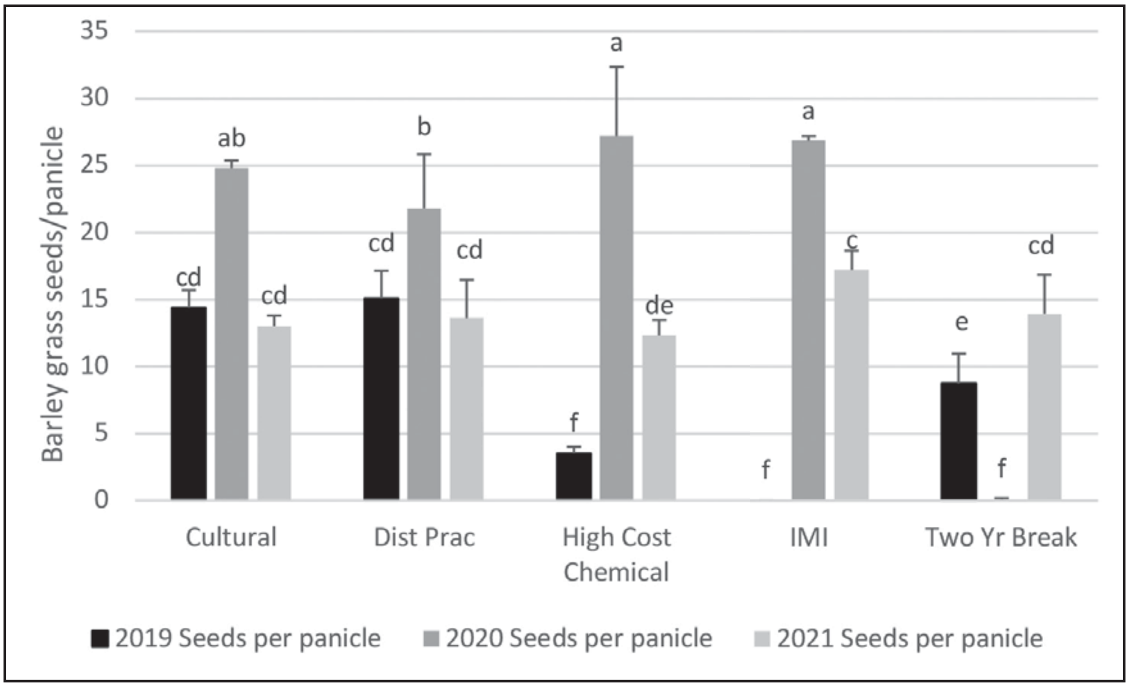

Figure 2. The five different management strategies and the number of barley grass weed seeds per panicle for each season (2019-2021) at Minnipa Agricultural Centre, paddock S3 different letters are significantly different LSD = 4.6. Error bars represent standard deviation of the population.

What does this mean?

The MAC S3 barley grass is a later germinating population with a requirement for cold (vernalisation), therefore avoids early weed control with pre-sowing herbicide applications, and it also has confirmed Group 1/A resistance to quizalofop.

The three years of the broadacre barley grass management strategies have shown:

- The traditional management of pasture systems results in an increase in barley grass weed set.
- In 2019 the use of propyzamide in pasture and a desiccated late hay freeze reduced the barley grass weed seed set by 75%.
- The use of TT canola systems with simazine reduced barley grass weed seed set.
- The IMI chemistry worked well in the year of application (2019) but barley grass weed seed set still increased in the sown pasture system in the following season.
- There is seasonal variation with the number of seeds set per panicle in a season, with 2020 having a high weed seed set.
- Despite getting good control in one season barley grass has the ability to germinate from the weed seed bank the following season and still set high weed seed numbers.
- There was no overall management strategy identified to control barley grass numbers and weed seed set over the three seasons which means barley grass management and lowering weed seed set needs to be a focus in all seasons in low rainfall farming systems.

While the IMI herbicide system is working well at MAC it tends to be quite prone to evolution of resistance in weeds. The strategic use of the IMI herbicide system must be used to maximise the effectiveness and long term use of this system. Growers also need to be aware of herbicide breakdown and plant back periods, especially in low rainfall seasons to avoid bare paddocks.

With confirmed Group 1/A resistance levels at Minnipa Agricultural Centre in barley grass populations to FOPS, moving to clethodim could be effective for the short term. Generally a higher rate of clethodim (500 mL/ha) appears to be effective on most populations where the 250 mL/ha rate does not work effectively at present. However, resistance to the higher rate is likely to evolve over the next few years. The broadleaf spraying at MAC is done separately several days after the grass weed control, not in the same tank mix. The environmental conditions can also affect the spray efficacy, especially cold weather/frost either 2-3 days before or after spraying, so avoid these events if possible. Dry conditions, plant stress and soil constraints may also affect spray efficacy.

The Group 1/A herbicide resistance is becoming a major issue on MAC and in this region. The loss of Group 1/A chemicals within our pasture break system has the potential to totally change farming systems. Currently farmers on upper EP rely on self-regenerating medic-based systems with a profitable livestock enterprise, with grass control applied to prevent weed seed set in spring. The loss of the ability to control barley grass weeds using Group 1/A herbicides will result in medic pasture having to be sprayed out using glyphosate in spring. This will reduce the feed base and carrying capacity, reduce the medic seed bank, incur later sowing times in the cropping phase to gain weed control or more cropping dominant systems with other break crops (canola, vetch, lentils) and alternative herbicide groups which will increase risk and impact on profitability.

To ensure Group 1/A resistance is kept in check, farmers may want to make sure any suspected resistant plants are dealt with in pasture systems by following up with a knockdown herbicide as early as possible to prevent seed set. Always have follow up options to control any survivors and to preserve Group 1/A herbicides. Using alternative chemical groups by including canola or introducing Clearfield systems as a different rotational break may also be an option. The loss of Group 1/A herbicides within current farming systems may result in high barley grass seed set and seed bank carry over. Reducing the weed seed bank is pivotal to managing all grass weeds.

If barley grass herbicide resistance is suspected, the first step is to test the population to know exactly what you are dealing with and ensure the best use of chemicals to maximise the herbicide efficacy. This is the final season of this GRDC southern cropping region research.

Acknowledgements
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Farmers listening to Amanda Cook at the MAC South 3 broadacre low rainfall barley grass demonstration, 2021.

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Herbicide resistance in barley grass populations from the Eyre Peninsula

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Key messages

- **Barley grass populations from farms on Eyre Peninsula were collected for resistance testing in 2018 (n=29), 2019 (n=22) and 2020 (n=12). These populations were collected randomly in 2018 to avoid any bias but in 2019 and 2020 many populations came from paddocks where control failures had been observed.**
- **In 2018 when populations were collected randomly, 13.8% of EP populations were resistant to quizalofop (e.g. Targa® or Leopard®). As expected, the level of resistance to quizalofop was much higher in the non-random sampling of 2019 (77.3%) and 2020 (58.3%). These results clearly highlight that group 1/A resistance is having a negative impact on barley grass management on many farms in Eyre Peninsula.**
- **Resistance to imidazolinone (IMI) herbicide Intercept® (imazamox + imazapyr) was detected in barley grass samples collected from Eyre Peninsula in 2018 and 2019 but not in 2020 samples. The frequency of resistance to IMI herbicides was below 7%, which could be reassuring for growers thinking about integrating Clearfield® crops into their rotations.**
- **Resistance testing over 3 years did not identify any resistance to paraquat or glyphosate in barley grass populations from Eyre Peninsula. However, resistance in barley grass to these herbicides has already been identified in other low rainfall regions of Australia.**

Why do the trial?

A survey by Llewellyn *et al*. (2015) showed that barley grass has now become one of the top 10 weeds of Australian cropping in terms of area infested, crop yield loss and revenue loss. In this survey, barley grass was ranked as the 7th most costly weed to control by the growers in SA and VIC Mallee and Mid-North, Lower Yorke and Eyre Peninsula. Resistance to group 1/A herbicides in barley grass has been known for more than 10 years. In this GRDC funded project, barley grass samples have been tested to assess resistance to all commonly used herbicide groups. In order to manage barley grass effectively, growers need to determine resistance status of populations on their farm.

How was it done?

In late 2018, GRDC organised advisers across NSW, VIC, SA and WA to collect barley grass populations for herbicide resistance testing. These populations were selected without any consideration of suspected resistance. Therefore, the sample of 2018 can be considered a random collection. In this sample, 29 samples were received from the low rainfall zone of Eyre Peninsula. In order to gain further understanding of herbicide resistance, samples of barley grass were collected from Eyre Peninsula in 2019 (n=22) and 2020 (n=12). Most of the samples collected in 2019 and 2020 came from paddocks where weed control was lower than expected. Therefore, these samples cannot be considered random and are likely to have a higher level of resistance than the first survey of 2018.

Seeds of barley grass populations were sown into potting mix (cocoa peat) in seedling trays in April. When barley grass seedlings had reached 1-leaf stage, they were transplanted into pots (10 plants/pot). Seedlings were sprayed with the label rates of group A, B, L and M herbicides (Table 1). Adjuvants recommended by the manufacturers were added to the spray solution of all herbicides. A research track sprayer (De Vries Manufacturing, Hollandale, United States) was used to apply the herbicide treatments, which was calibrated to deliver 100 L/ha through a single TeeJet® 8002E (TeeJet Technologies, Illinois, United States) flat-fan nozzle at a speed of 3.6 km/h. Plants were assessed for survival 4 weeks after the herbicide treatment and individuals with new growth were counted as survivors.

What happened?

Group 1/A resistance

Resistance to group 1/A herbicide quizalofop was detected in barley grass samples from EP in each of the three years of testing. In 2018 when populations were collected randomly, 13.8% of EP populations were resistant to quizalofop. As expected, the level of resistance to quizalofop was much higher in the non-random sampling of 2019 (77.3%) and 2020 (58.3%) (Figure 1). These results clearly highlight that group 1/A resistance is having a negative impact on barley grass management on many farms in Eyre Peninsula. These results also highlight the need for growers to be aware of resistance status of their barley grass populations so that informed decisions on its management can be taken.

Table 1. Details of herbicides used for screening barley grass populations.

Active ingredient (group)	Trade name, manufacturer	Dose
Untreated control	N/A	-
Quizalofop 100 g/L (group 1/A)	Leopard®, Adama	250 mL/ha
Clethodim 240 g/L (group 1/A)	Grasidim® 240EC, Sipcam	250 mL/ha
Imazamox 33 g/L + imazapyr 15 g/L (group 2/B)	Intercept®, Nufarm	600 mL/ha
Glyphosate 470 g/L (9/M)	Weedmaster® DST®, Nufarm	760 mL/ha
Paraquat 250 g/L (22/L)	Para-Ken 250®, Kenso Agcare	1.2 L/ha

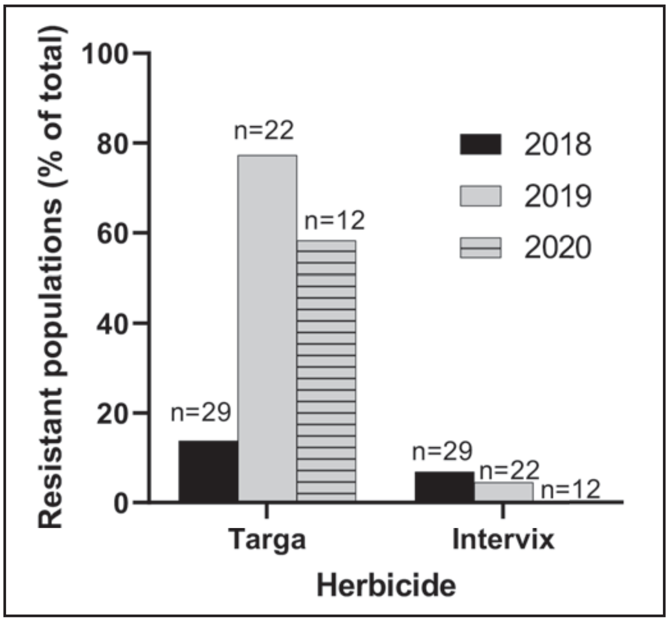

Figure 1. Resistance to Targa® (quizalofop) and Intervix® (imazamox + imazapyr) in barley grass populations from Eyre Peninsula. Samples in 2018 were collected without any consideration for the presence of herbicide resistance (i.e. random). In contrast, most of the samples in 2019 and 2020 were collected from fields where growers had experienced some difficulty in controlling barley grass.

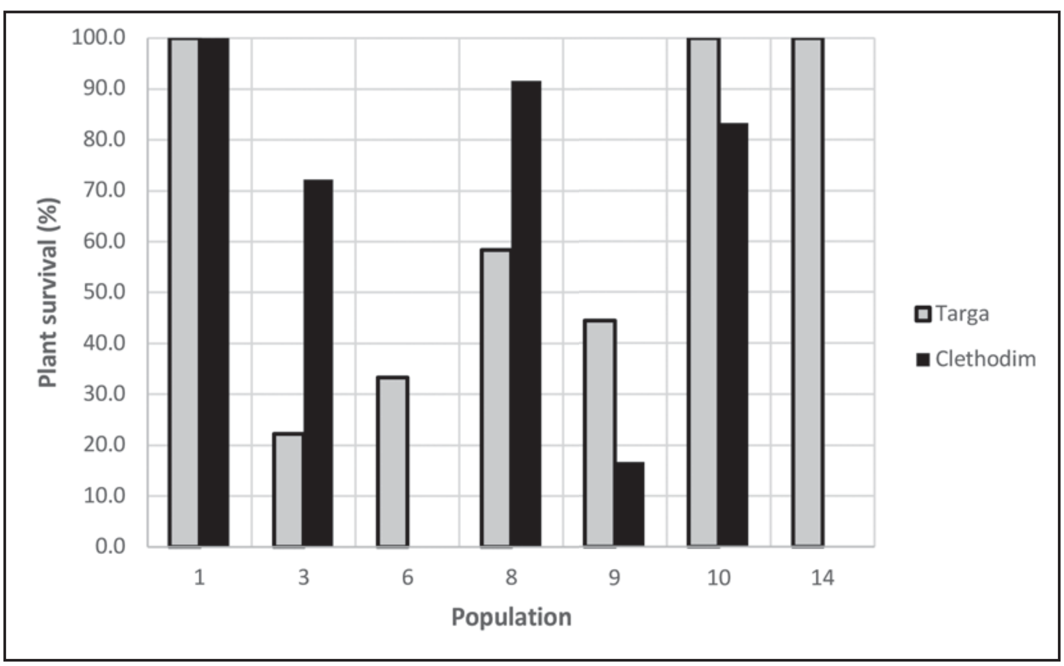

Figure 2. Association between resistance to Targa® (quizalofop) and Clethodim® (clethodim) in barley grass populations collected from Eyre Peninsula in 2020. Note two populations resistant to Targa were killed by clethodim.

Most barley grass populations with resistance to quizalofop were also resistant to clethodim (Figure 2). However, there were some exceptions to this general trend. For example one of the populations from this region that showed no mortality when sprayed with quizalofop, was completely killed when sprayed with clethodim (population 14). These differences in barley grass response to quizalofop and clethodim are likely to be related to the mechanisms of resistance present in different populations. Some of the target site (ACCase gene) mutations in weeds are known to confer resistance to both FOP and DIM herbicides whereas others only provide resistance to FOPs but not to DIMs. Herbicide resistance testing in such populations can provide valuable information about which herbicides are certain to fail but also on herbicides that are still effective. Consistent with previous results, butroxydim (Factor®) provided effective control of most of the clethodim resistant barley grass populations. However, resistance to butroxydim was detected in one barley grass population from the Mid North region of SA. Therefore, butroxydim should only be used within the framework of integrated weed management to slow down the rate of resistance evolution.

Group 2/B resistance

Resistance to imidazolinone (IMI) herbicide Intercept® (imazamox + imazapyr) was detected in barley grass samples collected from Eyre Peninsula in 2018 and 2019 but not in 2020 samples. The frequency of resistance to IMI herbicides was 6.9% in 2018 and 4.5% in 2019, which may be reassuring for growers thinking about integrating Clearfield® crops into their rotations. Growers in the low rainfall regions are often reluctant to use IMI herbicides because of their long-term persistence in soil which can restrict rotational crop options next year. Relatively low adoption of Clearfield® crops on EP may be the reason for low levels of resistance detected to this herbicide group.

Group L and M resistance

Resistance testing over 3 years did not identify any resistance to paraquat or glyphosate in barley grass populations from Eyre Peninsula. These results highlight resilience of these important herbicides and it's a great news for growers on Eyre Peninsula. However, there is a need for caution and vigilance because resistance to both of these herbicides was detected this year in samples collected from the Victorian Mallee in 2020. Resistance to paraquat was confirmed in 4 barley grass samples from the Victorian Mallee. These samples came from paddocks where paraquat had been regularly used for weed control in lucerne. Resistance to glyphosate was confirmed in 2 barley grass populations from the Victorian Mallee where it had been used for pre-sowing knockdown weed control.

What does this mean?

Herbicide resistance testing of barley grass populations from Eyre Peninsula over the last 3 years has consistently detected resistance to group 1/A herbicides. Resistance to this herbicide group appears to be still increasing so growers who experience unexpected control failures with these herbicides should have their populations tested. As expected, the level of resistance to group 1/A herbicides detected was much lower in the random survey of 2018 (13.8%) than in subsequent selective sampling in 2019 (77.3%) and 2020 (58.3%). However, the main message is that as a region Eyre Peninsula appears to have the highest frequency of group A resistant barley grass in Australia. Some of FOP resistant populations were also highly resistant to clethodim but others were still killed by this herbicide. Somewhat unexpectedly, butroxydim (Factor®) was highly effective against most of FOP and clethodim resistant populations of barley grass. However, over reliance on butroxydim may lead to evolution of resistance to this herbicide as well.

On a positive note, resistance to IMI herbicides used on Clearfield® crops is still very low on Eyre Peninsula. Resistance to these herbicides was detected in 2018 (6.9%) and 2019 (4.5%) testing but not in 2020. Therefore, IMI herbicides could provide an effective option for growers facing group A resistance in this weed. However, IMI herbicides can persist in soil for longer than desirable and can negatively affect crop or pasture growth in the next growing season.

Even though resistance to glyphosate and paraquat was not detected in any of the populations from the EP, barley grass with resistance to these herbicides was detected in 2020 samples from the Victorian Mallee. Therefore, growers experiencing difficulty in controlling barley grass with these herbicides should send their samples for testing to a resistance testing service.

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Improving the management of Group 1/A resistant barley grass in Eyre Peninsula farming systems

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Location
Mount Cooper
Rainfall
Av. Annual: 411 mm
Av GSR: 326 mm
2021 Total: 420 mm (52 mm Jan and Feb summer rainfall)
2021 GSR: 312 mm
Soil type
Red loam
Paddock history
2021: Self-regenerating medic pasture
2020: Wheat
2019: Canola
Plot size
12 m x 1.7 m x 3 replicates

Location
Minnipa N6
Rainfall
Av. Annual: 325 mm
Av GSR: 241 mm
2021 Total: 406 mm
2021 GSR: 248 mm
Soil type
Red loam
Paddock history
2021: CL Hammer wheat
2020: Spartacus barley
2019: Hay mix (Oats, vetch and canola)
Plot size
12 m x 1.7 m x 3 replicates

Key messages

- **New herbicides with different chemistries will provide future opportunities for grass weed management.**
- **Herbicide and seed separation is important when using Luximax®; greater than 3 cm crop sowing depth is needed to ensure crop safety and adequate germination.**
- **Overwatch® treatment caused visual bleaching of the plants for three weeks after emergence at Minnipa but did not impact on overall plant establishment, early dry matter or yield. Only small blotches on leaves were observed at Mount Cooper.**
- **Mateno Complete® is a herbicide with grass and broadleaf weed activity for use in wheat and barley, with flexible incorporated by sowing (IBS), or in wheat before GS Z23 early post-sowing application. The early post sowing application may provide an additional management option for grassy paddocks when partnered with an adequate pre-emergent herbicide.**
- **Sakura® is still a good option for barley grass weed control in cereals.**
- **Peas with Ultro®, peas with Terbyne® and Vetch with Ultro® plus propyzamide had low barley grass weeds numbers.**
- **The herbicide efficacy investigations showed that both herbicide application and herbicide resistance contributed to herbicide control failures. While herbicide resistance was confirmed in many of the failure sites, some were found to be fully susceptible to herbicide indicating application failures. However, it should also be noted that herbicide resistance levels varied greatly between and even within paddocks.**

Why do the trial?

Barley grass is currently the most problematic grassy weed on the upper Eyre Peninsula. It possesses several biological traits that make it difficult to control in low rainfall farming systems. These include:

- Increased seed dormancy delays barley grass emergence often until well after the crop is established, avoiding weed control from knockdown herbicides prior to seeding.
- Increasing herbicide resistance, especially to Group 1/A herbicides which are used to control grassy weeds in pasture and break crop phases.
- Early onset of seed production, which reduces effectiveness of crop-topping or spray-topping in pastures.
- Shedding seeds well before crop harvest, reducing the effectiveness of harvest weed seed control strategies compared to weeds such as ryegrass, which have longer seed retention.

This research aims to assess the impact of new herbicides and management options in both cereals and break crops for improving barley grass control and to assess current barley grass genotypes on upper Eyre Peninsula for their seed dormancy and germination characteristics in 2022. It will also monitor several farmer paddocks where barley grass escapes control measures or herbicide resistance is suspected. Also to identify if environmental factors and management strategies are affecting the efficacy of current herbicides. This is the first season of the three-year research program.

How was it done?

In 2021 a three-year rotational trial was established at Mount Cooper. The cereal and grass herbicide trial (Trial 1) was sown 1 June, both the break crops and IMI system trials were sown on 2 June. An extra cereal herbicide trial (Trial 1) was also sown at Minnipa Ag Centre (MAC N6) on 31 May for discussion with growers attending the MAC Field Day.

Trial 1. Cereal grass treatments 2021 - Mount Cooper and Minnipa

Variety: Scepter 70 kg/ha with MAP @ 60 kg/ha
Knockdown herbicides:
Weedmaster 1.5 L/ha and LI700 @ 300 ml/100 L. Herbicide treatments applied are listed in Table 1 and Table 2.

This trial was established to evaluate new chemistries against current herbicide options for barley grass weed management. The new chemistries included:

- Luximax® is a new mode of action herbicide (Group 30/Z) containing cinmethylin. This product has a seeding depth specification (minimum 3 cm sowing depth) on the label much like many other pre-emergent chemicals, as the crop safety comes from the separation of the seed from the chemical layer. Registration does not include barley as crop damage is too high for that crop.
- Mateno Complete® a herbicide which has the active ingredients of aclonifen 400 g/L (Gp 32), diflufenican 66 g/L (Gp 12), pyroxasulfone 100 g/L (Gp 15). It has grass and broadleaf weed control in wheat and barley, with flexible IBS or in wheat before GS Z23 early post sowing application.
- Overwatch® (Group 13 or Q) active ingredient bixlozone. Overwatch® controls annual ryegrass and some broadleaf weeds and has been registered for use in wheat, barley and canola. Suppression of barley grass, brome grass and wild oats can occur. The safest use pattern is incorporated by sowing (IBS) with knife-points and press wheels.

Trial 2. Break crops and IMI system

Varieties: Butler peas @ 80 kg/ha, Studencia vetch @ 65 kg/ha, Seraph strand medic (PM-250) @ 7.5 kg/ha, Canola ATR-Stingray @ 3 kg/ha, Razor CL wheat and Spartacus CL barley @ 70 kg/ha.
Fertiliser: MAP @ 60 kg/ha
Knockdown herbicides:
Weedmaster 1.5 L/ha and LI700 @ 300 ml/100 L.
Break crops and herbicide treatments applied are listed in Table 3.

During the growing season the trials were assessed for plant establishment, early and late dry matter, early and late grass weeds, grain yield and grain quality.

At Mount Cooper plant establishment and early grass weed numbers were assessed on 29 June, early dry matter was measured on 2 August. Late dry matter and grass weeds were assessed 25 October. The break crop treatments were harvested on 1 November, but unfortunately due to livestock damage the cereal yields were unable to be accurately assessed at Mount Cooper.

At Minnipa plant establishment was assessed 5 July, early dry matter and grass weed measurements were made 13 August. Late dry matter and grass weed assessments were made 7 October. The trial was harvested on 16 November.

Herbicide efficacy

As part of this research, the efficacy of herbicides due to environmental factors and management will be assessed. During 2021 five paddocks with escaped barley grass weed patches were identified in the Minnipa region after application of Gp 1/A grass weed herbicide application. Smaller live grass weed samples were collected from different patches in the paddock to replicated pots then moved to the Minnipa glasshouse. Larger weed samples were also collected from the same locations to grow for mature seed to assess in the weed seed trays for longer-term seed dormancy. The samples were watered to remove any environmental plant stresses.

Clethodim herbicide was applied at 500 ml/ha with LI700 @ 1 L/100 L to the smaller plants (3-4 leaf) on 22 September using the MAC plot straddler with a shielded sprayer at 2 bar pressure using medium coarse droplets (T11002 nozzles) with water rate of 100 L/ha. The plant samples in pots were watered weekly then assessed after four weeks for herbicide efficacy.

Weed seed trays from 30 paddocks across upper EP have also been set up at MAC to be assessed in 2022 and 2023 for the length of seed dormancy and germination patterns.

What happened?

The 2021 season had a late start with the break of the season occurring on 20 May, with above average rainfall for June and July in most regions on upper Eyre Peninsula and very little rainfall was received in September. Heavy rains occurred too late to benefit crops in early November which resulted in delayed harvesting and reduced grain quality. Minnipa recorded a decile 4 rainfall in 2021, and Mount Cooper had decile 5 rainfall season with some subsoil moisture from summer rains.

Trial 1. Cereal grass treatments

The Minnipa site was sown before strong winds on the afternoon of 31 May followed by a 15 mm rainfall event the following week. At the Minnipa site there was a reduction in plant establishment in the Luximax® treatments (Table 1) which may have been due strong winds moving the soil into seed rows with the following rain causing the herbicide to be washed down and come into contact with the crop seed reducing the plant numbers.

Luximax® has a seeding depth specification (minimum 3 cm sowing depth) on the label much like many other pre-emergent chemicals, as crop safety comes from the separation of the seed from the chemical layer.

At Minnipa the Overwatch® treatment caused bleaching of the plants for three weeks after emergence but did not impact on overall plant establishment (Table 1). At Mount Cooper there was no differences in plant emergence due to herbicide treatments (Table 2). There was very little visual bleaching of the Overwatch® herbicide at Mount Cooper with only some slight spotting on leaves with these treatments. This may have been due to the higher clay content of this soil compared to the lighter Minnipa soil.

Early barley grass plant density was different between herbicide treatments at the Minnipa site (Table 1) but showed no differences at Mount Cooper. The Mount Cooper site had lower than anticipated barley grass population. At Minnipa there were no differences in early dry matter due to herbicide applications (data not presented). However, the timing of sampling was several weeks later than planned due to COVID restrictions at the time. There were no differences between herbicide treatments for late barley grass density (Table 1) or barley grass weed seed heads at Minnipa (data not presented).

There were no statistical differences between herbicide treatments in barley grass plant density at Mount Cooper, where overall weed numbers were low (Table 2). However, the late barley grass seed head density was significantly different, which is strongly related to the amount of weed seeds produced infesting following season. While the differences were small due to low weed pressure, they were significant (Table 2). Barley grass seed head panicles ranged from 0-20 heads/m^2 depending on herbicide treatment (Table 2).

The final grain yields at Minnipa reflected the initial crop damage and plant establishment with the Luximax® treatments having lower grain yields compared to the other herbicide treatments (Table 1).

Trial 2. Break crops and IMI system

The break crop trial at Mount Cooper established well with the sown annual medic plants, pulses and canola all achieving adequate plants numbers (Table 3). Early dry matter was not taken for the medic treatments as there was not adequate growth in early August. There were no differences in early dry matter or early barley grass plant density between the herbicide treatments applied on the pulses or canola at Mount Cooper (data not presented).

Table 1. Plant and barley grass weed numbers and grain yield at Minnipa in 2021.

Chemical Treatment	Crop establishment 5 July (plants/m^2)	Early barley grass 13 Aug (plants/m^2)	Late barley grass 7 Oct (heads/m^2)	Yield 16 Nov (t/ha)
Luximax® (500 ml/ha) with Voraxar® (100 ml/ha) IBS	81 h	14.3 a	2.07	2.10 b
Boxer® Gold 2.5 L/ha IBS	140 a	15.7 a	5.66	2.58 a
Trifluralin 1.8 L/ha plus Sakura® (118 g/ha) and Avadex® (500 g/L) 1.6 L/ha IBS	123 cd	5.2 bc	3.16	2.64 a
Mateno Complete® 1 L/ha IBS	141 a	3.9 c	0.98	2.62 a
Trifluralin 1.8 L/ha plus Avadex® (500 g/L) 1.6 L/ha IBS	119 cde	7.4 abc	1.31	2.50 a
Overwatch® (1.25 L/ha) with Voraxar® (100 ml/ha) IBS	130 abc	1.7 c	1.74	2.68 a
Sakura® (118 g/ha) and Avadex® (500 g/L) 1.6 L/ha IBS	136 ab	3.9 c	0	2.65 a
Sakura® (118 g/ha) IBS	119 cde	6.1 bc	0.76	2.74 a
Trifluralin 1.8 L/ha IBS - District Practice	118 cde	12.6 ab	2.40	2.68 a
Mateno Complete® 1 L/ha early post emergent (EPE)	114 def	14.4 a	1.96	2.81 a
Luximax® 500 ml/ha IBS (sown below 3 cm)	108 ef	15.7 a	3.92	2.54 a
Overwatch® 1.25 L/ha plus Avadex® (500 g/L) 1.6 L/ha IBS	127 bc	4.8 bc	1.63	2.62 a
Overwatch® 1.25 L/ha plus Trifluralin (1.8 L/ha) IBS	108 ef	3.9 c	2.40	2.79 a
Overwatch® (1.25 L/ha)	112 def	3.5 c	2.07	2.68 a
Sakura® (118 g/ha) with Voraxar® (100 ml/ha) (IBS	136 ab	7.4 abc	0	2.87 a
Luximax® (500 ml/ha) plus Trifluralin (1.8 L/ha) IBS	93 gh	4.4 c	1.74	2.15 b
Luximax® (500 ml/ha) plus Avadex® (500 g/L) 1.6 L/ha IBS	103 fg	7.8 abc	6.54	2.07 b
Trifluralin (1.8 L/ha) plus 900diuron (500 g/ha) IBS	123 cd	3.5 c	4.14	2.74 a
LSD (P=0.05)	*13*	*8.2*	*ns*	*0.25*

IBS – incorporated by sowing, PSPE – post sowing pre-emergent.

Table 2. Cereal plant and barley grass weed numbers, and dry matter at Mount Cooper in 2021.

Chemical Treatment	Crop establishment 29 June (plants/m²)	Early dry matter 2 Aug (t/ha)	Early barley grass numbers 29 June (plants/m²)	Late barley grass 25 Oct (weeds/m²)	Late barley grass 25 Oct (heads/m²)
Luximax® (500 ml/ha) with Voraxar® (100 ml/ha) IBS	100	0.14 e	1.31	2.18	7.0 cde
Boxer® Gold 2.5 L/ha IBS	112	0.19 bcde	2.61	2.61	7.8 bcde
Trifluralin 1.8 L/ha plus Sakura® (118 g/ha) and Avadex® (500 g/L) 1.6 L/ha IBS	108	0.15 de	2.61	1.31	5.2 de
Mateno Complete® 1 L/ha IBS	111	0.23 abc	1.31	1.31	1.3 de
Trifluralin 1.8 L/ha plus Avadex® (500 g/L) 1.6 L/ha IBS	102	0.17 cde	3.27	3.49	14.8 abcde
Overwatch® (1.25 L/ha) with Voraxar® (100 ml/ha) IBS	114	0.21 abcde	1.31	3.92	16.3 abcd
Sakura® (118 g/ha) and Avadex® (500 g/L) 1.6 L/ha IBS	124	0.28 a	2.61	2.61	4.6 de
Sakura® (118 g/ha) IBS	118	0.21 abcde	0.65	1.30	1.3 de
Trifluralin 1.8 L/ha IBS – District Practice	110	0.22 abcd	5.23	3.92	6.5 cde
Mateno Complete® 1 L/ha early post emergent (EPE)	120	0.24 abc	2.61	1.31	3.9 de
Luximax® 500 ml/ha IBS (sown below 3 cm)	103	0.14 e	0	2.61	8.7 bcde
Overwatch® 1.25 L/ha plus Avadex® (500 g/L) 1.6 L/ha IBS	121	0.25 ab	1.31	3.27	8.5 bcde
Overwatch® 1.25 L/ha plus Trifluralin (1.8 L/ha) IBS	113	0.26 ab	0	3.27	24.2 a
Overwatch® (1.25 L/ha)	122	0.20 bcde	3.92	5.01	10.7 abcde
Sakura® (118 g/ha) with Voraxar® (100 ml/ha) IBS	104	0.19 bcde	2.61	0	0 e
Luximax® (500 ml/ha) plus Trifluralin (1.8 L/ha) IBS	117	0.24 abc	1.31	5.23	11.1 abcde
Luximax® (500 ml/ha) plus Avadex® (500 g/L) 1.6 L/ha IBS	116	0.22 abcd	5.23	6.32	22.9 ab
Trifluralin (1.8 L/ha) plus 900diuron (500 g/ha) IBS	110	0.15 de	1.96	5.66	21.8 abc
LSD (P=0.05)	*ns*	*0.08*	*ns*	*ns*	*15.4*

There were differences due to break crops and herbicide treatments in the late barley grass plant density and in barley grass seed head panicles at Mount Cooper (Table 3). Peas with Ultro®, peas with Terbyne® and Vetch with Ultro® plus propyzamide had low barley grass weed numbers.

The medic, medic hay freeze, canola with Overwatch® and canola with propyzamide treatments all had high numbers of late barley grass seed heads and likely weed seed set, except the medic hay freeze which would be expected to not have viable seed (Table 3). The were no differences in pulse or canola yields due to the herbicide treatments, but the canola yielded lower overall than the pulses (Table 3).

At Mount Cooper in 2021 there were no differences in plant establishment, early or late dry matter, early or late barley grass weed numbers and weed seed set between the Clearfield wheat system and Scepter wheat with Trifluralin at 1.8 L/ha plus Sakura® (118 g/ha) IBS.

Herbicide efficacy

The efficacy of Group 1/A herbicides will be assessed due to environmental factors and management. Smaller live grass weed samples were collected and transplanted from the field and watered for three weeks to remove any environmental plant stresses. Clethodim herbicide was applied at 500 ml/ha with Hasten™ @ 1 L/100 L to the smaller plants using the MAC plot straddler with a shielded sprayer. Barley grass survival was used to assess herbicide efficacy, four weeks after herbicide was applied (Table 4).

The results from the paddocks show Paddock 1 had 100% herbicide efficacy when applied to non-stressed plants, indicating that the escaped barley grass in this paddock is due to management and herbicide application issues.

All other paddocks (Paddocks 2 to 5) showed a reduced level of herbicide efficacy or barley grass weed resistance. Within the paddock in the three areas where samples were collected there were different levels of resistance indicated by the range (Table 3).

Table 3. Break crop establishment and barley grass weed numbers, and yield at Mount Cooper in 2021.

Break Crop Treatment	Crop establishment (plants/m²) 29 June	Late barley grass (weeds /m²) 25 Oct	Late barley grass (heads/m²) 25 Oct	Yield (t/ha) 1 Nov
Vetch	82 b	3.9 ab	13.5 cde	2.00 a
Vetch Ultro® (1.1 kg/ha) plus propyzamide Rustler® 0.7 kg/ha	74 bc	0 b	0 e	1.79 a
Vetch with Ultro® (1.1 kg/ha) plus Reflex® 500 gm/ha PSPE	79 b	1.96 ab	6.1 cde	2.12 a
Vetch with Ultro® (1.1 kg/ha)	80 b	5.2 a	13.1 cde	2.18 a
Vetch propyzamide Rustler® 0.7 kg/ha	82 b	5.2 a	33.1 abcd	2.16 a
Brown Manure Vetch (Glyphosate DST 2.5 L/ha)	77 b	2.6 ab	9.2 cde	-
Peas Terbyne® 850 ml/ha PSPE	66 bc	0 b	0 e	2.64 a
Peas with Ultro® (1.1 kg/ha) IBS	65 bc	0 b	0 e	2.48 a
Peas with Ultro® (1.1 kg/ha) IBS plus Reflex® 500 gm/ha PSPE	65 bc	1.3 ab	5.2 de	2.68 a
Peas Simazine (1 kg/ha) IBS	67 bc	1.3 ab	6.5 cde	2.30 a
Peas 900diuron (500 gm/ha) IBS	76 b	3.1 ab	15.7 cde	2.58 a
Peas with Boxer® Gold (2.5 L/ha)	73 bc	2.6 ab	7.8 cde	2.34 a
Medic with propyzamide, Rustler® 0.7 kg/ha IBS	129 a	2.7 ab	23.5 bcde	-
Medic (hay freeze) with Weedmaster (1.5 L/ha)	119 a	5.9 a	49.2 ab	-
Medic	110 a	4.4 a	34.4 abc	-
Canola ATR-Stingray Overwatch® 1.25 L/ha	79 b	5.2 a	57.5 a	1.15 b
Canola ATR-Stingray with propyzamide, Rustler® 0.7 kg/ha IBS	73 bc	3.1 ab	33.6 abcd	1.02 b
Canola ATR-Stingray	54 c	3.1 ab	25.3 bcde	1.14 b
LSD (P=0.05)	*21.5*	*3.2*	*29.1*	*0.34*

Table 4: Cereal plant and barley grass weed numbers, and yield of IMI cereals at Mount Cooper in 2021.

Imidazolinone (IMI) Treatment	Crop establishment 29 June (plants/m²)	Late barley grass 25 Oct (weeds/m²)	Late barley grass 25 Oct (heads /m²)
Scepter Wheat with Trifluralin 1.8 L/ha plus Sakura® (118 g/ha) IBS	113.7	1.7	5.2
Razor CL Wheat with Intercept (500 ml/ha)	122.8	0	0
Spartacus CL Barley with Intercept (500 ml/ha)	128.1	0	0
LSD (P=0.05)	*ns*	*ns*	*ns*

Table 5. Group 1 (A) Clethodim herbicide applied at 500 ml/ha with LI700 @ 1 L / 100 L to barley grass in pots without paddock environmental stresses in 2021.

Paddock	Locations in paddock	Number of pots	Number of plants tested	% herbicide efficacy	Range
1	3	3	98	100	All 100%
2	3	3	89	30	6-56
3	3	3	70	40	15-67
4	2	2	59	28	17-39
5	3	3	92	37	25-51

What does this mean?

Sakura® is currently the best option for barley grass weed control in cereals but can have variable results in low rainfall environments for pre-emergent control of grasses as soil moisture is needed for weed uptake of the herbicide. 2021 was the first season of evaluation of the new herbicides in lower rainfall upper EP environments for barley grass weed management.

Unfortunately, the Mount Cooper site had lower barley grass weed numbers than expected to test the newer chemistries but having two trial sites provided some insights into some of the new herbicide chemical behaviours.

Seeding depth to achieve greater than 3 cm separation between the herbicide and seed is very important when using the Luximax® herbicide. Wind events at Minnipa caused the movement of soil and the herbicide into the seeding row, followed by 15 mm of rain the following week which resulted in lower plant establishment (i.e. crop damage). Registration of this herbicide does not include barley as crop damage is high.

Overwatch® caused visual bleaching of wheat plants at the Minnipa site for three weeks after emergence but did not impact on overall plant establishment or early dry matter. There were no bleaching symptoms but only slight spotting of leaves at Mount Cooper in a heavier clay soil with 25 mm of rainfall after sowing.

Mateno Complete®, a herbicide with both grass and broadleaf weed activity in wheat and barley with flexible IBS or in wheat bofore GS Z23 early post sowing application. This may provide an additional management option for grassy paddocks. The Clearfield systems in cereals had low barley grass weed numbers.

These new chemistries with different groups will provide future opportunities for grass weed management in current farming systems to ensure the best crop growth and grass weed control. Continued evaluation of these new herbicides will determine the best management practices and the economics of using these options in lower rainfall systems.

Ultro® is a new herbicide for grasses in all pulse crops, and Reflex® is a herbicide for broadleaf weed control in pulses, especially for hard-to-control broadleaf weeds such as turnip, Indian hedge mustard and sowthistle. There were no issues with plant establishment or early dry matter between the herbicide treatments applied on the pulses or canola at Mount Cooper.

There were differences due to break crops and herbicide treatments in the late barley grass numbers at Mount Cooper (Table 3). Peas with Ultro®, peas with Terbyne® and Vetch with Ultro® plus propyzamide had lower late barley grass weed numbers, and reduced weed seed set.

The break treatments with high numbers of late barley grass seed heads and weed seed set were medic, medic hay freeze, canola with Overwatch® and canola with propyzamide at Mount Cooper. The rotation trial at Mount Cooper will be ongoing until 2023 to provide growers with information on management strategies and herbicides to reduce the impact of Group 1/A herbicide resistant barley grass and lower barley grass weed numbers in low rainfall systems.

The paddock monitoring for herbicide efficacy in 2021 showed there will be some paddocks on the upper EP where management is an issue to ensure herbicide application results in an effective spray job. However, there are also paddocks with levels of resistance and these levels vary with different populations across the paddock. To ensure Group 1/A resistance is kept in check, farmers may want to ensure that any suspected resistant plants are dealt with in pasture systems by following up with a knockdown herbicide as early as possible to prevent seed set. Always have follow up options to control any survivors and to preserve Group 1/A herbicides. Using alternative chemical groups by including canola or introducing Clearfield systems as a different rotational break may also be an option.

The loss of Group 1/A herbicides within current low rainfall farming systems may result in high barley grass seed bank carry over. Reducing the weed seed bank is pivotal to managing all grass weeds. If barley grass herbicide resistance is suspected, the first step is to test the population to know exactly what you are dealing with and ensure the best use of chemicals to maximise herbicide efficacy. The paddock monitoring will be ongoing for the next two seasons.

Acknowledgements

This research was funded by SAGIT through the ‘Improving management of Group 1/A resistant barley grass in current farming systems’ (SAGIT SUA121). Sincere thanks to SAGIT and their valuable input into regional South Australian research. Thank you to Kieran Kelsh for having the field trials on his property. Thank you to Katrina Brands, Marina Mudge and Rebbecca Tomney for field work and processing samples.

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Weeds

The effect of combinations of crop row spacing, seedbed utilisation and pre-emergence herbicides on ryegrass management in barley

Ben Fleet[1], Gurjeet Gill[1], Amanda Cook[1,2] and Ian Richter[2]

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Key messages

- **Barley crop establishment was significantly reduced in the wider row spacing treatments. This is most likely due to increased crop intra-row competition rather than fertiliser toxicity from reduced seed bed utilisation (SBU) as fertiliser was banded for crop safety and crop establishment was similar for the two seed boot treatments.**
- **Herbicide treatments achieved varying levels of annual ryegrass (ARG) control with trifluralin reducing ARG plant density by 30%, Overwatch 67% and Boxer Gold 88% compared to untreated control (1092 ARG plants/m^2).**
- **Improved crop competition in narrower row spacing was reflected in 28% lower ARG seed set in the 25 cm row spacing than the wider 37.5 cm row spacing. Even though Boxer Gold reduced ARG seed set by 86% compared to the control, ARG was still able to produce 4787 seeds/m^2. Such a high level of ARG seed production is likely to have a serious impact on crops grown next year.**

Why do the trial?

As a general principle, large inter-row space tends to encourage weed invasion in field crops. At the start of the trend towards no-till, many growers adopted wider row spacing of crops as a way of achieving stubble retention. At present there is large variation in the row spacing used by growers for seeding wheat crops across the southern region. In wider row configurations, crop canopy closure is either delayed or not achieved, which allows weeds to compete with crops and set large amounts of seed. In a review of research gaps by Widderick *et al*. (2015), crop row spacing was identified as a priority area of research for the southern region. Seedbed utilisation (SBU) as a concept has been used by Australian agronomists to achieve safer use of fertilisers at crop sowing. Greater SBU reduces the concentration of fertiliser close to crop seed which improves safety. The same concept has relevance for increasing the inter-row space occupied by crop plants, which has the potential to improve the crop's competitive ability with weeds. Greater SBU by crops can be achieved by altering seed boots that provide greater lateral spread of crop seed. Some growers have been using 'Ribbon seeders' such as Concord or retro-fitting splitter boots to increase SBU and resource utilisation by their crops.

How was it done?

This field trial investigated combinations of the following management tactics.

Row spacing x splitter boots (4 treatments): 25 cm (10") and 37.5 cm (15") - with and without DBS v2 / ground hog style splitter boots

Herbicides treatments (4 treatments):

(i) Control (knockdown treatment only)

(ii) Trifluralin 1.5 L/ha incorporated by sowing (IBS)

(iii) Overwatch 1.25 L/ha (IBS)

(iv) Boxer Gold 2.5 L/ha (IBS)

Variety: Compass barley

Trial design: split-plot design

Replicates: 4.

Measurements: pre-sowing weed seedbank, crop density, weed density, ARG spike density, ARG seed production, barley grain yield.

All data collected during the growing season was analysed using the Analysis of Variance function in GenStat version 20.

In 2021, annual rainfall received at Minnipa was 25% above the long-term average but the growing season rainfall was only 3% above the long-term average. The rainfall received in June, July and November was greater than the long-term average with other months being close to average, except for April and September that were well below the long-term average (Table 2).

What happened?

Barley plant density

Even though the same seed rate was used in the normal (25 cm) and wide row (37.5 cm) treatments, barley plant density was 19% lower in the wide row spacing ($P<0.001$). This level of reduction in crop establishment is consistent with similar trials at Minnipa in wheat and barley. Barley establishment was not significantly influenced by seed boot treatment ($P=0.646$), which is in contrast to previous studies at Minnipa where splitter boot had between 9-13 % higher crop establishment in wheat and barley.

Table 1. Key management operations undertaken.

Operation	Details
Location	Minnipa, SA
Seedbank soil cores	April, 2021
Plot size	1.5 m x 10 m
Seeding date	7 June 2021
Fertiliser	At sowing - MAP (10:20) @ 55 kg/ha
Variety	Compass barley
Seeding rate	180 seeds/m^2
Herbicides	(i) Control (knockdown treatment only) (ii) Trifluralin 1.5 L/ha incorporated by sowing (IBS) (iii) Overwatch 1.25 L/ha (IBS) (iv) Boxer Gold 2.5 L/ha (IBS)

Table 2. Rainfall received at Minnipa in 2021 and the long-term average for the site (Bureau of Meteorology).

Month	Rainfall (mm)	
	2021	Long-term rainfall
Jan	18.0	11.5
Feb	16.2	14.7
Mar	9.6	18.6
Apr	2.6	15.8
May	21.8	27.5
Jun	72.4	37.8
Jul	53.4	35.0
Aug	29.2	38.2
Sep	4.4	26.8
Oct	26.2	21.8
Nov	101.4	19.6
Dec	3.0	18.4
Annual total	358.2	286.8
GSR total	*210*	*202.9*

Table 3. The effect of crop row spacing on ARG spike density (P=0.058)

Crop row spacing	ARG spike density (spikes/m^2)
25 cm	506
37.5 cm	573

Table 4. The effect of herbicide treatment on ARG spike density (P<0.001)

Herbicide treatment	ARG spike density (spikes/m^2)
Untreated control	979 d
Trifluralin 1.5 L/ha (IBS)	704 c
Overwatch 1.25 L/ha (IBS)	319 b
Boxer Gold 2.5 L/ha (IBS)	156 a

Table 5. Effect of crop row spacing on ARG seed production at Minnipa, 2020 in wheat and 2021 in barley, letters show significant difference P<0.05 within individual trial.

Row Spacings	2020 Wheat ARG seedbank (1218 seeds/m^2)	2021 Barley ARG seedbank (8101 seeds/m^2)
25 cm	5847 a	15991 a
37.5 cm	12653 b	22127 b
ARG reduction NR vs WR	*54%*	*28%*

Weeds

Herbicide treatment did not have a significant effect on barley plant density (P=0.181), indicating good crop safety of pre-emergent herbicide treatments applied. The average barley plant density in the trial was only 108 plants/m^2, which while quite low considering the seed rate used in the trial (180 seeds/m^2). However, barley density achieved was still suitable for this agro-ecological environment.

Seedbed utilisation (SBU)

Seedbed utilisation was not measured at this site in 2021 but was measured in detail in 2019 in a trial with identical row spacing and seed boot treatments. In the previous trial, the SBU percentage ranged from 6% for wide row spacing with narrow seed boot to 29% for the normal row spacing with the splitter seed boot.

Annual ryegrass seedbank and plant density

Assessment of soil cores for ARG seedbank showed that the average seedbank at the trial site was 8101 ± 1175 seeds/m^2. This level of ARG seedbank would be regarded as a heavy infestation and expected to cause significant crop yield losses.

As expected, herbicide treatment had a significant effect on ARG plant density (P<0.001). Row spacing (P=0.345) and seed boot treatments (P=0.437) did not have a significant effect on ARG plant density. Averaged across the row spacing and seed boot treatments, Trifluralin (769 ARG plants/m^2), Overwatch (359 ARG plants/m^2) and Boxer Gold (127 ARG plants/m^2) reduced ARG plant density by 30%, 67% and 88%, respectively compared to the untreated control (1092 ARG plants/m^2).

Annual ryegrass spike density and seed production

The density of ARG spikes was strongly influenced by barley row spacing (P=0.058), and the herbicide treatment (P<0.001). However, unlike previous wheat trials, there was no significant influence of the seed boot treatment on ARG spike density (P=0.467). Barley is well known for its prolific tillering capacity, which may have allowed a low SBU crop to cover the inter-row space to effectively compete with the ARG. The 25 cm row spacing had 12% lower ARG spike density than the 37.5 cm row spacing treatment (Table 3). The level of reduction in ARG spike density in narrower row spacing was much lower than the 43% reduction in ARG spike density observed in a similar trial at Minnipa with wheat. Boxer Gold reduced ARG spike density by 84% compared to the untreated control, whereas Trifluralin and Overwatch caused a 28% and 67% reduction in ARG spike density, respectively (Table 4).

Consistent with the spike density data, ARG seed production was significantly affected by the crop row spacing (P=0.001) and herbicide treatment (P<0.001). However, unlike previous work with wheat at Minnipa, seed boot treatment did not significantly influence ARG seed production in barley (P=0.273). At the normal row spacing (25 cm) ARG set 28% less than at the wide row spacing (37.5 cm). Reduction in ARG seed production by the narrower row spacing was roughly half of the difference observed previously with wheat (Table 5). These results indicate that in a less competitive crop such as wheat, crop architecture is even more important than with a more competitive crop like Compass barley.

ARG produced 33784 seeds/m^2 in the untreated control, which was reduced by 21% by Trifluralin (26521 seeds/m^2), 67% by Overwatch (11144 seeds/m^2), and 86% by Boxer Gold (4787 seeds/m^2) (Figure 1). All herbicide treatments had significantly lower ryegrass seed set than the untreated control. These results highlight the difficulty of eliminating ARG through the use of pre-emergence herbicides alone. Even in the most effective treatment of Boxer Gold in this trial, ARG was able to produce 4787 seeds/m^2. This level of ARG seed production would allow serious weed infestation in crops grown next year. This figure would be expected to be even higher in a less competitive barley such as Spartacus or a wheat crop. Therefore, growers need to consider integration of harvest weed seed control or other management tactics such as narrower row spacing and splitter boots to further reduce injection of ARG seeds into the seedbank.

Barley grain yield

Barley grain yield was significantly influenced by crop row spacing (P<0.001), and herbicide treatments (P<0.001). Seed boot treatments did not significantly influence barley grain yield (P=0.186). In 25 cm row spacing, barley produced 2.75 t/ha grain yield, which was significantly greater (9%) than the yield in 37.5 cm rows (2.53 t/ha).

Barley grain yield increased significantly in response to ARG control with herbicide treatments (Figure 2). Presence of ARG at 1092 plants/m^2 in the untreated control, reduced grain yield by 21% compared to Boxer Gold or 15% compared to Overwatch and 7% compared to trifluralin. In the previous wheat trial in 2020, a much lower ARG population reduced wheat yield by 30% compared to the most effective herbicide treatment. Such comparisons suggest that Compass barley is more tolerant of ARG than wheat. Barley yield response to herbicides represents a return on investment of 4.6:1 for Boxer Gold, 2.8:1 for Overwatch and 3.2:1 for trifluralin. Therefore, it was worth applying these herbicides despite their wide range of ARG control (Figure 1).

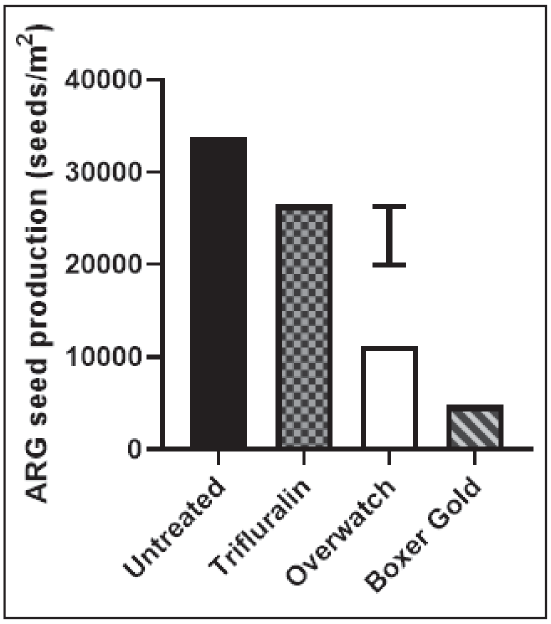

Figure 1. The effect of herbicide treatments on ryegrass seed production across all row spacing and seed boot treatments. The vertical bar represents the LSD (P=0.05).

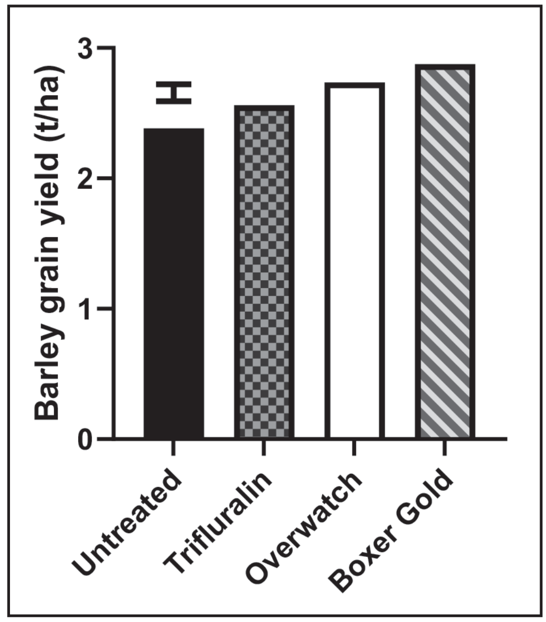

Figure 2. The effect of herbicide treatments on barley grain yield. The vertical bar represents the LSD (P=0.05).

Barley grain quality

Field trials were harvested at earliest opportunity, before substantial rains that resulted in poor quality issues across the region. Screenings percentage in barley grain was not influenced by any treatments (P>0.05). Small but significant differences in grain protein were achieved by herbicide treatments (P=0.003) relative to the untreated control (10.84%), but Overwatch (11.44%) was the only herbicide that had significantly higher grain protein than the untreated. Grain size (1000 grain weight) was significantly affected by crop row spacing treatment (P=0.048), where the wider 37.5 cm row spacing (40.12 g/1000 seeds) had 5% larger grain size than the 25 cm row spacing (38.31 g/1000 seeds). However this did not relate to yield with the narrower row spacing yielding 9% more barley.

What does this mean?

Barley crop establishment was significantly reduced in the wider row spacing treatments. This is most likely due to increased crop intra-row competition rather than fertiliser toxicity from reduced seed bed utilisation (SBU) as fertiliser was banded for crop safety and crop establishment was similar for the two seed boot treatments.

Herbicide treatments achieved varying levels of annual ryegrass (ARG) control with trifluralin reducing ARG plant density by 30%, Overwatch 67% and Boxer Gold 88% compared to untreated control (1092 ARG plants/m^2).

Improved crop competition in narrower row spacing was reflected in 28% lower ARG seed set in the 25 cm row spacing than the wider 37.5 cm row spacing. Even though Boxer Gold reduced ARG seed set by 86% compared to the control, ARG was still able to produce 4787 seeds/m^2. Such a high level of ARG seed production is likely to have a serious impact on crops grown next year. While the impact of crop row spacing and seed boot choice had less of an impact in a more competitive compass barley than had previously found in wheat, it showed value in suppressing ARG. This is of particular importance as pre-emergent herbicides alone are often not providing adequate ARG control to drive down paddock soil weed seed banks.

Acknowledgements

The authors thank Bruce and Kathryn Heddle for hosting the site. Malinee Thongmee Tina McIntosh (University of Adelaide), Craig Standley, Katrina Brands, Marina Mudge and Rebbecca Tonmey (SARDI) for their technical input to the trial. We also acknowledge the investment from GRDC for the research into 'Cultural management for weed control and maintenance of crop yield' (9175134).

Effect of sowing time x seed rate x herbicides on ryegrass management in barley at Minnipa

Ben Fleet[1], Gurjeet Gill[1], Amanda Cook[1,2] and Ian Richter[2]

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Key messages

- **Three week delay in seeding barley reduced annual ryegrass (ARG) plant density by 45% in the control (knockdown only) and by 28% for the weaker trifluralin treatment. However in the most effective herbicide treatments (Boxer Gold and Overwatch), high levels of ARG control was achieved in both TOS 1 and TOS 2.**
- **The interaction between sowing time and herbicide (P<0.001) was reflected in 45-50% lower ARG spike density in TOS 2 than in TOS 1 for the control and trifluralin treatments. However, no such effect of delayed sowing was observed for the more effective treatments of Boxer Gold and Overwatch that reduced ARG spike production by 81% and 78%, irrespective of sowing time.**
- **Barley seed rate did have a significant effect on ARG seed production (P=0.022) with crop sown at 150 and 200 seeds/m^2 having 29% and 21% lower ARG seed set than seed rate of 100 seeds/m^2. It is a serious cause for concern that ARG was able to set 7705 and 8700 seeds/m^2 in the most effective herbicide treatments Boxer Gold and Overwatch. These results highlight the need for growers to integrate tactics such as improved crop competitiveness and harvest weed seed control along with herbicides to achieve a decline in the seedbank of this difficult to manage weed.**
- **Herbicide treatment had a significant effect on barley grain yield with Trifluralin (1.99 t/ha) increasing grain yield by 16%, Overwatch (2.30 t/ha) 34% and Boxer Gold (2.33 t/ha) by 36% compared to the control (1.72 t/ha). These yield gains approximately equate to a 5:1 return on the cost of trifuralin, a 4.5:1 return on Overwatch and a 5.8:1 return on Boxer Gold.**

Why do the trial?

Change in crop sowing time can have multiple effects on crop-weed competition. Delayed sowing can provide opportunities to deplete weed seedbank before seeding the crop but weeds that establish in late sown crops can be more competitive on a per plant basis. This is one of reasons why farmers who have adopted early seeding have reported excellent results in crop yield and weed suppression. Therefore, it is important to investigate sowing time in combination with other practices across different rainfall zones. The review of Widderick *et al*. (2015) also recommended research on sowing time in many crops. Delayed sowing can also reduce crop yield so the gains made in weed control may be completely nullified by the yield penalty.

There has been some research already on the influence of crop seed rate on weed suppression but none of these studies have investigated the benefits of higher crop density in factorial combinations with sowing time and herbicide treatments. Crop seed rate is an easy tactic for the growers to adopt provided they are convinced of its benefits to weed management and profitability. Furthermore, growers in the low rainfall areas tend to be reluctant to increase their seed rate due to concerns about the negative impact of high seed rate on grain screenings.

This field trial at Minnipa was undertaken to investigate factorial combinations of sowing time, seed rate and herbicides on the management of annual ryegrass in barley.

How was it done?

This field trial investigated combinations of the following management tactics:

1. Sowing time (2 treatments): mid May and early June
2. Seed rate (3 treatments): 1x (200 seeds/m^2), 0.75x (150 seeds/m^2), 0.5x (100 seeds/m^2)
3. Herbicides (4 treatments):

(i) Nil (knockdown treatment only)
(ii) Trifluralin 1.5 L/ha IBS
(iii) Overwatch 1.25 L/ha IBS
(iv) Boxer Gold 2.5 L/ha IBS

Variety: Compass
Trial design: split plot design
Replicates: 3
Measurements: pre-sowing weed seedbank, crop density, weed density, ARG spike density, ARG seed production, wheat grain yield.

All data collected during the growing season was analysed using the Analysis of Variance function in GenStat version 20.

In 2021, annual rainfall received at Minnipa was 25% above the long-term average but the growing season rainfall was close to the long-term average.

Table 1. Key management operations undertaken.

Operation	Details
Location	Minnipa, SA
Seedbank soil cores	9 April, 2021
Plot size	1.5 m x 10 m
Seeding date	TOS 1: 20 May, 2021 TOS 2: 9 June, 2021
Fertiliser	At sowing – MAP (10:20) @ 55 kg/ha
Variety	Compass barley
Seeding rate	100 seeds/m² 150 seeds/m² 200 seeds/m²
Herbicides	20 May and 9 June 2021 (applied just before seeding) Boxer Gold 2.5 L/ha IBS Overwatch 1.25 L/ha IBS Trifluralin 1.5 L/ha IBS Control (knockdown treatment only)

Table 2. Rainfall received at Minnipa in 2021 and the long-term average for the site (Bureau of Meteorology).

Month	Rainfall (mm)	
	2021	Long-term rainfall
Jan	18.0	11.5
Feb	16.2	14.7
Mar	9.6	18.6
Apr	2.6	15.8
May	21.8	27.5
Jun	72.4	37.8
Jul	53.4	35.0
Aug	29.2	38.2
Sep	4.4	26.8
Oct	26.2	21.8
Nov	101.4	19.6
Dec	3.0	18.4
Annual total	358.2	286.8
GSR total	*210.0*	*202.9*

The rainfall received in June, July and November was greater than the long-term average with other months being close to average, except for April and September that were well below the long-term average (Table 2).

What happened?

Barley plant density

Barley establishment was affected by the interaction ($P<0.001$) between sowing time and seed rate (Figure 1). As a general trend, barley seedling establishment efficiency reduced as seed rate increased. There was clearer separation between the seed rate treatments in TOS 2 where SR200 had significantly higher barley plant density than in TOS 1. Higher crop establishment in TOS 2 than in TOS 1 might be associated with above-average rainfall received after sowing in June.

Annual ryegrass seedbank and plant density

The average seedbank of annual ryegrass (ARG) at the site was 7969 ± 2961 seeds/m^2. ARG plant density was significantly influenced by herbicide treatment ($P<0.001$) and the interaction between the time of sowing and herbicide ($P=0.001$).

There was a large impact of the 3 week delay in seeding barley on ARG plant density (Figure 2). This was particularly evident in the untreated control in which ARG density decreased from 1589 plants/m^2 in TOS 1 to 882 plants/m^2 in TOS 2 (45% reduction). This large response of ARG density to a three week delay in sowing is most likely related to rainfall events in May and early June, which would have caused weed emergence prior to knockdown herbicides at seeding (Figure 2). Minnipa population of ARG has low seed dormancy and emerges rapidly after rainfall events.

Weeds

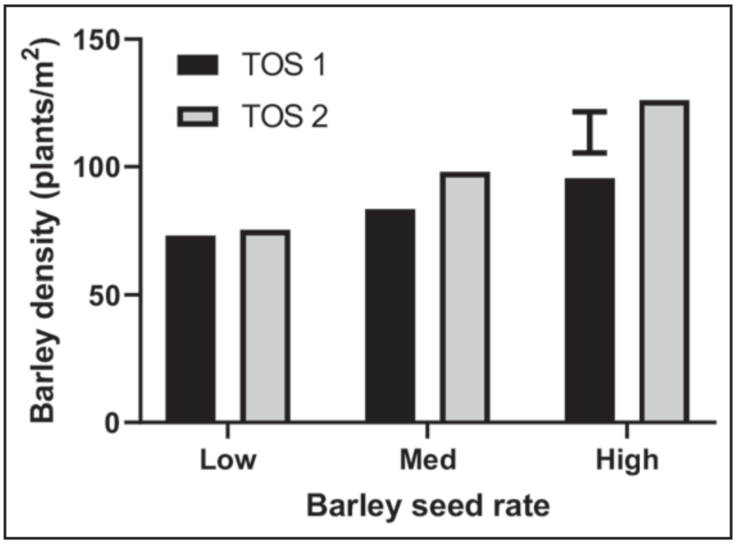

Figure 1. The effect of seed rate on barley plant density in time of sowing 1 (TOS 1) and time of sowing 2 (TOS 2). The vertical bar represents the LSD (P=0.05).

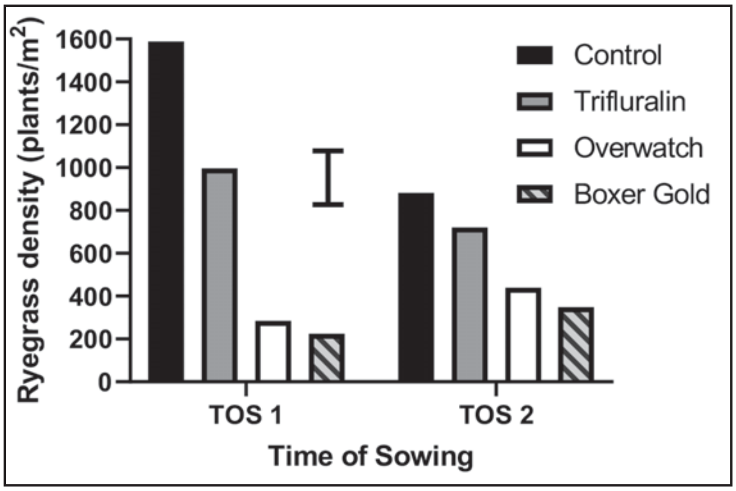

Figure 2. The interaction between the time of sowing and herbicide treatments (P<0.001). The vertical bar represents the LSD (P=0.05).

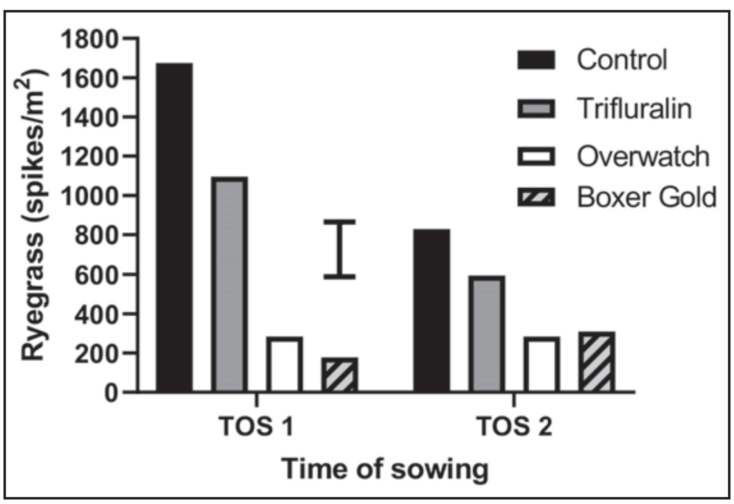

Figure 3. The effect of interaction between the time of sowing and herbicide treatments (P<0.001) on ARG spike density. The vertical bar represents the LSD (P=0.05).

The reduction in ARG plant density due to delayed seeding was also evident in the weaker trifluralin herbicide treatment (Figure 2) where TOS 2 had a 28% lower ARG density than TOS 1. However in the most effective herbicide treatments (Boxer Gold and Overwatch), high levels of ARG control were achieved in both TOS 1 and TOS 2, making any benefits from delayed sowing largely redundant.

Annual ryegrass spike density and seed production

ARG spike density was significantly influenced by the time of sowing (P=0.039), herbicide treatment (P<0.001) as well as the interaction between the TOS and herbicide treatment (P<0.001). However, there was no effect of barley seed rate on ARG spike density (P=0.307). When averaged across the seed rates and herbicide treatments, the three week delay in seeding at Minnipa reduced ARG spike density from 808 spikes/m^2 to 504 spikes/m^2 (38% reduction).

The interaction between sowing time and herbicide (P<0.001) followed a similar trend to ARG plant density, where TOS 2 had 45-50% lower ARG spike density than in TOS 1 for the control and trifluralin treatments. No such difference was observed for the two more effective herbicide treatments (Boxer Gold and Overwatch), where sowing time made no significant difference (Figure 3). These results clearly highlight the ability of Boxer Gold and Overwatch to manage the large ARG seedbank present at this site. ARG spike production across the site was reduced by 81% and 78% for Boxer Gold and Overwatch, respectively.

Consistent with the trends observed for ARG spike density, ARG seed production was also significantly influenced by the time of sowing (P=0.011), herbicide treatments (P<0.001) and the interaction between the TOS and the herbicide treatments (P<0.001). Barley seed rate did have a significant effect on ARG seed production (P=0.022) with crop sown at 150 and 200 seeds/m^2 having 29% and 21% lower ARG seed set than barley sown at 100 seeds/m^2, respectively. The interaction between sowing time and herbicide (P<0.001) followed a similar trend to both ARG plant and spike densities. TOS 2 had significantly lower ARG seed set than in TOS 1 for the control (57%) and trifluralin (55%). However, no reduction in ARG seed set in TOS 2 was detected for Overwatch and Boxer Gold treatments (Figure 4).

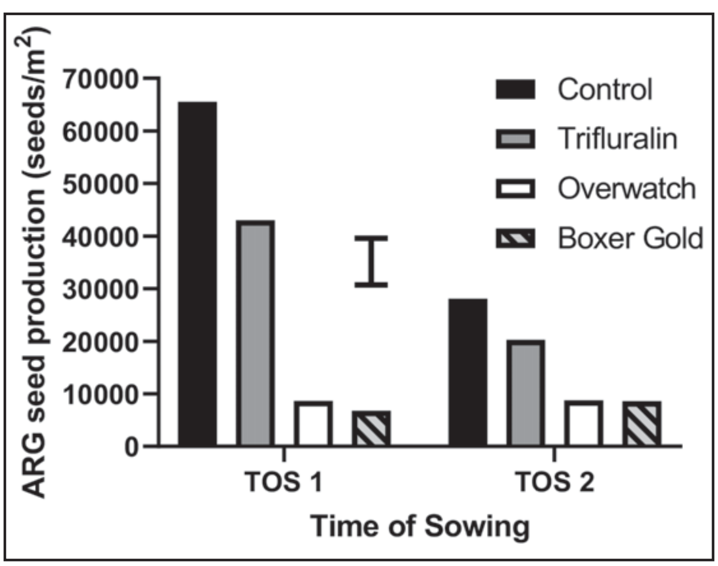

Figure 4. The effect of interaction between the time of sowing and herbicide treatments (P=0.001) on ARG seed production. The vertical bar represents the LSD (P=0.05).

These results clearly highlight the ability of Boxer Gold and Overwatch, under good soil moisture conditions, to manage high levels of ARG seedbank present at this site. It is somewhat alarming to note that ARG was able to set 7705 and 8700 ARG seeds even when treated with Boxer Gold or Overwatch. Therefore, a sizable seedbank of ARG will be present in the next crop grown in the rotation. These results highlight the need for growers to integrate tactics such as improved crop competitiveness and harvest weed seed control along with herbicides to cause a large decline in the seedbank of this difficult to manage weed.

Barley grain yield

Barley seed rate (P<0.001), and herbicide treatment (P<0.001) had a significant effect on grain yield. Barley yield increased as seed rate increased from low (1.84 t/ha), to medium (2.10 t/ha) and high (2.32 t/ha) (Figure 5). The increase in barley yield as seed rate increased from low to high was 26% and is consistent with previous trials in wheat and barley. Increased seed rate had no negative influence on the percentage of barley screenings; however barley screenings reduced with increased control of annual ryegrass with herbicides.

Herbicide treatment had a significant effect on barley grain yield with Trifluralin (1.99 t/ha) increasing grain yield by 16%, Overwatch (2.30 t/ha) 34% and Boxer Gold (2.33 t/ha) by 36% compared to the control (1.72 t/ha) (Figure 6). These yield gains approximately equate to a 5:1 return on the cost of trifuralin, a 4.5:1 return on Overwatch and a 5.8:1 return on Boxer Gold.

The three week delay in sowing barley did result in a small, but significantly increase in grain yield (P=0.028). This is in complete contrast to a similar trial on wheat in 2018 where a 6 week delay in sowing reduced wheat grain yield by 36%, however, these results from 2021 are similar to 2019 barley trial where a three week delay did not significantly affect barley yield (P=0.644).

This lack of impact from delay in sowing barley on its yield is most likely related to its greater early vigour and earlier maturity (i.e. shorter life-cycle) than wheat. These results give some confidence in using a short delay in sowing barley to achieve ARG control compared to wheat, however the cost of that delay would be dependent on seasonal conditions and the variety of barley grown. Compass barley grown in this trial is quite weed competitive and well adapted to a short growing seasons.

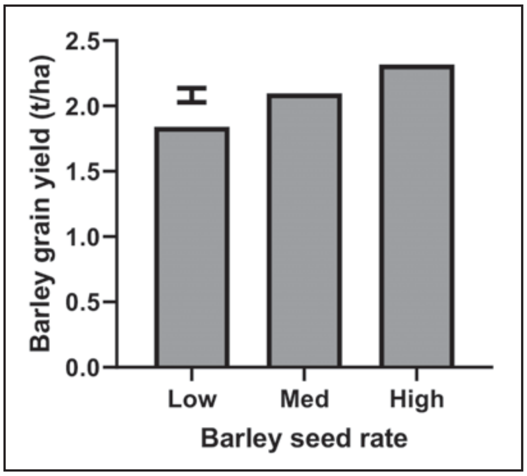

Figure 5. The effect of barley seed rate treatments (P<0.001) on barley grain yield. The vertical bar represents the LSD (P=0.05).

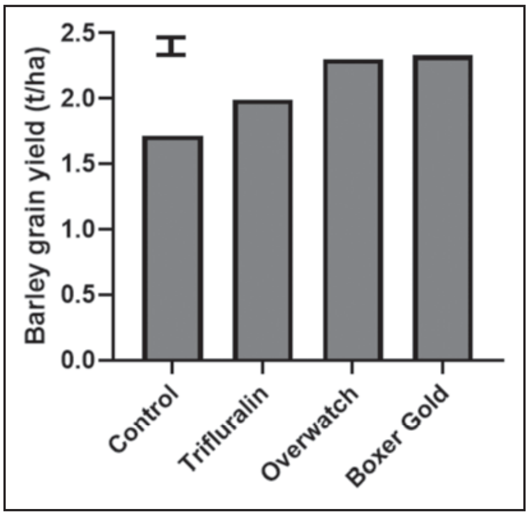

Figure 6. The effect of herbicide treatments (P<0.001) on barley grain yield. The vertical bar represents the LSD (P=0.05).

If a long season barley like Planet or less competitive barley like Spartacus was grown, the penalty from delayed seeding could be larger.

What does this mean?

Three week delay in seeding barley reduced annual ryegrass (ARG) plant density by 45% in the control (knockdown only) and by 28% for the weaker trifluralin treatment. However in the most effective herbicide treatments (Boxer Gold and Overwatch), high levels of ARG control were achieved in both TOS 1 and TOS 2. The interaction between sowing time and herbicide (P<0.001) was reflected in 45-50% lower ARG spike density in TOS 2 than in TOS 1 for the control and trifluralin treatments. However, no such effect of delayed sowing was observed for the more effective treatments of Boxer Gold and Overwatch that reduced ARG spike production by 81% and 78%, irrespective of sowing time. Barley seed rate did have a significant effect on ARG seed production (P=0.022) with crop sown at 150 and 200 seeds/m^2 having 29% and 21% lower ARG seed set than seed rate of 100 seeds/m^2. It is a serious cause for concern that ARG was able to set 7705 and 8700 seeds/m^2 in the most effective herbicide treatments Boxer Gold and Overwatch. These results highlight the need for growers to integrate tactics such as improved crop competitiveness and harvest weed seed control along with herbicides to achieve a decline in the seedbank of this difficult to manage weed. Herbicide treatment had a significant effect on barley grain yield with Trifluralin (1.99 t/ha) increasing grain yield by 16%, Overwatch (2.30 t/ha) 34% and Boxer Gold (2.33 t/ha) by 36% compared to the control (1.72 t/ha). These yield gains approximately equate to a 5:1 return on the cost of trifuralin, a 4.5:1 return on Overwatch and a 5.8:1 return on Boxer Gold.

Acknowledgement

The authors thank Bruce and Kathryn Heddle for hosting the site. Malinee Thongmee, Tina McIntosh (University of Adelaide), Craig Standley, Katrina Brands, Marina Mudge and Rebbecca Tomney (SARDI) for their technical input to the trial. We also acknowledge the investment from GRDC for the research into 'Cultural management for weed control and maintenance of crop yield' (9175134).

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Government of South Australia
Department of Primary Industries and Regions

SARDI
SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE

Demonstrating adaptive cropping systems to improve crop competition

Amanda Cook[1,2], Ian Richter[1], Bruce Heddle[3], Andrew Polkinghorne[4] and Tim Polkinghorne[4]

[1]SARDI, Minnipa; [2]University of Adelaide Affiliate Associate Lecturer; [3]Farmer, Minnipa; [4]Farmer, Lock.

Location
Lock
A & J and T & E Polkinghorne
Rainfall
Av. Annual: 336 mm
Av GSR: 250 mm
2021 Total: 352 mm
2021 GSR: 242 mm
Soil type
Red loam flats and sand hills
Demonstration size
8 rows of splitter boot x 4 measurements on each soil type. Disc seeder, 12 m width x 4 measurements

Location
Minnipa
B & K Heddle
Rainfall
Av. Annual: 324 mm
Av GSR: 241 mm
2021 Total: 406 mm
2021 GSR: 248 mm
Soil type
Red sandy loam and grey loam rise
Plot size
27 m wide paddock seeder strips x 4 measurements

Key messages

- **Crop establishment in 2021 was better in a no-row cropping system in a poor production zone at Minnipa.**
- **At Lock in 2021 cereal establishment was better using Stilletto splitter boots in 30 cm row spacings and also better using a single disc system with 25 cm row spacing, compared to a single boot 30 cm system.**
- **In 2021 ryegrass populations were the same for all seeding systems but there were higher weed populations in the poorer soil zones.**
- **In both seasons at Lock, splitter boots resulted in better wheat establishment in the sandy soil which may be an important management tool for light fragile soils.**

Why do the trial?

A NLP2 Smart Farms grant (4-BA9KBX5) was received in October 2019 through EPARF, now AIR EP, to demonstrate different cropping systems which increase crop competition with weeds, including splitter boots and narrower row spacings. Two demonstration sites were established in both 2020 and 2021 to evaluate seeding systems with increased seed 'spread' using splitter boots for the prospect of better weed competition and better cover for fragile soils.

How was it done?

Two farmer implemented demonstrations were undertaken in 2021.

The sites and treatments were:

- Minnipa (Bruce Heddle); 30 cm tine spacings with splitter boots resulting in 25 cm row spacings, and a no-row spacing seeding system. The no-row system was chosen to control woody weeds at seeding and increase crop competition against grass weeds.
- Lock (Andrew and Tim Polkinghorne); Seedhawk® on 30 cm tine spacings, either with Stilletto® splitter boots (resulting in 25 cm row spacings) or with 30 cm single narrow boots, or a Bourgault® single disc system on 25 cm row spacings.

The demonstration at each site was conducted over two soil types, a red loam and a sandier rise. The rise was a grey loam at Minnipa and a white sand at Lock. The demonstration strips were managed the same as the whole paddock by the grower using current best practice.

Crop establishment, grass weed numbers (early and late), dry matter (early and late), grain yield and grain quality were assessed.

What happened?

Late opening rains were received in late May/early June 2021 at both sites which resulted in seeding later than the ideal sowing window in the upper EP environment. June and July had above average rainfall resulting in good crop growth until August, but little rainfall in September resulted in crop stress at the critical timing of flowering and seed fill. Late October rainfall was too late to have a positive impact on earlier sown crops in the region but had some benefit on later crops.

Table 1: Wheat performance and grass weed numbers in two seeding systems on two soil types at Minnipa, 2021.

Soil type	Seeding system	Wheat establishment (plants/m²)	Early ryegrass (plants/m²)	Early wheat biomass (t/ha)	Late ryegrass (plants/m²)	Late wheat biomass (t/ha)	Yield (t/ha)	Protein (%)
Red Loam	Splitter boots	121 b	25	0.34	17	7.2	2.0 c	14.2
	No rows	124 b	10	0.40	7	6.5	2.9 a	11.2
Grey Loam	Splitter boots	167 a	17	0.13	37	5.6	1.9 c	10.8
	No rows	102 b	16	0.12	34	5.4	2.3 b	10.5
Seeding system x Soil type	*LSD (P=0.05)*	*27*	*ns*	*ns*	*ns*	*ns*	*0.2*	-

Table 2: Wheat performance and grass weed numbers on two soil types at Minnipa, 2021 (averaged over both seeding systems).

Soil type	Wheat establishment (plants/m²)	Early ryegrass (plants/m²)	Early wheat biomass (t/ha)	Late ryegrass (plants/m²)	Late wheat biomass (t/ha)	Yield (t/ha)	Protein (%)
Red Loam	122	17	0.37	12	6.9	2.44	12.7
Grey Loam	134	16	0.13	36	5.5	2.09	10.7
LSD (P=0.05)	*ns*	*ns*	*0.9*	*11.4*	*0.9*	*0.12*	-

Table 3. Wheat performance and grass weeds in seeding systems and soil types at Lock, 2021.

Soil type	Seeding system	Wheat (plants/m²)	Early ryegrass (weeds/m²)	Early wheat dry matter (t/ha)	Late ryegrass (weeds/m²)	Late wheat dry matter (t/ha)	Yield (t/ha)	Protein (%)
Heavy Red Loam	30 cm single row	98 b	69	0.10 d	360	4.6	1.92	13.8
	30 cm Stilletto splitter boot (25 cm row spacing)	88 c	67	0.13 cd	198	5.0	2.03	14.3
Sandy rise	30 cm single row	100 b	6	0.18 b	27	7.2	3.65	10.9
	30 cm with Stilletto splitter boot (25 cm row spacing)	129 a	29	0.45 a	11	9.1	4.32	12.1
	25 cm single disc	122 a	11	0.15 bc	5	11.6	4.54	14.0
Seeding system x Soil type	*LSD (P=0.05)*	*8*	*ns*	*0.04*	*ns*	*ns*	*ns*	-

Table 4: Wheat performance and grass weed numbers on two soil types at Lock, 2021.

Soil type	Wheat establishment (plants/m²)	Early ryegrass (plants/m²)	Early wheat biomass (t/ha)	Late ryegrass (plants/m²)	Late wheat biomass (t/ha)	Yield (t/ha)	Protein (%)
Heavy Red Loam	93	68	0.11	279	4.79	1.97	14.1
Sandy rise	110	16	0.28	16	8.82	4.09	12.3
LSD (P=0.05)	*5*	*12*	*0.03*	*78*	*1.07*	*0.52*	-

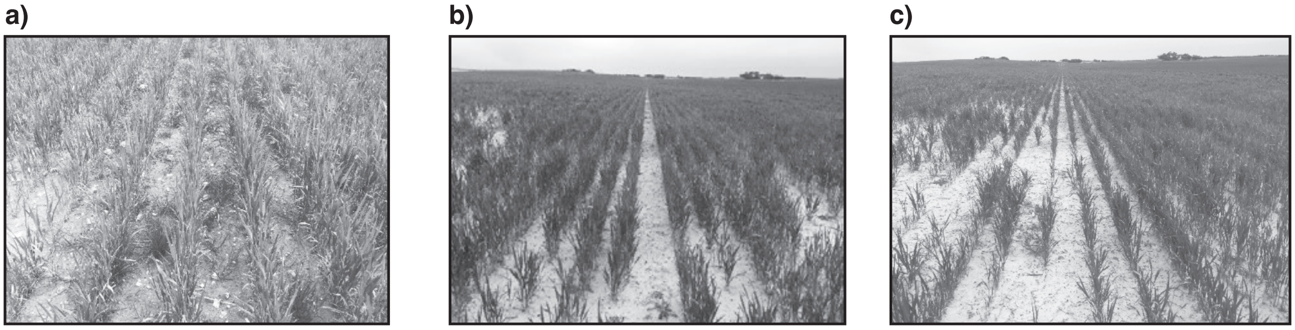

Figure 1. Three different seeding systems at Lock in 2021, (a) Lock red loam - single row (left) and splitter boot (right), (b) Lock sand - splitter boot middle eight rows (larger gap is edge of seeder run), rest is single row and (c) Lock sand - single row disc system.

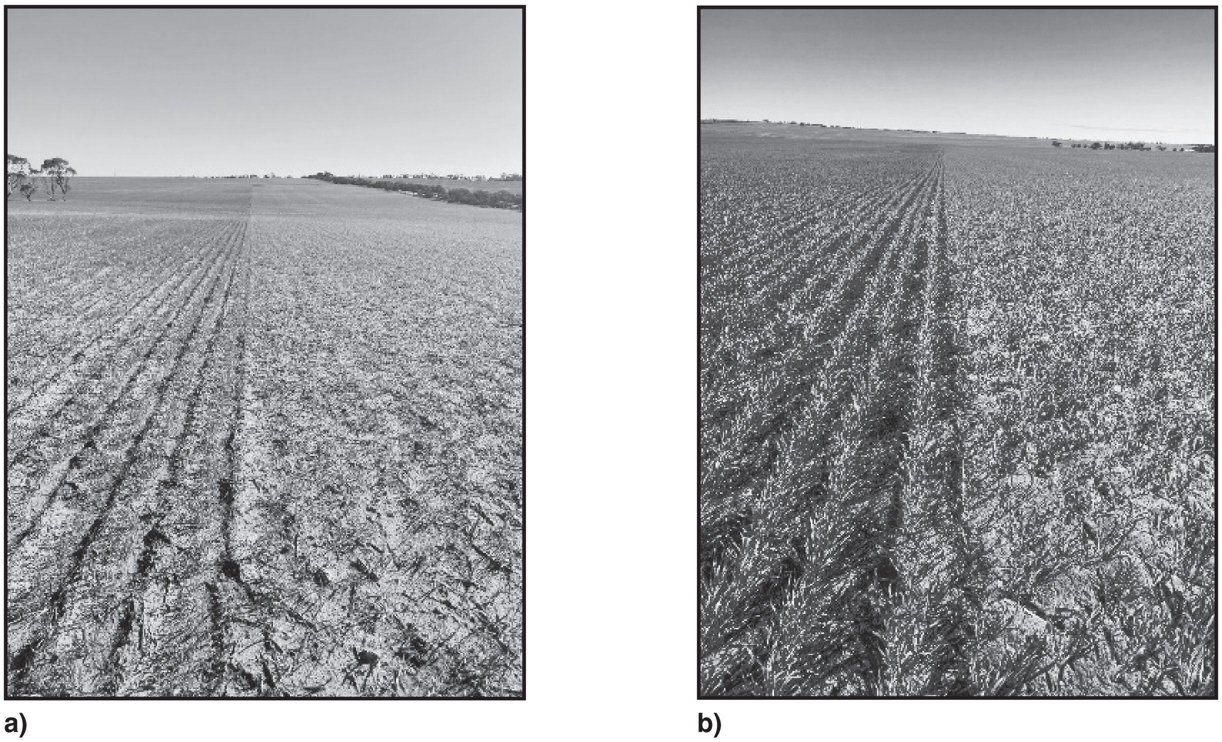

Figure 2. Two different seeding systems at Minnipa in 2021. 30 cm with splitter boot system (left) and no row seeding system (right). (a) sandy rise, (b) red loam.

Minnipa

At Minnipa crop establishment was higher in the no-row system in the grey soil type (Table 1). The poor paddock zone is a greyer soil type on top of a rise and the good zone is a red sandy loam. There were no differences in early or late ryegrass numbers between the seeding systems in the two soil types at Minnipa (Table 1). The poor paddock zone had higher weed numbers than the good zone (Table 2).

There were no differences in early or late crop dry matter between seeding systems, but again the good red loam soil zone had higher late dry matter than the poorer zone (Table 1).

Grain yield at Minnipa was higher in the no-row system on the red loam. Grain protein was also higher in the good zone compared to the poor zone (Table 1).

Lock

At Lock wheat establishment was better with Stilletto splitter boots (25 cm row spacing) and the 25 cm single disc system, than the 30 cm single row (Table 3) on the sandy rise. In the heavier red loam wheat establishment was greater in the single row than with Stilletto splitter boots.

Early and late ryegrass numbers were the same for all seeding systems on each soil type at Lock (Table 3), although the heavier red loam soil had much higher weed numbers overall than the sandy soil (Table 4).

Early crop dry matter was higher with Stilletto splitter boots on the sandy rise (Table 3) but by flowering, crop biomass was the same for all seeding systems. Crop biomass was higher at flowering on the sandy rise than on the heavy red loam flat.

Similar grain yields were produced with all seeding systems on both soil types (Table 3 and 4). Grain protein was higher on the heavier red loam (14.1%) compared to the sand (12.3%) (Table 3).

What does this mean?

The two seasons of the paddock scale demonstrations showed:

- In 2021 crop establishment was higher in the no-row system in the sandy rise at Minnipa.
- In 2021 at Lock cereal establishment was higher with Stilletto splitter boots and the 25 cm single disc system, compared to the 30 cm single row.
- In 2021 there were no differences in ryegrass populations between the seeding systems but there were differences in weed numbers and potential weed seed set between the soil zones in the paddocks.
- In 2020 at Minnipa establishment counts were lower in the no-row system due to herbicide damage.
- At Lock in 2020 early ryegrass numbers were lower in the split row seeding system on the red loam supporting previous research that increasing crop competition is a management tool to lower grass weed numbers. Late grass weed numbers and seed set were similar in both seeding systems.
- In both seasons at Lock there was better wheat establishment in the sandy soil with the splitter boot which may be an important management tool in light fragile soils.

Acknowledgements

Thanks to the growers for implementing and hosting the seeding systems demonstrations.
This extension demonstration funded through AIR EP/EPARF was possible via NLP2 SFSG2 grants investment in project 4-BA9KBX5. Thank you to Katrina Brands and Marina Mudge for processing samples.

Bruce Heddle, Amanda Cook and Andrew Polkinghorne speaking at Minnipa Field Day, September 2021.

Section 7

Section Editor:
Phil Davies
SARDI, Waite

Pastures

Dryland Legume Pasture Systems (DLPS): New pasture cultivars

David Peck[1,3], Fiona Tomney[2], Jeff Hill[1], Kym Zeppel[2] and Ross Ballard[1,3]
[1]SARDI, Waite; [2]SARDI, Minnipa; [3]University of Adelaide Affiliate

Key points

- **Seraph (PM-250), a powdery mildew (PM) resistant strand medic, is commercially available.**
- **Evaluation of spineless burr medics is well advanced, and it is expected that a line will be chosen as a cultivar in autumn 2022.**
- **An arrowleaf clover selection is very promising, showing a 30% increase in dry matter over current variety Cefalu.**
- **A hardseeded Trigonella balansae may be chosen as a cultivar in autumn 2022.**
- **Disc and strand medics with increased ability to fix nitrogen are being developed.**

Why do the trial?

New ley pasture legume cultivars are being developed to increase pasture adoption and production and thus benefit livestock and subsequent grain crops.

Ley legume pasture cultivars need to have appropriate hardseed levels so that they can persist through 1 to 3 years of crops. They are often bred to overcome significant soil or management constraints. Several other selection criteria include:

1. Seed harvestability and seedling vigour.
2. Seasonal herbage production and N fixation.
3. Time of flowering.
4. Seed production.
5. Suitability for livestock grazing and production, and subsequent grain crops.
6. Tolerance to common soil constraints.
7. Suitable hardseed level.
8. Tolerance to pests and diseases.

We have focused on legume species that perform well on neutral to alkaline soils as these soils are widespread in the low/medium rainfall zones of South Australia and Victoria. Included are traditional medic species and alternative species such as arrowleaf clover that can have seed harvested with grain harvesters. The highest pasture production occurs when the best cultivar of a species, that is well adapted to the soil type and growing season, is combined with good agronomy. This article provides an overview of breeding components of the DLPS project from the southern node and a short overview of breeding components of the western node. It provides details of a new cultivar, advanced cohorts and provides an update on pipeline material.

How was it done?

Once traits of interest, such as tolerance to a disease or soil constraint, are identified and tolerant material developed, agronomic evaluation is undertaken in multiple target environments to ensure prospective new cultivars are suitably adapted and productive. Initially, a source of tolerance to the constraint has to be identified and is often found by screening diverse genotypes obtained from The Australian Pasture Genebank (APG). Often the accession with the required trait needs to be crossed with other cultivars/accessions to develop lines that combine the new trait with high agronomic performance.

This project has built on the foundations of previous selection and pre-breeding work. Further, in the first year of the project speed breeding methods (up to six generations per year instead of 1-2 generations) were used to generate the material for field evaluation. For each breeding target the material has been evaluated on relevant soil types (eg. sandy or loamy) across the upper EP, Murray Mallee and parts of the mid-North.

What happened?

Seraph strand medic

Seraph strand medic was commercially available in a limited amount in autumn 2021 and will be readily available in 2022. Seraph has featured in all the DLPS species adaptation, agronomic work, and grazing studies where it was referred to by its breeding code PM-250. The main objective in the development of Seraph was resistance to powdery mildew (PM) which is a widespread disease of annual medics. PM is particularly common in springs following wet summers/autumns. In addition to infected swards being less productive, livestock are known to avoid PM infected medics resulting in reduced livestock growth and fertility. The PM resistant parent was highly productive in its own right and contributed to Seraph achieving increased dry matter production. Even in the absence of PM, averaged across many sites Seraph medic delivered a 15% increase in dry matter production compared to the cultivar (Angel) it replaced. Seraph is also tolerant of SU and Intervix herbicide residues and resistant to bluegreen aphids (BGA). Seraph strand medic is recommended for neutral to alkaline sandy loam soils.

Spineless Burr medics

The DLPS project is evaluating two spineless burr medic cohorts: 1) tolerant of boron (B) and 2) tolerant to red legged earth mites (RLEM). A prior MLA pre-breeding project had screened accessions from the Australian Pastures Genebank (APG) and identified tolerant accessions.

High levels of B are common in the subsoil in neutral to alkaline soils. Although B tolerant cereals, pulses, barrel and strand medics have been developed, all existing burr medic cultivars are intolerant. Speed breeding was used to develop a cohort of B tolerant lines and they have been evaluated in the mid-north, Minnipa, NSW and WA. Their relative B tolerance has been confirmed in glasshouse screens. A short list of five lines is being considered, from which a line will be selected for cultivar release in autumn 2022.

RLEM is a widespread pest of pasture legumes as well as many crops. RLEM are particularly damaging to emerging pastures. Damage is seen as silvering on cotyledons and leaves. Due to the widespread occurrence of RLEM combined with increasing reports of insecticide resistance, efforts have been directed at the development of a tolerant cultivar. A spiny accession highly resistant to RLEM was crossed with a spineless resistant accession. We selected spineless plants with high dry matter production and early flowering. Initial field evaluation was used to shortlist lines and screen for RLEM tolerance and B tolerance. All lines were found to be tolerant to RLEM. Two lines have been short listed with high agronomic performance and RLEM tolerance.

Trigonella

Trigonella balansae, a species closely related to annual medic, can hold its pods and approximately 50% of its seed can be harvested with a grain harvester. In historic work APG5045 was identified as having the best agronomic performance but its hardseed levels are too low (~30%) for a ley legume pasture (for medics we aim for 70-90%). In the DLPS project it was included in most legume species adaptation trials, agronomy trials and the Minnipa grazing trials. In general, it failed to regenerate after a single wheat crop supporting the original assessment that its hardseed levels are too low. Two rounds of selection for increased hardseed have subsequently been completed. The new lines have performed well for production in the field in 2020 and 2021. At the end of autumn 2022 we will complete hardseed studies and regeneration counts after the 2021 wheat crop. Data will be reviewed to determine if any of the lines are suitable as a cultivar.

Trigonella is a new species for agriculture and before releasing a cultivar, it needs to pass a grazing study which measures animal performance, animal health and meat tasting. This DLPS work is being led by CSIRO (Perth) and needs to be completed before a decision about cultivar release is made.

Arrowleaf clover

Arrowleaf clover is used in NSW as a ley legume option on mixed farms. Its seed can be aerial harvested. While the earliest flowering cultivar is relatively late flowering it has produced a high amount of DM late in the season which is valuable in finishing lambs. However its winter dry matter is relatively low. In species adaptation trials it has performed well on alkaline soils. It is reported as growing well on a wide range of pH, it is deep rooted and grows well above perched water tables at 1-2 m (may be useful above a saline seep). An earlier cultivar would expand the area where it can be grown, especially on low rainfall mixed farms. Selections from a range of wild material have been made with the aim of earlier flowering with increased winter dry matter production. Field evaluation in 2021 has shown that the new line had ~30% increased dry matter compared to Cefalu throughout the year. Hardseed studies will be completed in late autumn 2022 and a decision made on suitability for cultivar release. The line looks promising and is likely to expand the area that can grow arrowleaf as well as increasing its dry matter production.

Disc and strand medics with increased nitrogen fixation

Disc medics are well adapted to deep alkaline sandy soils. Historically the cultivars Tornafield and Toreador were sold, but no cultivar is currently commercially available. Disc medics have consistently performed well on sandy sites in DLPS adaptation trials.

Previously, a survey of soils has shown that many soils where medics are grown contain rhizobia that form symbioses that are sub-optimal for N fixation and limit legume dry matter production compared to the current commercial rhizobia strain. Pre-breeding work identified an accession (from the APG) that more frequently forms effective N fixation symbioses. The line has been used to develop a cohort of disc and strand medics with increased ability to form effective relationships with rhizobia strains. They have had limited field evaluation, but their agronomic performance is promising. In early 2022 we will test lines with a range of rhizobia strains to find the lines best able to form effective rhizobia relationships. Short listed lines will then be tested with rhizobia from a range of soils. It is expected that by the end of the DLPS project we will have demonstrated the potential of the trait and shortlisted lines for cultivar release. It is likely that further work is required to complete cultivar development. If we can demonstrate success with this work the approach can be used for other pasture legumes species and pulses.

Cultivar development from the Western Node of DLPS

The western node of the DLPS project is also developing new cultivars. The western node has a focus on species adapted to acidic soils but also includes species for mildly acidic to neutral soils. Cultivar development is advanced for French serradella, early bladder clover and early trigonella.

Murdoch University (western node of DLPS) developed Frano French serradella to be earlier flowering than the cultivar Margurita. It was made commercially available in autumn 2021. Frano is expected to have a large uptake on acidic deep sandy soils in WA and NSW. In SA and Victoria it is expected to have niche role to play on acidic to neutral sandy soils. Like Margurita, Frano pods can be harvested with a grain harvester and planted at 0.5 -1 cm depth in February to allow for seed to soften and establish with opening rain. The pods of this species must be below the soil surface as light inhibits seed softening.

Fiona Tomney and Brianna Guidera presenting pastures research at the Minnipa Field Day, Septemer 2021.

What does it mean?

Ley legume pasture cultivars have been widely adopted on low rainfall mixed farms. The success of future cultivars depends on their suitability to both the grazing and cropping phases in complex mixed farming systems. New cultivars that are being developed to address widespread constraints must also equal or surpass the range of other selection criteria satisfied by existing pasture cultivars. Key attributes of the new cultivars being developed include: larger seed size for early vigour (Seraph, strand and disc medics); increased herbage production (Seraph medic and arrowleaf clover); increased N-fixation (strand and disc medics); tolerance to common soil constraints (B tolerant spineless burr medics, SU and Intervix herbicide residue tolerance in strand and disc medics); increased hardseed levels for ley farming (trigonella, arrowleaf clover); pest tolerance (RLEM spineless burr medics, BGA tolerance in Seraph) and disease resistance (Seraph is resistant to PM).

Seraph strand medic is commercially available. We expect to identify a spineless burr medic and arrowleaf clover in autumn 2022 as suitable for cultivar release. Trigonella is a promising new pasture species but needs to pass duty of care studies before a line for cultivar release can be chosen. New cultivars need 2-3 years of pre-commercial seed increase before they will be commercially available. With the ever-increasing cost of nitrogen fertiliser, it is more important than ever that N fixation is maximised. We hope to have demonstrated increased N fixation in strand and disc medics. Best legume pastures are obtained by sowing the best cultivars for the environment combined with the best agronomy.

Acknowledgments

SAGIT invested in the development of Seraph through projects S1310R and S1213 and GRDC invested in the development of Seraph through project DAS00042.

The MLA pre-breeding project B.PBE.0037 identified B & RLEM parents and developed the speed breeding method.

APG as source of donor parents.

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Dryland Legume Pasture Systems (DLPS): Adaptive pasture sowing strategies to overcome a shifting seasonal break

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Location
Lameroo
Robert Pocock
Rainfall
Av. Annual: 382 mm
Av. GSR: 270 mm
2021 Total: 267 mm
2021 GSR: 170 mm
Yield
French/Schultz yield potential: 1.84 t/ha
Actual 2021 control yield: 1.85 t/ha
Paddock history
2020: Lupin/vetch mix
2019: Barley
2018: Wheat
Soil type
Deep sand
Soil test
pH $CaCl_2$ 7 at 0-10 cm
Profile mineral N (2021 continuous cereal treatment) 77 N kg/ha
Colwell P 22 mg/kg 0 -10 cm
S KCl 6 mg/kg at 0-10 cm
OC 0.6% at 0-10 cm
Salinity Ec 1:5 0.1 dS/m 0-10 cm
Plot size
15 m x 1.68 m x 4 reps
Trial design
Experimental: randomised complete block
Yield limiting factors
Late start of growing season (26 May): impact moderate, below average GSR

Key messages

- **Analysis of the seasonal break indicates that there has been increasing summer rain and later autumn sowing breaks in the last 30 years for much of the southern and western Australian wheatbelt.**
- **Biomass production was higher for summer-sown trigonella and medic compared to autumn-sown at Lameroo in the 2020 growing season.**
- **Weed density was greatest in summer sown (13 weeds/m²) and twin-sown (8 weeds/m²), compared to autumn-sown (3 weeds/m²) pastures.**
- **Bladder clover and trigonella biomass production was competitive with medic at autumn sowing.**
- **There is potential to sow productive novel legume pastures and establish a pasture seedbank while still achieving a substantial crop 'break effect'.**

Why do the trial?

Delays in the seasonal break and plant establishment can result in continued summer-autumn feed gaps requiring supplementary feeding and reduced grazing during the winter period when cool temperatures slow pasture growth. A shift towards early sowing systems and a drying trend in autumn in southern Australia are changing traditional farming systems, and growers need adaptive genetic and management strategies for plant establishment that do not rely on the seasonal break. A recent analysis has revealed spatial and seasonal variability in the seasonal break with the earliest median seasonal break (27 March) in New South Wales (NSW) and Victoria, and the latest (3 June) in Western Australia (WA). Notably the Mid-north, York and Eyre regions have experienced a median 8 day delay in seasonal break (Figure 1).

On mixed livestock-cropping farms where sowing of pasture phases can clash with main season cropping programs, novel management may include the use of unscarified 'hardseed' of adapted pasture cultivar options, sown either in late summer (summer sowing) or with the previous crop (twin sowing) (Nutt *et al*. 2021). Novel pasture sowing systems avoid peak crop sowing times, reduce establishment costs and can increase early season feed supply but have had limited evaluation in the SA medium-low rainfall environment. As part of the DLPS (Dryland Legume Pasture Systems) project, summer and twin sowing methods using unscarified hardseed have also been evaluated in Waikerie, SA and Piangil, Victoria. This paper focuses on results from Lameroo in 2020 and 2021 growing seasons. Results from Waikerie in 2019 and 2020 are reported in EPFSS 2020 p. 201. EPFSS 2020 p. 211 reports harvesting seeds/pods of novel legumes and EPFSS 2021 p. 219 reports on harvesting medic pods.

Aim: Evaluation of the suitability of different pasture legume species for establishment using summer and twin sowing methods that provide growers with greater flexibility in pasture establishment, and assessment of grain yield benefit after a 1 year pasture phase.

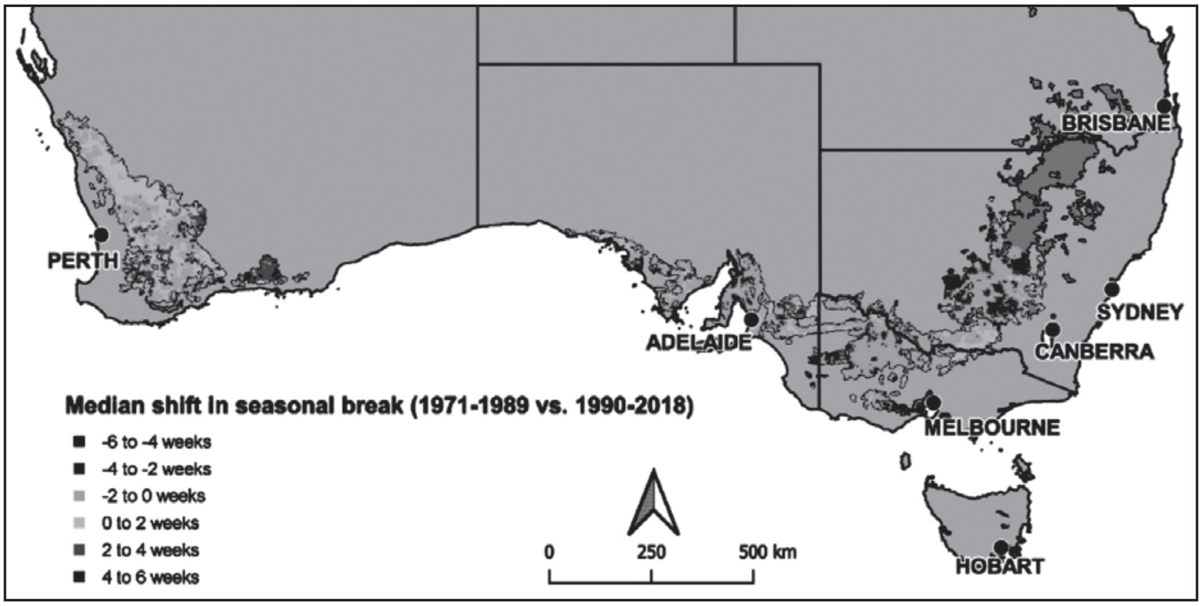

Figure 1. Median shift in seasonal break between the periods two 1971-1989 and 1990-2018 in cropping regions throughout southern and western Australia based on the 7-day rolling sum of the rainfall:evaporation ratio **(Flohr et al*. 2021).***

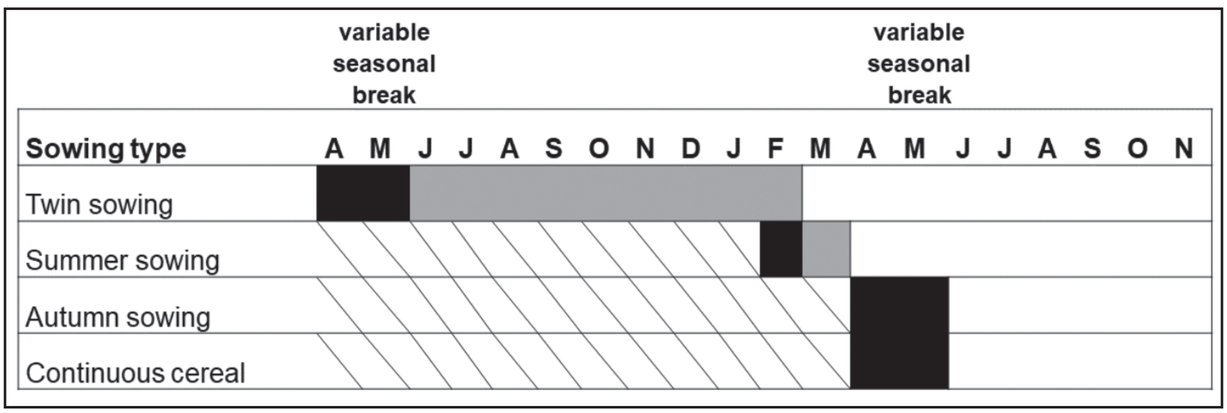

Figure 2. Timeline of sowing date (black shading), hard seed breakdown (grey shading) and plant growth period (white) of pasture sowing methods tested.

How was it done?

Seasonal break modelling

A seasonal break is deemed to occur when the sum of rainfall over any 7-day period exceeded pan evaporation over the same period after 1 March. The seasonal break was analysed for each of the DLPS experimental sites.

Novel pasture sowing methods

Three pasture sowing methods were evaluated at Lameroo (2020) and included legume pasture species that have not been traditionally grown in the region. Soil type at Lameroo is sand (0-10 cm pH $CaCl_2$ is 7). Sowing methods evaluated were: a) twin-sowing (20 May 2019), where 'hard' pasture seed/pod was sown with wheat seed in 2019 for 2020 pasture establishment; b) summer-sowing (18 February 2020), where hard seed/pod was at a depth of 2 cm in February to establish on the autumn break; and c) autumn-sowing (control treatment representing farmer practice, 28 April 2020), where scarified germinable seed was sown on the break of the season (Figure 2). Pasture treatments were compared to system controls of autumn sown brown manure vetch (terminated 15 September 2020), long fallow (16-month chemical fallow) and continuous cereal.

At each site, pasture and weed densities were recorded in June, and multiple measures of biomass production were recorded July-November. At the November biomass recording a seed set estimate was made by sieving seed from biomass and surface soil in the quadrant area. The sowing rates for the legumes are reported in Table 1 and all legumes were inoculated with their specific rhizobia group using peat slurry. Granular inoculant (ALOSCA) was also sown with each legume at a rate of 10 kg/ha. The residual effects of the pasture treatments implemented in 2020 were measured at Lameroo in 2021 when plots were sown to wheat (cv. Scepter) on 26 May 2021 with 20 N kg/ha, and pests and diseases were managed for maximum yield. Plant establishment, biomass production and grain yield were analysed by GenStat 19.

Table 1. Sowing rates of pod or seed (kg/ha) in Twin and Summer sowing treatments and sown rate of germinable seed (kg/ha) in the autumn sown treatment.

Species	Twin and Summer sowing (kg/ha)	Autumn sowing (kg/ha)
Seraph (PM-250) medic	30 (pod)	11
Trigonella 5045	12 (seed)	8
Bartolo Bladder clover	12 (seed)	11
SARDI Rose clover	10 (seed)	11
Margurita French serradella	30 (pod)	8
Studenica Vetch		40
Scepter Wheat		70

Table 2. Selected sites in the Australian cropping region showing 25-75th percentiles of the seasonal break (1971-2018), the range in days, and median 7-day sum of rainfall (mm) at the seasonal break based on the 7-day rolling sum of the rainfall:evaporation ratio.

Location	State	25th percentile	Median	75th percentile	Range (days)	Median 7-day rain sum (mm)
Lameroo	SA	19-Apr	11- May	29-May	40	21
Waikerie	SA	20-Apr	7-May	27-May	37	21
Roseworthy	SA	11-Apr	1-May	20-May	39	27
Minnipa	SA	3-May	24-May	9-Jun	37	22

What happened?

Seasonal break analysis

Table 3 shows the median seasonal date, range and rainfall volume that defined the seasonal break for local South Australian sites. The shift in median seasonal break in South Australia ranged from a 3-day delay in the Mallee region, to an 8-day delay in Mid-north, York and Eyre regions during the period 1990-2018.

Novel pasture sowing methods

There were inconsistencies between the species × sowing time combinations that were optimal for pasture production in the 2020 growing season (Figure 3). Average plant establishment in autumn-sown treatments was 72 plants/m^2, summer-sown treatments was 29 plants/m^2 and twin-sown treatments was 14 plants/m^2. In Lameroo, an early break in the first week of March 2020 enabled earlier establishment of pasture species from summer and twin sowing and resulted in higher biomass production for summer-sown trigonella and medic compared to autumn-sown (Figure 3). However, lower plant numbers were less productive compared to autumn sown plant numbers in the bladder clover treatment. Rose clover and serradella established adequate numbers from autumn sowing but overall biomass production was low suggesting the available varieties were not well adapted to the Lameroo environment. Weed density was greatest in summer-sown (13 weeds/m^2) and twin-sown (8 weeds/m^2), compared to autumn-sown (3 weeds/m^2). Pasture production was generally low for all species when twin sowing was implemented, presumably due to excessive seeding depth, an aspect of twin sowing that needs to be addressed before the method can be recommended for pasture establishment. At Lameroo, bladder clover and trigonella production was competitive with medic at autumn sowing and are considered the best novel pasture options for that environment.

The 2021 growing season rainfall was below average at Lameroo (170 mm, long term average 270 mm). The additional ~30 mm of total soil water, and 70 kg/ha soil mineral N available under brown manure vetch and long fallow treatments resulted in an additional 1.5 t/ha wheat grain yield compared to the continuous cereal treatment (Figure 4). The 2020 pasture treatments were not terminated to allow for seed set and therefore used more water than long fallow and brown manure vetch treatments, but still resulted in a 2021 wheat yield benefit of ~0.7 t/ha. Pasture seed production was over 1 t/ha for the best establishment treatment for each species. Autumn sowing generated the highest seed production for all except summer-sown serradella, with medic and trigonella the highest.

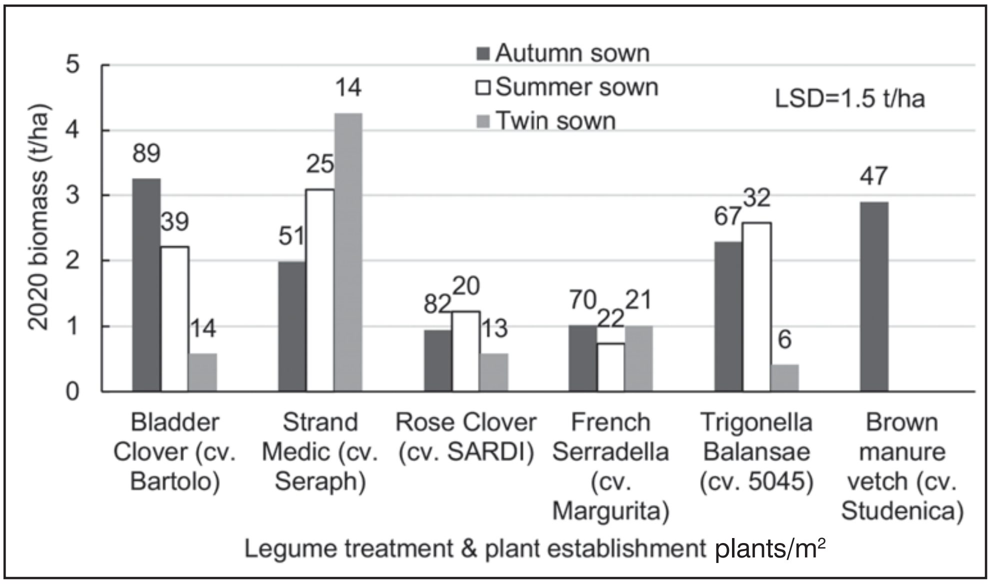

Figure 3. Biomass production of legume pasture species (15/09/2020) established via autumn, summer and twin sowing methods in Lameroo in 2020 LSD (5%) 1.5 t/ha, P-value <.001. Number above each column is plant number/m^2, LSD (5%) 14, P-value <.001.

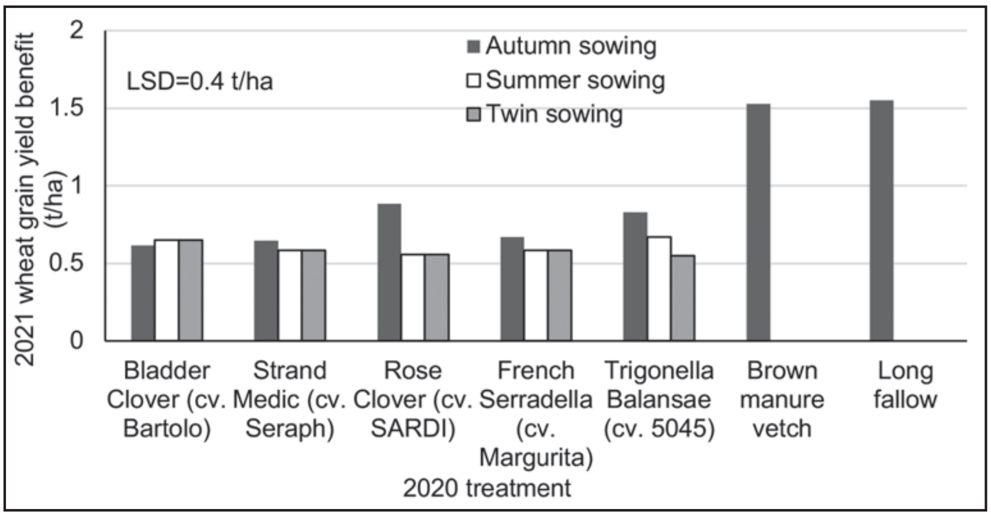

Figure 4. The 2021 wheat grain yield benefit following 2020 treatments relative to continuous cereal treatment. P-value (5%) <.001.

What does this mean?

Characterisation of the seasonal break is an important step for novel cultivar adaptation and management strategies across crop growing regions of southern Australia. Summer 'dry' pasture establishment methods have demonstrated potential in mixed farming systems; however, they are not well-suited for all pasture legume species and weed control challenges need to be addressed. There is potential to sow productive novel legume pastures and establish a substantial pasture seedbank while still achieving a substantial crop 'break effect' (~0.7 t/ha).

Acknowledgements

The research reported in this publication is made possible by significant contributions of growers through both trial cooperation and the support of Grains Research and Development Corporation (Project number 9175959). The authors acknowledge The Dryland Legumes Pasture Systems project supported by funding from the Australian Government Department of Agriculture, Water and Environment as part of its Rural R&D for Profit program (Project No. RnD4Profit-16-03-010), the GRDC, Meat and Livestock Australia and Australian Wool Innovation. We thank Christina Ratcliff for providing training in QGIS software.

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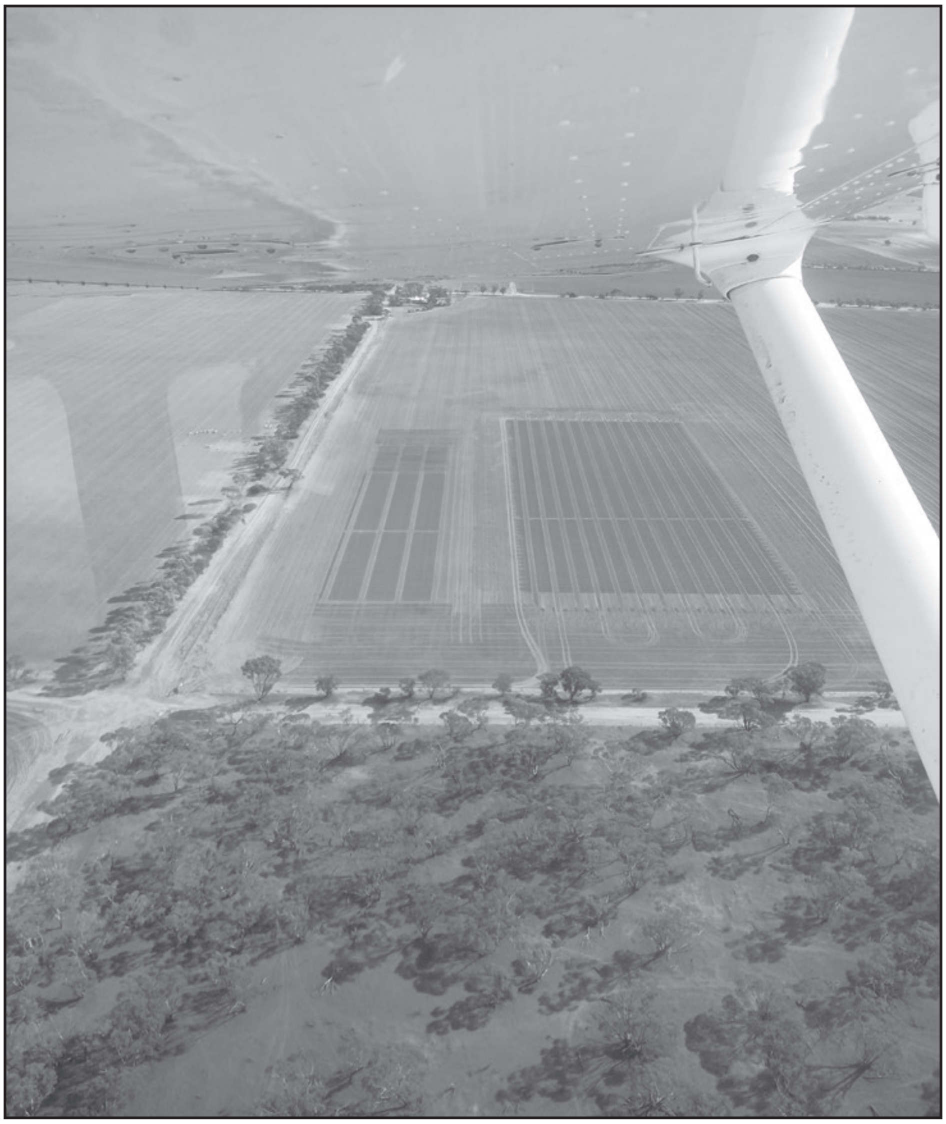


Early sown NVT cereal and NVT cereal trials at Minnipa Agricultural Centre, 2021.

Pastures

Dryland Legume Pasture Systems (DLPS): Identifying improved annual pasture legume options for the Victorian Mallee

Roy Latta and Michael Moodie
Frontier Farming Systems

Location
Piangil, Eastern Mallee
Rodney Hayden
Rainfall
Av. Annual: 300 mm
Av. GSR: 210 mm
2021 Total: 183 mm
2021 GSR: 160 mm
Yield
Potential: 50 kgDM pasture/mm plant available water = 2 tDM/ha
Actual: Annual medic 1 tDM/ha on 40 mm
Paddock history
2019: Pasture
2020: Wheat
Soil type
Sandy loam over clay
Soil test
Trial 1: 0-10 cm; pH 7.7 CaCl2
10-100 cm; pH 8 - 8.5 CaCl2
Plot size
7 entries x 3 reps, 18 m x 1.68 m
Yield limiting factors
Nil
Livestock
Enterprise type: Multipurpose hay, grain graze

Key messages

- **Seraph medic and the legume species Casbah biserrula and SARDI rose clover, bladder clover and gland clover regenerated successfully after a cereal crop, from a 2019 seed bank at Piangil Vic.**
- **Regenerating pastures of Casbah biserrula and SARDI rose clover produced more late biomass than Seraph annual medic in 2021, a season with a late break and above average spring rainfall.**

Why do the trial?

2021 is year four of a study identifying alternative pasture legumes for low rainfall farming systems. Years 1 and 2 (2018 and 2019) pasture establishment, year 3 (2020) cereal to year 4 (2021) assessing the regenerative performance of the annual pastures. The previous years of the study have been reported in the EPFSS 2019 p. 211 and 2020, p. 230.

How was it done?

The trial design was reported in EPFSS 2019, p. 211. It was 3 replicates of 9 treatments, (7 annual pastures, wheat and vetch field crops) by 3 times of establishment, June 2018, February 2019 and May 2019. This report specifies the May 2019 establishment treatment and its subsequent 2021 regeneration (21 June from 8 by 0.1 m^2 quadrants) biomass production (4 and 26 September, 20 October and 16 November from 5 by 0.1 m^2 quadrants) and seed yield (9 December from 5 by 0.1 m^2 quadrants) of the seven pasture legumes, Casbah biserrula, Bartolo bladder clover, Prima gland clover, Seraph strand medic, SARDI rose clover, Margurita French serradella and Trigonella balansae (APG5045).

Statistical analysis with GenStat of plant density, biomass production and seed yield were carried out by a general analysis of variance.

What happened?

The experiment was located at Piangil, Victoria, (35° S, 143.2°E) on a gradational calcareous red brown sandy clay loam without detectable free lime. The A horizon is at 10 cm with a soil pH ($CaCl_2$) increasing from 7 (0-0.1 m) to >8 at depth (1 m).

In 2021 rainfall from June (season break) to September totalled 83 mm. A further 80 mm fell in October-November, totalling 160 mm for the extended growing season.

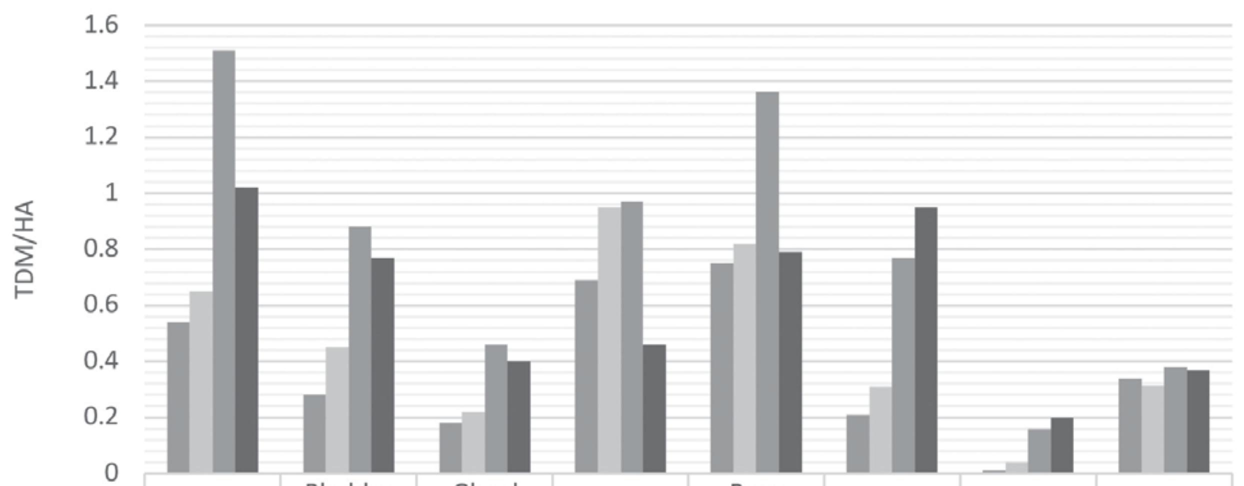
Five of the 7 pasture cultivars regenerated at adequate levels, >200 plants/m^2. The serradella, with a lower 2019 seed yield, and trigonella regenerated lower populations than Seraph annual medic, gland clover and biserrula with rose and bladder clover regenerating higher populations. The 2021 Seraph seed yield was higher than all legumes apart from serradella. The gland clover did not produce any useful seed from an adequate regeneration.

The annual medic Seraph reached maximum biomass production in late September. Biserrula, bladder, gland and rose clover, continued to grow into October, serradella and trigonella into November. Biserrula, Seraph and rose clover were the most productive cultivars at the September assessment, whilst biserrula and rose clover had the highest biomass at the October assessment.

Table 1. 2019 pasture seed yield (t/ha) and the subsequent 2021 plant regeneration (plants/m²) and seed yield (t/ha) of 7 pasture legumes following a cereal in 2020.

2019 Entries	Cultivar	Seed yield (t/ha) 2019	Regeneration (plants/m²) 2021	Seed yield (t/ha) 2021
Biserrula	Casbah	0.14	273	0.11
Bladder clover	Bartolo	0.49	502	0.11
Gland clover	Prima	0.15	231	<0.01
Strand medic	Seraph	0.28	281	0.25
Rose clover	SARDI	0.24	766	0.13
French serradella	Margurita	0.17*	73	0.15
Trigonella	APG 5045	0.23	11	<0.01
LSD (P=0.05)			*192*	*0.10*

**pod with an approximate 46% seed to pod ratio suggests 0.08 t/ha of seed*



	Biserrula	Bladder Clover	Gland Clover	Seraph	Rose Clover	Serradella	Trigonella	LSD P-0.05
4-Sep	0.54	0.28	0.18	0.69	0.75	0.21	0.01	0.339
26-Sep	0.65	0.45	0.22	0.95	0.82	0.31	0.04	0.313
20-Oct	1.51	0.88	0.46	0.97	1.36	0.77	0.16	0.38
16-Nov	1.02	0.77	0.4	0.46	0.79	0.95	0.2	0.369

Figure 1. Biomass production (tDM/ha) of 7 pasture legumes at 4 times of sampling in 2021.

Dry matter of the biserrula, medic and rose clover pastures declined as they senesced and at the November assessment had similar biomass to bladder clover and serradella. The biomass production of gland clover and trigonella was generally less at all assessment times.

What does this mean?

Ley farming, incorporating annual medics as a self-regenerating pasture in a pasture-crop rotation, has long been the basis of mixed farming in the Victorian Mallee. Early maturity, appropriate hardseed levels and associated high winter biomass production are important traits underlying the adaptation of annual medics in the Mallee. However mixed farmers are also looking towards filling the spring feed gap, the period between the senescence of the current winter annuals and the availability of crop residues. This study has shown that there may be those opportunities to help fill the gap within the alternative cultivars assessed. Rose clover and biserrula regenerated at similar or higher levels than Seraph annual medic and produced similar early and higher spring biomass production.

The 2 year pasture-crop rotation of this study is not more common than a 3 year pasture-crop-crop rotation. The ability of the alternative legumes to regenerate (their level of hardseed) at adequate plant populations following more than 1 year of crop in the mallee environment, as is the case with annual medics, is uncertain. However, taking into account their generally smaller seed size (annual medic 3 to 400,000 seeds/kg, biserrula 7-800,000/kg) the ongoing seed numbers of biserrula, for example, was approximately 1500/m^2 compared to 1000/m^2 for Seraph annual medic. Although Seraph maintained a similar seedbank in both the 2019 and 2021 assessments it was due to an unidentified proportion of retained 2019 seedbank in the 2021 measurement. Serradella seed yield benefited from the late spring rains and its indeterminate flowering trait.

Acknowledgements

Frontier Farming staff, Todd McDonald and Chris Davies.

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Dryland Legume Pasture Systems (DLPS): Demonstrating the commercial application of French serradella in the Victorian Mallee

Roy Latta and Michael Moodie
Frontier Farming Systems

Location
Ouyen, Central Mallee
Munro Brothers
Pathewollock
Munro Brothers

Rainfall
Ouyen
Av. Annual: 300 mm
Av. GSR: 210 mm
2021 Total: 160 mm
2021 GSR: 140 mm
Patchewollock
Av. Annual: 337 mm
Av. GSR: 337 mm
2021 Total: 160 mm
2021 GSR: 130 mm

Yield
Potential: 50 kgDM pasture/mm plant available water = 4 tDM/ha
Actual: Serradella 3.5 tDM/ha on 80mm

Paddock history
2020: Barley both sites
2019: Barley both sites

Soil type
Both sites are light textured calcarosols

Soil test
Ouyen 0-10 cm; pH 6.7 $CaCl_2$ 10-70 cm; pH 7.9 - 8.7 $CaCl_2$
Patchewollock 0-10 cm; pH 6.2 $CaCl_2$ 10 - 70 cm; pH 6.3 - 7 $CaCl_2$

Plot size
Both sites are appoximately 1 hectare, sub blocks 0.25 hectares

Yield limiting factors
Rainfall

Livestock
Enterprise type: Multipurpose hay, grain graze

Key messages

- **In a season of below average growing season rainfall 1 ha blocks of French serradella produced useful levels of plant biomass and seed production on neutral to acidic sands.**
- **There is adequate information available to support growing commercial serradella as a phase pasture on sandy Mallee soils.**

Why do the trial?

There have been at least six years of research and development assessing the adaptation of serradella to Mallee soils and environments (EPFSS 2016 p. 155, 2019, p. 230 and 2020, p. 211). In 2021 the aim was to demonstrate serradella on commonly encountered Mallee soil types, from the peak of a sand dune to the neighbouring swale. Secondly the opportunity to harvest seed at a semi commercial level was investigated. Both these issues, suitable soil type and successful seed harvest, required further demonstration to support the commercial uptake of a serradella package on suitable soil types in the Victorian Mallee.

How was it done?

Two sites of approximately 1 hectare were dry sown in 2021, on 1 March at Ouyen and 2 March at Patchewollock. The sites were selected on the basis of having been sown to lupin in 2019 and cereal in 2020. Within each hectare, four treatments or sub-blocks of approximately 0.25 hectare were sown. Margurita French serradella sown as (1) seedpod or (2) seed and a mixture of Margurita and Eliza serradella sown as pod (3) with or (4) without the added Group G/S rhizobia. Margurita is a hard-seeded mid-season maturity French serradella cultivar. Eliza is a soft-seeded, early season maturity French serradella cultivar. The 100 m sub-plot length ran from the near peak of an east west sand dune to the neighbouring flat. The site was intersected into 3 zones described as hill, mid-slope and flat. A block of Volga vetch was sown alongside to provide a comparative assessment of current local practice. The 0-0.1 m soil pH ($CaCl_2$) was < 7 only on the hill location at Ouyen, increasing to > 8 on the flat. At the Patchewollock location soil pH ($CaCl_2$) was < 7 down to 0.5 m on the hill and 0.3 m on the flat.

Seedpods of the serradella had been harvested in December 2020 from local trials, the Margurita and Volga seed was commercially acquired. Seeding rates were based on germination tests and seed weight in an attempt to achieve 100+ plants/m^2 of serradella and 20+ plants/m^2 of vetch. The Margurita pod with 25% germination was sown at 20 kg/ha. The serradella mixture of the hard seeded Margurita and soft seeded Eliza pod with 50% germination was sown at 10 kg/ha and the Margurita and vetch seed with more than 90% germination at 5 and 20 kg/ha respectively.

Table 1. Establishment (plants/m²) of the four serradella treatments and vetch in July 2021 at Ouyen and Patchewollock.

Site	Location	Soil pH $CaCl_2$	Margurita		Margurita and Eliza pod		Vetch
			Seed	Pod	+rhizobia	-rhizobia	
Ouyen	Hill	6.7 (0-10 cm)	90	66	55	61	28
	Mid-slope	7.2 (0-10 cm)	112	82	73	72	32
	Flat	8.7 (0-10 cm)	48	30	49	34	26
Patchewollock	Hill	6.7 (0-50 cm)	63	38	40	50	16
	Mid-slope	6.3 (0-30 cm)	68	43	55	56	16
	Flat	6.4 (0-10 cm)	75	53	67	73	13

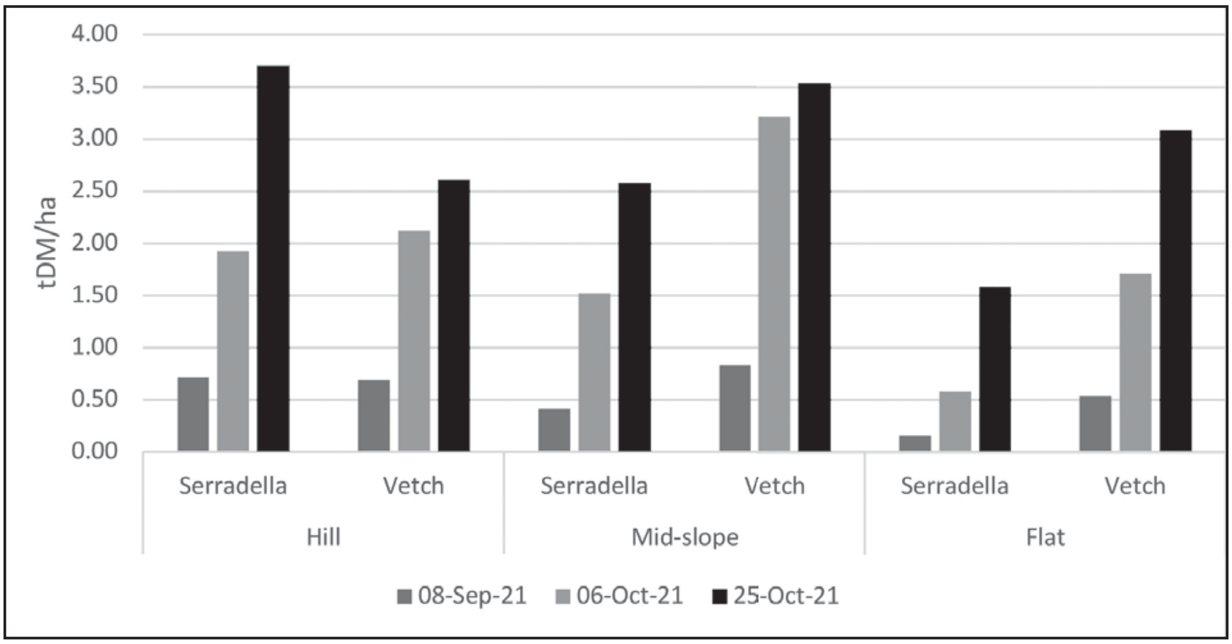

Figure 1. Total serradella and vetch biomass (tDM/ha) in the 3 soil zones, at 3 sampling times at Ouyen.

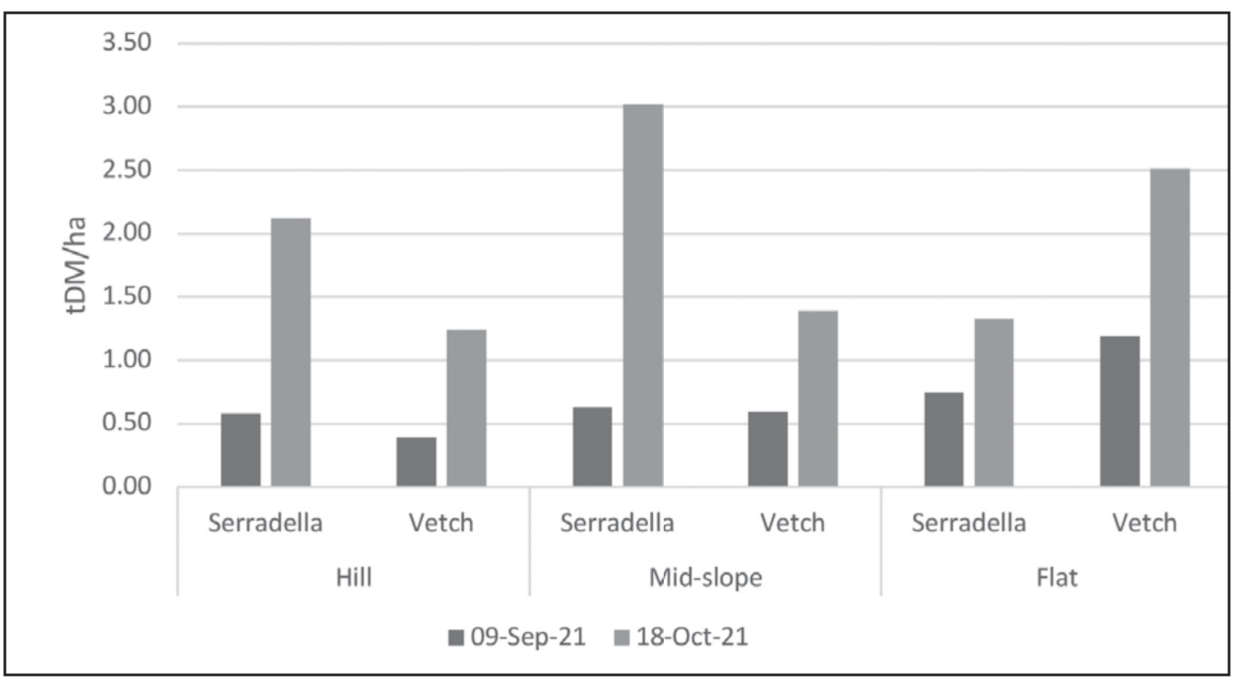

Figure 2. Total serradella and vetch biomass (tDM/ha) in the 3 soil zones, at 2 sampling times at Patchewollock.

Table 3. Machine harvested seedpod and seed yields (t/ha) of serradella and vetch in December 2021 at Ouyen and Patchewollock.

Site	Location	Margurita	Margurita and Eliza	Vetch
Ouyen	Hill	0.33	0.63	0.35
	Mid-slope	0.27	0.38	0.36
	Flat	0.15	0.15	0.24
Patchewollock	Hill	0.31	0.41	*
	Mid-slope	0.18	0.20	*
	Flat	0.07	0.09	*

** Not measured*

Measurements collected included plant establishment densities (plants/m^2) on 19 and 17 July, biomass yields (tDM/ha) on 8 September, 6 and 25 October, and 9 September and 18 October and machine harvested pod yields (t/ha) on 22 and 23 December at Ouyen and Patchewollock, respectively.

Sites had fertiliser applied at sowing at 8 kg P/ha. Weeds were controlled by applying Spinnaker post sowing pre-emergent (PSPE) and post emergent grass selective herbicides during the season. Insecticide for Heliothis control was undertaken in November at both sites.

What happened?

There was no measurable rain from seeding in March until late May. Then both sites received approximately 100 mm for the period from the end of May through to the end of September. A further 60 mm in October November resulted in a total GSR of near 160 mm at both sites.

The serradella achieved the projected 100 plants/m^2 establishment density in only one treatment, Margurita seed sown at Ouyen. Margurita serradella sown as seed established at higher densities than the serradella sown as pod, which all established at similar levels. The flat zone at Ouyen had lower serradella establishment, most likely as a result of a May to June rainfall deficit on the loam soil type as opposed to the sand on the hill but also possibly partly due to the increasing soil pH. The vetch established at 100% and 50% of projected densities at Ouyen and Patchewollock respectively.

Biomass production of the serradella was similar for the four treatments and is therefore presented as means at each time of sampling (Figure 1 and 2).

Serradella produced an extra 1 to 1.5 t biomass than vetch on the hill zones at both locations and on the mid-slope site at Patchewollock.

Vetch produced an extra 1 to 1.5 t of biomass to serradella on the flat sites at both locations and on the mid-slope site at Ouyen.

Seedpod harvest results were similar within the same species so results of the Margurita seed and pod sown treatments, and the Margurita and Eliza + and - rhizobia treatments were amalgamated and averaged. The declining serradella seedpod yield was correlated with increasing pH and associated soil type from hill to flat at both sites. The vetch seed yield trended lower in the flat zone at Ouyen. The low vetch population established at the Patchewollock site resulted in the plants collapsing at senescence and was not harvestable.

The harvested seedpod numbers of the serradella versus the seed numbers of the vetch at the trial average seedpod/seed yields of 0.3 t/ha were approximately 6000 serradella seedpods/m^2 versus 600 vetch seeds/m^2.

What does this mean?

The results suggest serradella can provide a dual purpose (hay, grain, grazing) alternative to vetch on neutral to acidic deep sandy Mallee soils. These soil types are where lupins are commonly grown. Serradella can also provide operational benefits over vetch such as summer sowing and lower seeding rates.

To successfully establish a French serradella phase pasture we recommend:

- Sowing in February early March. The time of seeding is necessary to continue the rate of seed softening of the shallow sown seedpods.
- Sowing on-farm produced seedpod at 5 to 20 kg/ha. The seeding rate is based on the small seedpod size (10 kg/ha = ~250 seedpods/m^2) but cultivar hard seeded differences require sowing at 5 kg/ha for a soft seeded cultivar, 10 kg/ha for a mixture and 20 kg/ha for a hard-seeded cultivar to achieve around 100 plants/m^2.
- The application of Group G/S rhizobia. However, this did not affect establishment or production in 2021, which is consistent with the previous history of lupin cultivation in the paddocks. The lupin history does reduce the risk of inadequate nodulation and the need for inoculation, particularly where summer sowing of pod is used to establish the pasture.
- Chemical weed control options include post-seeding pre-emergent Spinnaker (not Simazine) and/or post-emergent Broadstrike and grass selective herbicides plus a spring insecticide for Heliothis control.

Acknowledgements

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Mixed legume pastures for the upper Eyre Peninsula and other dryland farming systems

Fiona Tomney
SARDI, Minnipa

Location
Minnipa Agricultural Centre, S7
Rainfall
Av. Annual: 324 mm
Av. GSR: 241 mm
2021 Total: 405 mm
2021 GSR: 248 mm
Paddock history
2020: Barley
2019: Wheat
2018: Medic pasture
Soil type
Red sandy loam
Plot size
10 m x 1.5 m x 3 reps x 25.4 cm row spacing

Key messages

- **PM-250/Seraph strand medic grown as a monoculture or in a mixture with one other pasture legume was the most productive pasture option in early spring.**
- **Seraph mixtures with two or more other pasture legumes were less productive.**
- **Mixtures that did not contain medic had below average early spring production.**
- **The clover mixture and alternative mixture without medic, were the most productive in late spring, however these had the lowest production in early spring.**

Why do the trial?

This is an NLP2 Smart Farms grant project developed to extend work examining alternative pasture legume species in the Dryland Legume Pasture Systems project (2018 – present). In these trials the late flowering alternative species, particularly the arrowleaf clovers (Zulu and Cefalu) and biserrula, responded to the above average spring rainfall that was received in the 2018, 2019 and 2020 seasons (see EPFSS 2018, p. 153; EPFSS 2019, p. 209 and EPFSS 2020, p. 186).

This project examines the capacity of mixed legume pastures to increase soil cover and reduce wind erosion whilst extending the growing season for farmers on the upper Eyre Peninsula. The aim is to grow pasture species that will extend the available feed on offer beyond that currently offered by medics (*Medicago spp*.) which generally senesce in September, dropping their leaves and providing a lesser amount and less nutritious feed for grazing. Other legume species may be able to continue growing throughout spring, take advantage of out of season rainfall events, and maintain soil cover to protect the soil from wind erosion and improve long-term soil health. A successful outcome will improve the sustainability of farming on the Eyre Peninsula whilst increasing livestock productivity. The additional plant residue will also provide greater options for farmers to manage ground cover over summer, protecting the soil until the pasture is sown to cereal in autumn.

How was it done?

The trial was sown into moist soil on 4 June 2021 at the Minnipa Agricultural Centre (MAC) in paddock S7 (red sandy loam) with 60 kg/ha DAP. All seed was inoculated with its required rhizobia prior to seeding (see Table 1). Trials were arranged in a fully randomised block design with three replications. A second trial was sown at Chandada (grey calcareous soil) on 25 May 2021 but failed to sufficiently establish.

What happened?

Cold winter temperatures slowed pasture establishment and growth despite the above average rainfall (Table 3). The medics and vetch emerged about three weeks after sowing, closely followed by the trigonella. The clovers were still emerging in early July and biserrula was only just emerging when plant counts were completed at MAC on 14 July. Vetch establishment was likely reduced due to grazing by rabbits.

The MAC trial was scored for vigour and NDVI (Green Seeker) on 1 September (Table 2). Average plot vigour score was 4.1 and average NDVI reading was 0.52. The most vigorous treatments were the Medic Control, the Medic + Vetch mix, and the Medic Mix with Seraph and Jester barrel medic.

Table 1. Mixed Annual Legume Pasture Treatments.

Pasture Mixture	Legume Species
Medic control	PM-250/Seraph strand medic @ 10 kg/ha
Vetch control	Studenica vetch @ 40 kg/ha
Medic Mix	PM-250/Seraph strand medic + Jester barrel medic @ 5 kg/ha each.
Medic + Vetch	PM-250/Seraph strand medic + Volga vetch @ 10 kg/ha each.
Medic + Trigonella	PM-250/Seraph strand medic @ 5 kg/ha + DL59 Trigonella @ 2.5 kg/ha
Medic + Clover	PM-250/Seraph strand medic + SARDI rose clover @ 5 kg/ha each.
Medic + Clover + Late Clover	PM-250/Seraph strand medic @ 3.3 kg/ha + SARDI rose clover @ 3.3 kg/ha + Cefalu arrowleaf clover @ 1.7 kg/ha
Alternative Mix	DL59 Trigonella + Casbah biserrula + Cefalu arrowleaf clover @ 1.7 kg/ha each.
Ground Cover Mix	PM-250/Seraph strand medic @ 3.3 kg/ha + Bartolo bladder clover @ 3.3 kg/ha + Cefalu arrowleaf clover @ 1.7 kg/ha.
Medic + Clover + Late Alternative	PM-250/Seraph strand medic @ 3.3 kg/ha + SARDI rose clover @ 3.3 kg/ha + Casbah biserrula @ 1.7 kg/ha
Clover Mix	SARDI rose clover @ 3.3 kg/ha + Bartolo bladder clover @ 3.3 kg/ha + Cefalu arrowleaf clover @ 1.7 kg/ha.
Six Species Mix	PM-250/Seraph strand medic @ 1.7 kg/ha + DL59 Trigonella @ 0.8 kg/ha + SARDI rose clover @ 1.7 kg/ha + Bartolo bladder clover @ 0.8 kg/ha + Cefalu arrowleaf clover @ 0.8 kg/ha + Casbah biserrula @ 0.8 kg/ha.

Table 2. Average Early (28 September) and Late DM (23 November) Production at Minnipa in 2021.

Pasture Mixture	Plot Vigour Score (/5) 1 Sept	NDVI 1 Sept	Early DM (t/ha) 28 Sept	Late DM (t/ha) 23 Nov
Medic Control	4.8 a	0.66 a	3.7 a	0.77 b
Vetch Control	3.8 c	0.33 d	1.4 c	0.70 b
Medic Mix	4.6 ab	0.59 ab	3.1 ab	0.91 b
Medic + Vetch	4.7 ab	0.64 ab	3.1 ab	0.75 b
Medic + Trigonella	4.3 b	0.55 bc	3.0 ab	0.63 b
Medic + Clover	4.2 bc	0.56 b	3.0 ab	0.90 b
Medic + Clover + Late Clover	4.0 bc	0.55 bc	2.6 b	0.73 b
Alternative Mix	3.8 cd	0.43 cd	1.3 c	1.16 ab
Ground Cover Mix	4.0 bc	0.54 bc	2.5 b	0.62 b
Medic + Clover + Late Alternative	4.0 bc	0.54 bc	2.4 b	0.85 b
Clover Mix	3.4 d	0.38 d	1.1 c	1.33 a
Six Species Mix	3.8 c	0.47 c	2.2 b	0.90 b
LSD (P=0.05)	*0.3*	*0.08*	*0.70*	*0.32*

Table 3. 2021 and average monthly growing season rainfall for Minnipa (mm).

	April	May	June	July	August	September	October	Total GS
2021	3.8	26.0	85.0	64.0	36.4	4.6	27.8	247.8
Average	17.9	34.0	42.7	45.0	43.0	32.4	25.8	240.7

Early DM cuts were completed at Minnipa on 28 September 2021. Overall early spring growth was excellent with a site average of 2.45 t/ha of DM (Table 2.). The medic control of Seraph strand medic was the most productive (3.65 t/ha) along with the other treatments that contained medic as one component of the mix.

Late DM cuts were taken on 23 November 2021. The late spring growth had a site average of 0.85 t/ha. The medic had already finished setting pods and shed most leaves, so treatments containing medic generally had less harvestable DM. The best late spring growth was produced by the Clover Mix (SARDI rose, Bartolo bladder and Cefalu arrowleaf) with 1.33 t/ha which had similar levels of growth to the Alternative Mix. The late spring growth of these mixes was due mostly to the growth of the late flowering arrowleaf clover. The Clover Mix, Alternative Mix and the vetch had the poorest production in early spring as the alternative species were still establishing. In late spring these lines were actively growing when the medic had senesced.

What does this mean?

For early pasture growth at Minnipa, Seraph strand medic was the most productive species both as a monoculture or when grown in a mixture with one other pasture legume. Which pasture legume the medic was grown in combination with did not appear to substantially influence its production. Once more than one other pasture legume was combined with the medic, overall production decreased, however this may be a reflection of the medic being grown at a lower rate with less productive species, rather than its individual performance within the pasture mix, or the other legumes inhibiting its growth.

Late spring pasture growth was reduced by the extremely low rainfall in September (Table 3) with Minnipa only receiving 5 mm for the entire month, followed by an extremely dry second half of October. Some plants did appear moisture stressed however the biserrula and arrowleaf clover were able to respond to the above average November rainfall with 96 mm being received prior to the late DM cuts.

The low production of the vetch was most likely due to it being grazed by rabbits, shortly after emergence.

Despite the different pasture legumes germinating and establishing at differing rates, all treatments appeared to contain species in the approximate ratios that they were sown in. Seed yields were not measured however all pasture legumes flowered and set some seed. Legume regeneration after the cropping phase (2022), will be assessed in autumn 2023.

In 2022 ground cover after summer and early autumn regeneration will be measured. The sites will then be sown to wheat with yields and grain quality measured.

The trial showed that there is potential for late flowering arrowleaf clover to extend the available feed on offer beyond that currently offered by medics, however its late spring production must be offset by its low production in winter and early spring.

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Mixed Legume Pastures for the Upper Eyre Peninsula and Other Dryland Farming Areas. Activity ID 4-FZ7PPZ9

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Pastures

Dryland Legume Pasture Systems (DLPS): Minnipa grazing trial

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Location
Minnipa Agricultural Centre, S8
Rainfall
Av. Annual: 324 mm
Av. GSR: 241 mm
2021 Total: 404 mm
2021 GSR: 244 mm
Paddock history
2019: Various legume species or Scepter wheat
2018: Various legume species or Scepter wheat
2017: Scepter wheat
2016: Medic pasture
Soil type
Red sandy loam
Soil test
$pH(H_2 0)$ (0-10cm): 8.4
Plot size
2 ha x 3 reps

Key messages

- **Sheep weight was not significantly affected by four pasture legume treatments in the fourth year of the trial, but effects were likely masked by the dominance of background medic in all regenerating pasture treatments.**
- **Regeneration of trigonella and rose clover after a wheat crop was minimal, at <1 plant/m². These legumes are less well adapted to the Minnipa environment than the annual medics.**
- **In the absence of damaging levels of powdery mildew, blue green aphids or SU herbicide residues in the soil, the performance of the Harbinger and Seraph treatments was similar. The use of Seraph medic is best directed at paddocks where soil or disease constraints are likely to impact the performance of old cultivars and naturalised medics.**

Why do the trial?

In southern Australian low to medium rainfall mixed farming systems there are many opportunities for pasture improvement. The Dryland Legume Pasture Systems (DLPS) project aims to boost profit and reduce risk in medium and low rainfall areas by developing pasture legumes that benefit animal and crop production systems. A component of the DLPS project aims to quantify the impacts of different pasture legume species on livestock production and crops in the rotation. Included are widely grown legumes (strand medic and vetch) and legumes with novel traits and reasonable prospects of commercialisation (trigonella and rose clover).

A five year grazing and cropping system trial was established at the Minnipa Agricultural Centre (MAC) in 2018.

How was it done?

The large-scale (36 ha) grazing system experiment, measuring pasture production and persistence and animal and crop benefits from different pasture species, was established in paddock South 8 at MAC in 2018. The trial has six treatments (Table 1) arranged in a randomised block design with three replications. Pasture treatments were established in 2018/19, and after a 1 year cropping phase in 2020, all pasture treatments were left to regenerate in the 2021 growing season. As a control treatment, vetch was re-sown in 2021. Each 'plot' was two hectares in size to allow grazing during the pasture phases.

Legume regeneration density was estimated in each plot on 23 June (pasture treatments) and 2 August (vetch), approximately 4 weeks after the first substantial rainfall event in 2021 (11.8 mm on 25 May).

On 25 August 2021, eight 1 year old ewe hoggets were introduced into each treatment paddock, except for the continuous cereal treatment. Four grazing exclusion cages (1 m x 1 m) were placed in each 2 ha plot (treatment) area. Pasture biomass cuts were taken within and outside the cages to enable the estimation of pasture DM production and composition. Livestock weights and pasture production were measured when the sheep were introduced (25 August) and again on 16 September and 13 October.

Harbinger strand medic was included to represent an old and widely naturalised variety. Seraph strand medic was released in 2021 and has tolerance to powdery mildew and SU herbicide residues. Trigonella and rose clover were included because they retain seed that can potentially be harvested with a cereal harvester, to provide a source of cheap seed for on-farm sowing.

Table 1. Sequence of treatments in the grazing trial at Minnipa.

Treatment	2018 & 2019	2020	2021
Treatment 1	Wheat	Wheat	Sown Maximus barley
Treatment 2	Sown Volga vetch	Wheat	Sown Volga vetch
Treatment 3	Harbinger medic	Wheat	Regenerating pasture
Treatment 4	Seraph medic (PM-250)	Wheat	Regenerating pasture
Treatment 5	Trigonella balansae	Wheat	Regenerating pasture
Treatment 6	SARDI rose clover	Wheat	Regenerating pasture

What happened?

Results for the previous pasture and crop phases are reported in EPFSS 2019, p. 222 and 2020, p. 195. In brief, all pasture legumes regenerated satisfactorily in 2019 and produced levels of dry matter that supported good levels of livestock production. In 2020, wheat grain following the legume treatments had higher protein and lower screenings (mean 12.0% protein, 3.3% screenings) compared to the continuous cereal treatment (10.2% protein, 4.5% screenings). Grain yields did not differ significantly, although there was a trend for decreased yield following pasture, compared to the continuous cereal treatment.

The 2021 season was characterised by a late break with the first two rain events of >10mm on 25 May and 8 June. September was also dry (5 mm) however, overall growing season rainfall (244 mm) was close to average (241 mm).

2021 legume regeneration and growth

All regenerating pasture treatments were dominated by medic (>99%), which was measured at high densities of between 998 and 1,498 plants/m^2 (Table 2). Sown vetch established at 68 plants/m^2. The regeneration of trigonella and rose clover was minimal at less than 1 plant/m^2.

Maximum shoot dry matter (DM) production varied from 2219 kg/ha for sown vetch to 5459 kg/ha for sown barley (Figure 1). Maximum shoot DM production of the pasture treatments was greatest in the Harbinger medic treatment (4887 kg DM/ha) and lowest in the rose clover treatment (3241 kg/ha). Legume production in the trigonella and rose clover treatments was almost entirely the result of background medic rather than the sown pasture species, consistent with the regeneration densities of those legumes. Legume production of all pasture treatments was similar in August, but greater than vetch. By September, the Harbinger treatment had produced more DM than rose clover and vetch treatments. In October, DM of the pasture treatments declined, associated with pasture senescence and leaf loss. The decline was greater in the rose clover treatment. The lesser production of vetch (sown 10 June) was the result of later emergence associated with the late break of season.

Livestock performance

Sheep weight increased on average by 14.8 kg/animal. Increases ranged between 13.2 kg and 16.5 kg for the rose clover and Seraph medic treatments, respectively (Table 3). At the time sheep were removed in October (to comply with animal ethics minimum feed requirements) a trend of greater sheep weight in the Seraph treatment was emerging, but not significantly different. There were no significant treatment effects on fleece weight.

Table 2. Legume density in 2021 and the percentage of medic plants contributing to legume density. Regeneration of the pasture legumes is after a wheat crop in 2020.

Treatment	Legume density (plants/m^2)	Composition of legume regeneration medic % of total legume density
Volga vetch	68 c	0
Harbinger medic	1498 a	100
Seraph medic	1279 ab	100
SARDI rose clover	1278 ab	100
Trigonella balansae	998 b	>99
LSD (P = 0.05)	*283*	-

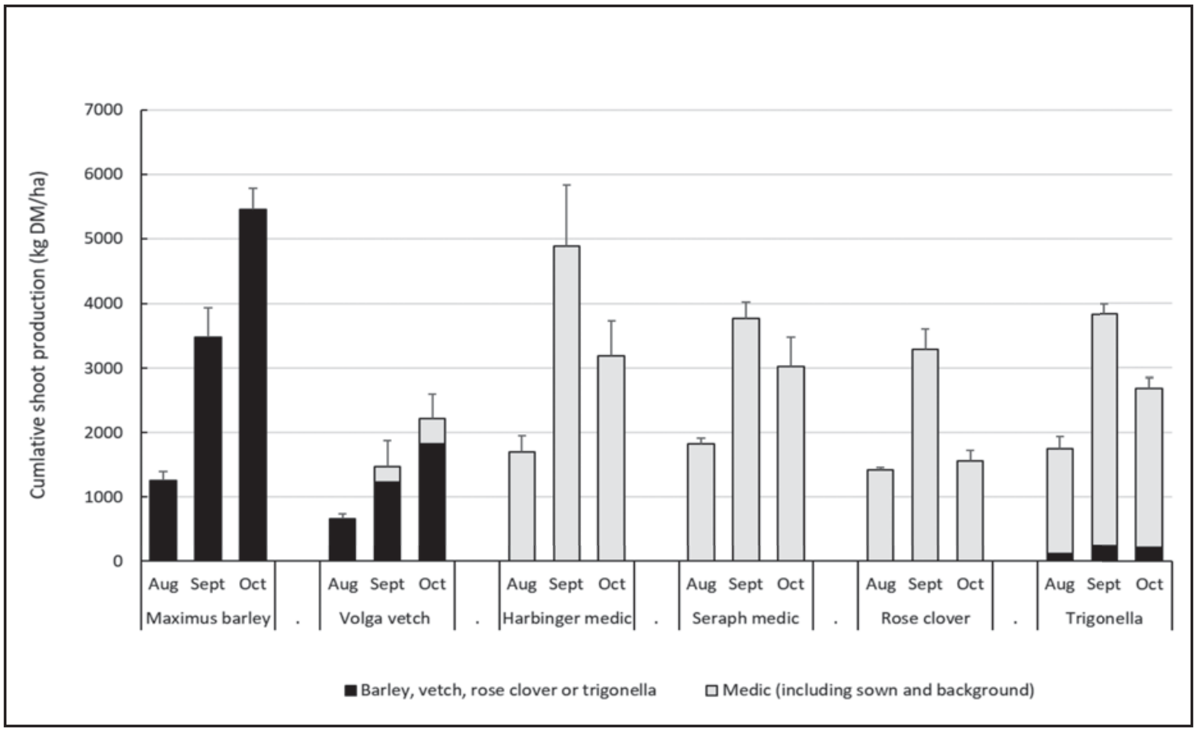

Figure 1. Cumulative shoot dry matter production (kg/ha) calculated using the mean of four herbage cuts per plot in August, September and October, at Minnipa in 2021. Legume treatments were grazed and production estimated using growth within livestock exclusion cages. Bars above columns indicate standard error of the mean. LSDs for comparison of means are 429, 1273 and 1154 for the August, September and October cuts, respectively.

What does this mean?

Annual medic dominated the pasture legume regeneration following a cereal crop in 2020. It demonstrates the robust adaptation of medic to the soil type, growing season and cropping system in the Minnipa trial. Conversely, the poor regeneration of SARDI rose clover and Trigonella balansae APG5045 indicates these genotypes lack a critical feature needed for longer term persistence and regeneration. That said, trigonella remains a legume of interest because it has previously grown well, supported good levels of sheep production and has readily harvestable seed. Other work had already indicated that the hard seed levels of trigonella line APG5045 used in this experiment were possibly too low. Harder seed lines are being developed to improve trigonella's ability to regenerate after crop (refer Peck *et al*., p. 185).

Whilst the extent that sown medics (Seraph and Harbinger treatments) contributed to the medic pasture was difficult to measure, the separation of herbage samples by pod type at the September assessment indicated that in the Seraph treatment approximately half of the pasture herbage was Seraph and half naturalised medic.

Previously vetch has outperformed the sown medic pastures. However, in 2021 the earlier establishment of medic pastures from seed banks resulted in greater DM production compared to the later sown vetch. This highlights the benefits of early pasture establishment and the greater production potential of established compared to first year pastures. Rose clover failed to regenerate in 2021, consistent with its previous inferior performance compared to the annual medics.

No inferences of sheep performance on rose clover or trigonella per se can be made given the negligible contribution of these species in the regenerating pastures.

This trial on Minnipa Agricultural Centre showed that, where there is a large background of naturalised medic, and no major powdery mildew incursion or damaging levels of SU herbicide residues in the soil, the Seraph medic treatment provided no advantage in DM production over the Harbinger medic treatment. Sheep performance was also similar.

Whilst the purported benefits of Seraph may have been masked by the dominance of background medic in the regenerating pasture treatments, the findings nonetheless indicate that the use of Seraph medic is best directed at paddocks where soil or disease constraints are likely to impact the performance of old cultivars and naturalised medics. More broadly, Seraph medic has provided mean production increases of 16% across a range of environments.

Table 3. Sheep live-weight and fleece weight, for five legume treatments at Minnipa in 2021. Values based on means of eight sheep/plot.

Treatment	Sheep weight August (kg/head)	Sheep weight October (kg/head)	Weight change Aug - Oct (kg (% of initial)	Fleece weight (kg/head)
Volga vetch	54.7	70.1	15.4 (+28)	4.23
Harbinger medic	53.4	67.6	14.2 (+27)	4.28
Seraph medic	55.7	72.2	16.5 (+30)	4.37
Rose cover	54.2	67.5	13.2 (+24)	4.20
Trigonella balansae	53.8	68.5	14.7 (+27)	4.31
LSD (P = 0.05)	*ns*	*ns*	*ns*	*ns*

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Antimethanogenic potential of legume pastures and grain supplements on the upper Eyre Peninsula

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Key points

- **Methane emissions from livestock are a large contributor to agriculture's total greenhouse gas (GHG) emissions.**
- **Legumes reduce total GHG emissions by reducing reliance on the manufacture of artificial nitrogen fertilisers and their distribution which are large GHG emitters.**
- **A literature review found that plant secondary compounds called saponins occur in annual medics and lucerne and can reduce methane emissions by up to 30%.**
- **Wheat grain supplements to dairy cows have reduced methane emissions compared to other grains.**
- **A survey of farmers found 5-27% of farmers would adopt and a further 41-68% may adopt methane emission lowering practices if they maintained production and were cheap and easy to implement.**

Why do the trial?

This pilot study was done to guide future research on reducing methane emissions from sheep on low rainfall mixed farms.

The world faces many challenges from current and future climate change and needs to reduce greenhouse gas (GHG) emissions to limit global temperature rise to less than 3°C. The two most abundant GHGs are carbon dioxide (CO_2) and methane. Methane has a greater global warming effect (about 23 times more) than CO_2 but breaks down in ten years compared to CO_2 which takes over 100 years. Therefore, a reduction in methane emissions can have a direct and timely effect on slowing climate change. Livestock emissions account for approximately one third of human-caused methane emissions. In November 2021, over 100 countries (but not Australia) signed "The Global Methane Pledge" to reduce methane emissions by 30% by 2030. Over time, this will increase pressure on Australia to reduce methane emissions through export requirements.

Currently, livestock production faces the challenge of increasing production to meet global demand for animal products whilst reducing the environmental impact. Increasingly, consumers are demanding that the agriculture products they consume are produced in an environmentally responsible way, which includes reducing methane emissions. This pilot study had three focus areas: 1) search the literature for viable and readily adoptable options to reduce methane emissions; 2) understand sheep management and feeding practices on the upper Eyre Peninsula; 3) understand farmers' willingness to adopt methane reduction practices. Project outputs will guide future research into methane reductions rather than provide clear guidelines that can be adopted now.

How was it done?

A literature search was done to identify readily adoptable methods to reduce methane from livestock on low rainfall mixed farms. Furthermore, a survey of 114 farmers on the upper Eyre Peninsula was done during the March 2021 SARDI Farmer Meetings to determine the willingness of farmers to adopt simple strategies, if they were proven to reduce methane emissions. More detailed discussion with a subset of farmers at Farmer Meetings and visits to 19 farms allowed us to understand how farmers manage and feed sheep throughout the year and to sample the stubble that sheep are grazing in the dry season.

What happened?

Literature review

Legumes play a role in reducing GHG emissions on farms. Legumes fix nitrogen, thus saving GHG emissions caused by the manufacture and distribution of artificial nitrogen fertilisers. Legumes are high protein, high quality forage species which improve animal production and reduce methane emissions (methane release per kg of animal product produced). Legumes also contain a range of plant secondary compounds that can directly affect the rumen flora and modify methane emissions. The tropical pasture legumes leucaena (sown on 300,000 ha in Australia) and desmanthus (50,000 ha) contain tannins and have been reported to reduce methane emissions.

A group of plant secondary compounds called saponins are present in all *medicago* species (annual medics and lucerne) tested. In the initial research, high saponin non-pasture plants (eg. tea) were added to pastures and reductions in methane emissions of up to 30% were observed.

Further research focused on the addition of a lucerne supplement to wheat stubble diets or concentrate with equivalent energy and protein levels. Lucerne added to the diet reduced methane emissions by up to 30%. This suggests that supplementing sheep grazing cereal stubbles over summer with lucerne or medic hay may reduce methane emissions.

Lucerne and annual medic pastures are widely grown in Australia as pure legume pastures. However, no research has been done on measuring their potential to reduce methane emissions compared to other pastures. Lucerne and annual medic hay is widely used in Australia, however only one Australian study (Charmley 2020) has investigated its ability to reduce methane emissions. The study found that adding 30% lucerne hay to a tropical grass diet reduced methane by 21% compared to adding 45% of desmanthus to the diet (balanced isonitrogenous; lucerne had higher crude protein). The fact lucerne produced less methane than desmanthus is a very encouraging result as desmanthus is widely reported as reducing methane.

Moate *et al*. (2017) fed dairy cows 1 of 4 diets: a corn diet (CRN) in which dairy cows were fed 10.0 kg DM/d of corn, 1.8 kg/d of canola, 0.2 kg of DM/d of minerals, and 11.0 kg of DM/d of chopped lucerne hay; a wheat diet (WHT) similar to the CRN with the corn replaced by wheat; a single rolled barely diet (SRB), and a double rolled barley diet (DRB). The CRN (49%), SRB (73%), DRB (78%) were associated with 49, 73 and 78% greater methane emissions than the WHT.

In the mixed farming zone, sheep are fed on wheat stubbles and rapidly consume unharvested grain (107 ± 80.2 kg /ha, Thomas *et al*. 2021). This unharvested wheat grain is potentially reducing methane emissions compared to feeding other stubbles. Mixed farmers could potentially reduce emissions by supplementary feeding with either wheat grain or wheat screenings during the dry season, rather than with barley or oats which are currently fed.

As pastures dry off at the end of the growing season, pasture quality decreases and methane emission intensity increases. Strategies that extend the growing season can decrease methane emission intensities and increase animal production. Strategies to extend the growing season include sowing later maturing cultivars (Tomney *et al*. 2020, Tomney 2021), growing perennial pastures such as lucerne and grazing unharvested cereal or legume crops (cereal grain has high ME, and legume grains have high protein and ME). Dzoma (2016) reported that sheep fed unharvested vetch gained 154 g/head/day with methane emission intensity of 17 g CH_4/day/100g average daily weight gain (ADWG) compared to sheep fed unharvested oats that gained 8 g/head/day with methane emission intensity of 300 g CH_4/day/100g ADWG. When grazing standing cereal crops, a protein supplement is needed (Frischke, 2020) and is likely to decrease methane emission intensity. Young stock have higher energy and protein requirements and particularly benefit from protein supplements.

Many studies have shown that adding small amounts of the seaweed asparagopsis to ruminants' diets can reduce methane emissions by over 70% and improve feed conversion efficiency. For this to be commercially adopted, an asparagopsis industry needs to be developed that can grow, harvest, and distribute the supplement for addition to a ruminant diet. In the first instance, asparagopsis is likely to be used by feed lots and dairies. Over time, delivery methods may be developed to enable addition of asparagopsis as a supplement fed to sheep grazing stubbles or pastures on Eyre Peninsula.

Survey and farmer discussions

The results from a survey of farmers are presented in Table 1. Questions 1-5 capture current practices and questions 6-8 relate to practice change. Seventy three percent of farmers who attended the cropping updates had sheep (i.e.. mixed farmers) with 79% grazing stubbles within 2 weeks of harvest. A low number (6%) of farmers currently feed wheat grain and a greater number (35%) feed wheat screenings. While only 3% of farmers saw methane emissions as a concern (Q 5), 5-27% said that they would adopt simple methods to reduce methane emissions and a further 41-68% would consider it (Q 6-8). In discussions after the meetings, and at the farm visits, the main concerns were that sheep productivity is at least maintained and that methods were simple and cheap to adopt. The potential methods for methane reductions came from our literature research and fit with current practices on the upper EP. According to the survey results, farmers were more likely to feed a legume hay or grow a legume pasture than to feed wheat screenings as a method of reducing methane emissions. In discussions and at farm visits the concerns were that wheat is usually the most valuable grain and that it can cause acidosis in sheep. For questions 6-8 relating to practice change, a high percentage (41-68%) of "maybe" responses were given. Discussions indicated that for farmers to change from "maybe" to "yes" they needed to see the scientific evidence for methane reduction and that any change would need to maintain production and be simple and easy to adopt.

Table 1: Survey questions and responses.

1. Do you have sheep on your property?	
Yes	73%
No	27%
2. When do you start grazing your stubbles?	
Immediately	62%
2 weeks	17%
4 weeks	21%
3. Do you feed out wheat grain?	
Yes	6%
No	71%
Sometimes	23%
4. Do you feed out wheat screenings?	
Yes	35%
No	38%
Sometimes	27%
5. Do you see methane emissions as a concern?	
Yes	3%
No	76%
Maybe	21%
6. Would you grow a legume if it was proven to reduce the amount of methane emissions?	
Yes	5%
No	27%
Maybe	68%
7. Would you be prepared to feed more wheat screenings to your livestock if it is proven that it reduces methane emission?	
Yes	17%
No	38%
Maybe	45%
8. Would you be prepared to feed legume hay/silage to your livestock if it is proven that it reduces methane emission?	
Yes	27%
No	33%
Maybe	41%

In Morgan's visits to 19 farms in March 2021, 16 flocks were grazing wheat stubble and 3 were grazing on barley stubbles. The sheep had consumed the unharvested grain and small chaff and coarse stubble was remaining. The stubble was of low quality (mean DMD 35.4, ME 4.4, NDF 72.5, ADF 46.7). Thirteen of the farms were supplementing the sheep, nine with barley, two with oats, and six with oaten hay. No farmers were supplementing with wheat grain as wheat is a valuable grain and because of the risk of acidosis. If future research finds that wheat screenings (Q 7) and legume hay/silage (Q 8) reduce methane emissions, up to two thirds of farmers would consider feeding more wheat screenings and legume hay/silage.

What does it mean?

Methane is a potent GHG and livestock emissions account for roughly one third of human-caused methane emissions. A literature review conducted as part of this pilot project found that *medicago* pasture species, wheat grain, adding asparagopsis to supplements, and extending the grazing season can potentially reduce methane emissions from sheep on the upper Eyre Peninsula. The outputs of this pilot study will assist the development of further research that may provide clear guidelines that can be readily adopted by the livestock industry. The inclusion of producer input to this pilot study will ensure that future research is relevant to farmers and will focus on outputs with a high likelihood of adoption by industry.

Acknowledgments

We thank the 114 farmers who completed our survey at SARDI Farmer meeting and the farmers who discussed their sheep management and feeding practices with us.

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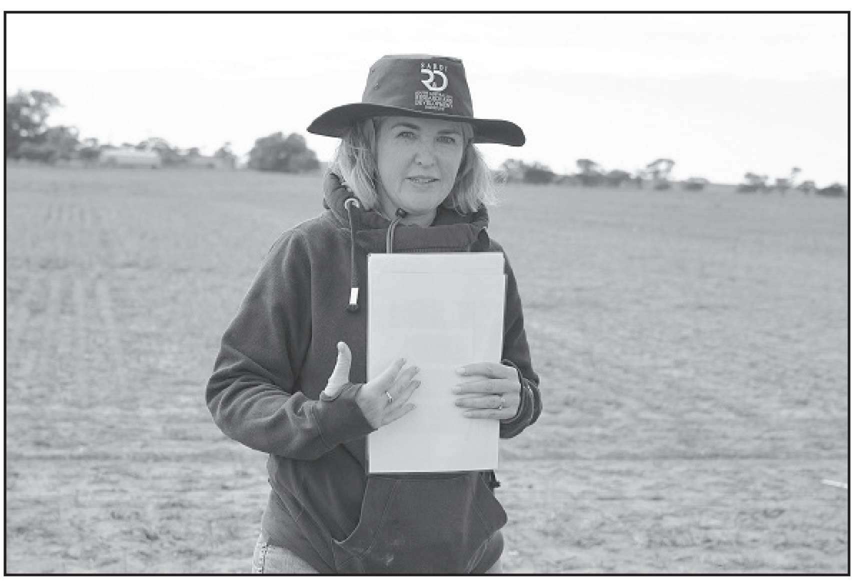

Fiona Tomney presenting the Mixed Legume Pastures trial for the SAGIT visit at Minnipa Agricultural Centre, September 2021.

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Dryland Legume Pasture Systems (DLPS): Pasture demonstration sites

Fiona Tomney[1], Morgan McCallum[1], Jessica Gunn[1], David Peck[2,3] and Ross Ballard[2,3]

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Location
Lock
Rainfall
Av. Annual: 340 mm
2020 Total: 322 mm
2020 GSR: 277 mm
Paddock history
2019: Medic
2018: Wheat
Soil type
Sandy loam
Plot size
2 m x 24 m x 2 reps

Location
Wirrulla
Rainfall
Av. Annual: 375 mm
2021 Total: 366 mm
2021 GSR: 197 mm
2020 Total: 315 mm
2020 GSR: 293 mm
Paddock history
2019: Medic
2018: Wheat
Soil type
Calcareous grey sandy loam
Plot size
2 m x 24 m x 2 reps

Location
Mount Cooper
Rainfall
Av. Annual:
2021 Total:
2021 GSR:
Paddock history
2020:
2019:
2018:
Soil type
Red Loam
Plot size
4 m x 200 m x 2 reps

Key messages

- **Volga vetch produced the most biomass in the establishment year at both sites.**
- **Grain protein, but not grain yield was significantly affected by the type of pasture legume previously grown.**
- **The annual medics were the most persistent species after cropping.**
- **The findings will be used to prioritise further research and development of novel pasture species on sandy soils.**

Why do the trial?

Over the past three decades there has been a shift from integrated crop-livestock production to intensive cropping in dry areas, which has significantly reduced the resilience of farms in low to medium rainfall areas. Intensive cropping is prone to herbicide resistant weeds, large nitrogen fertiliser requirements, and major financial shocks due to frost, drought or low grain prices.

A pilot project with MLA and AWI in WA and southern NSW has demonstrated how novel pasture legumes such as serradella, biserrula and bladder clover can improve livestock production while reducing nitrogen requirements, weeds and diseases for following crops. The extent to which these new legumes establish, grow and persist on South Australia's alkaline sandy soils requires clarification.

The demonstration sites are primarily an extension tool, unlike research trials requiring detailed data collection. The purpose of these sites is to gather information on regional legume performance, including benefits to the crops that follow.

How was it done?

The demonstration trials were designed after discussions with local farmers at the Minnipa Agricultural Centre 2018/19 harvest meetings in several locations across upper Eyre Peninsula. It was decided that the two sites chosen should target challenging soil types (particularly sandy soil) for establishing and successfully growing legume pastures in the mixed farming environment. Cultivars were chosen based on recommendations from low to medium rainfall pasture experts, site locality and soil profile information, including recent soil tests undertaken.

Site 1
Lock, SA (Kerran 'Gus' Glover)

Treatments established in 2019: Best bet variety demonstration - 2 reps x 10 treatments, 2 m x 25 m plots. The pastures were managed for maximum seed set, fenced off from grazing over summer and sown to Spartacus barley in 2020. Pasture treatments were:

- Casbah biserrula sown @ 5 kg/ha
- Toreador disc medic sown @ 7.5 kg/ha
- Seraph (PM-250) strand medic sown @ 7.5 kg/ha
- Sultan-SU barrel medic 2.5 sown @ 2.5 kg/ha
- Sultan-SU barrel medic 10 sown @ 10 kg/ha
- Scimitar spineless burr medic sown @ 7.5 kg/ha
- Volga vetch sown @ 40 kg/ha
- SARDI rose clover & Bartolo bladder clover mix sown @ 3.75 kg/ha
- Volga (40 kg/ha) & Sultan-SU (10 kg/ha) mix
- Margurita French serradella sown @ 7.5 kg/ha

In 2020 on 8 May, the site was sown to Spartacus barley @ 60 kg/ha, with DAP @ 70 kg/ha and 1.8 L/ha glyphosate, 100 ml/ha oxyfluorfen, 2 L/ha trifluralin applied pre-sowing. Soil sampling for soil nitrogen and soil borne diseases occurred on 4 April. GreenSeeker and weed assessments were conducted on 18 August. The site was harvested on 17 November. Lock received a total of 322 mm rainfall for the year with 277 mm falling within the growing season.

In 2021 the trial was monitored for the regeneration and subsequent performance of the legume pasture species after the cereal cropping phase. Plant regeneration counts were completed on 8 July 2021.

Site 2
Wirrulla, SA (Dion Trezona)

Treatments applied in 2019: Best bet variety demonstration with 2 reps x 10 treatments, 2 m x 25 m plots. The pastures were managed for maximum seed set, were fenced off from grazing over summer and sown to Scepter wheat in 2020. Pasture treatments were:

- Casbah biserrula sown @ 5 kg/ha
- Toreador disc medic sown @ 7.5 kg/ha
- Scimitar spineless burr medic sown @ 7.5 kg/ha
- SARDI rose clover & Bartolo bladder clover mix sown @ 3.75 kg/ha
- Margurita French serradella sown @ 7.5 kg/ha
- DL11 Boron tolerant spineless burr medic sown @ 7.5 kg/ha
- Seraph strand medic sown @ 7.5 kg/ha
- Sultan-SU barrel medic sown @ 2.5k g/ha
- Volga (40 kg/ha) & Sultan-SU (10 kg/ha) sown @ 10 kg/ha
- Sultan-SU barrel medic sown @ 10 kg/ha
- Volga vetch sown @ 40 kg/ha

On 21 May 2020, the site was sown to Scepter wheat with Granuloc Zinc DAP applied @ 60 kg/ha. Soil sampling for soil nitrogen and soil borne diseases occurred on 4 April. GreenSeeker, Canopeo (determines % area green) and weed assessments were conducted on 17 August. The site was harvested on 9 November. Wirrulla received a good amount of rainfall with an annual total of 315 mm and 293 mm of that falling within the growing season.

In 2021 the trial was monitored for the regeneration of the legume pasture species after the cereal cropping phase. Plant regeneration counts were completed on 10 August 2021.

Site 3
Mount Cooper, SA (Angus and Jessica Gunn)

On 28 May 2021 a new large-scale demonstration trial was sown at Angus and Jessica Gunn's at Mount Cooper. The purpose of this demo trial was to assess the performance of two new pasture legume cultivars using the first commercially available seed. These cultivars were Seraph (PM-250) strand medic and Frano French serradella. Seraph had already been shown to perform well within the DLPS project both in small plot research trials (see EPFSS 2018, p. 153; EPFSS 2019, p. 209 and EPFSS 2020, p. 186). Frano has a flowering time two weeks earlier than the previously available French serradella cultivar Margurita, so could potentially set more seed in a dry location. These new cultivars were compared against an older locally available medic cultivar Caliph barrel medic, and the regenerating medic already present in the paddock.

The Seraph, Frano and Caliph were sown at a high rate of 30 kg/ha in order to mimic the production of a regenerating pasture, which is generally much higher than a newly established one sown at a much lower rate. Plots were sown as double runs (4 m wide) in 200 m strips up and down a slope with two replications using small plot equipment. These demo strips were grazed by sheep in common with the wider paddock.

Plant establishment counts were completed on 29 June 2021.

What happened?

In 2019, Volga vetch produced the greatest biomass on both soil types (calcareous grey sandy loam at Wirrulla and sandy loam at Lock). Pasture production at Wirrulla in general was low in 2019, with the biomass ranging from 0.80 t/ha Margurita French serradella to 3.23 t/ha Volga vetch. Seed pod set was noticeably low at the Wirrulla site due to a dry finish, compared to the Lock site where the Seraph strand medic, Scimitar spineless burr medic and Casbah biserrula set the most pods. Overall, the majority of species at both sites produced adequate seed set for regeneration in 2021, following a cereal crop. At both sites in 2020 measurements including soil nitrogen, soil disease assessment and GreenSeeker analysis conducted throughout the growing season showed no differences between the treatments (data not shown).

The wheat and barley at Wirrulla and Lock showed consistent emergence (mean plants/m^2) across all pasture treatments, with no significant treatment differences observed. Cereal grain yields in 2020 ranged from 1.7 to 1.9 t/ha at Lock and from 1.0 to 1.2 t/ha at Wirrulla but there were no statistically significant differences between treatments.

Grain quality analysis was conducted for both sites and grain protein levels following the pasture treatments showed significant differences between treatments at both sites. At the Lock site, the average protein percentage ranged from 11.5% in the Volga vetch treatment to 10.5% for Scimitar spineless burr medic (Table 2). At Wirrulla grain protein ranged from 11.6% in the Seraph strand medic treatment to 10.8% in the Toreador disc medic.

Table 1. Grain yield of Spartacus barley (t/ha) at Lock and Scepter wheat (t/ha) at Wirrulla in 2020.

Lock		Wirrulla	
2019 Treatment	**Average yield (t/ha)**	**2019 Treatment**	**Average yield (t/ha)**
Casbah biserrula	1.88	Casbah biserrula	1.19
Toreador disc medic	1.85	Toreador disc medic	1.13
Seraph strand medic	1.80	Scimitar spineless burr medic	1.12
Sultan-SU barrel medic @ 2.5 kg/ha	1.78	SARDI rose clover & Bartolo bladder clover mix	1.12
Scimitar spineless burr medic	1.78	Margurita French serradella	1.10
Volga vetch	1.78	DL11 Boron tolerant burr medic	1.08
SARDI rose clover & Bartolo bladder clover mix	1.75	Seraph strand medic	1.07
Sultan-SU barrel medic @ 10 kg/ha	1.73	Sultan-SU barrel medic @ 2.5 kg/ha	1.06
Volga & Sultan-SU Mix	1.69	Volga & Sultan-SU Mix	1.06
Margurita French serradella	1.69	Sultan-SU barrel medic @ 10 kg/ha	1.06
		Volga vetch	1.04
LSD (P=0.05)	*ns*		*ns*

Table 2. Grain protein quality in 2020 from the Lock and Wirrulla sites.

Lock		Wirrulla	
2020 Treatment	**Grain protein (%)**	**2020 Treatment**	**Grain protein (%)**
Volga vetch	11.45 a	Seraph strand medic	11.60 a
Sultan-SU barrel medic @ 10 kg/ha	11.20 ab	Volga vetch	11.40 a
Seraph strand medic	11.15 a	DL11 Boron tolerant spineless burr medic	11.35 a
Volga & Sultan-SU Mix	11.15 a	Margurita French serradella	11.25 ab
Casbah biserrula	11.05 a	Sultan-SU barrel medic @ 2.5 kg/ha	11.20 ab
Margurita French serradella	11.0 a	Casbah biserrula	11.15 ab
SARDI rose clover & Bartolo bladder clover mix	10.95 ab	Sultan-SU barrel medic @ 10 kg/ha	11.15 ab
Toreador disc medic	10.75 ab	SARDI rose clover & Bartolo bladder clover mix	11.10 ab
Sultan-SU barrel medic @ 2.5 kg/ha	10.5 b	Scimitar spineless burr medic	11.10 ab
Scimitar spineless burr medic	10.5 b	Volga & Sultan-SU Mix	10.95 ab
		Toreador disc medic	10.80 b
LSD (P=0.05)	*0.76*		*0.65*

At Lock the annual medic species showed the best regeneration with Seraph having twice the number of plants as Sultan-SU (Table 3), which is due to the smaller seed size of Seraph combined with slightly lower hardseed levels. The differing seeding rates did not appear to affect the regeneration of the Sultan-SU. Counts of the medic plants may have included naturalised medic. Large biserrula plants were observed outside of the quadrats, indicating an earlier germination on summer rains. Only one serradella plant was observed over the entire site. At this site medics failed to regenerate in the Vetch/Sultan-SU treatment This indicates that competition from the vetch was detrimental to medic seed set and longer medic persistence. This observation may be relevant to competition effects in mixed pastures. The weeds were mostly barley grass and large broadleaf weeds which were predominantly turnip. The weed numbers indicate both broadleaf and grass herbicides should be used. The more the legume dominant the pasture the greater the nitrogen fixation and benefit to subsequent grain crops.

At Wirrulla annual medic species were also the most persistence species after cropping (Table 4.). Toreador disc medic performed well on the sandy site. New disc medic cultivars are being developed for sandy soils. As with the Lock site, the counts of the medic may have included some naturalised medic. The two clover species were small and had a red/yellow colouration. As the plants were too small to accurately discern the differences between rose and bladder clovers, they were counted collectively.

Table 3. Plant regeneration counts at Lock 8 July 2021.

Treatment	Number of (plants /m²)	Number of Grass (weeds/m²)	Number of Broadleaf (weeds/m²)
Sultan-SU barrel medic @ 10 kg/ha	37.5	67.5	91.3
Sultan-SU barrel medic @2.5 kg/ha	38.8	75	53.8
Toreador disc medic	16.3	35	98.8
Scimitar burr medic	10	53.8	163.8
Seraph strand medic	73.8	60	74.8
Margurita French serradella	0	96.3	14
Volga Vetch	0	70	10
Volga + Sultan-SU Mix	1	122.5	121.3
Casbah biserrula	0	83.8	71.3
SARDI rose +Bartolo bladder clover Mix	0	71.3	148.8

Table 4. Plant regeneration counts at Wirrulla 10 August 2021.

Treatment	Number of Plants /m²	Number of Grass Weeds/m²	Number of Broadleaf Weeds/m²
Sultan-SU barrel medic @ 10 kg/ha	145	162.5	37.5
Sultan-SU barrel medic @ 2.5 kg/ha	165	150	32.5
Toreador disc medic	241.3	158.8	43.8
Scimitar burr medic	155	163.8	36.3
Seraph strand medic	213.8	115	31.3
Margurita French serradella	0	130	48.8
Volga vetch	8.8	92.5	32.5
Volga + Sultan-SU Mix	3.8 V + 133.8 S	147.5	46.3
Casbah biserrula	38.8	148.8	37.5
SARDI rose + Bartolo bladder clover Mix	137.5	132.5	42.5
DL11 Boron tolerant burr medic	123.8	137.5	33.8

Table 5. Plant emergence counts at Mount Cooper 29 June 2021.

Treatment	Number of (plants /m²)	Number of Grass (weeds/m²)	Number of Broadleaf (weeds/m²)
Seraph strand medic	613	12	17.5
Frano French serradella	410	7.5	24.5
Caliph barrel medic	307	13.5	16.5
Regenerating medic	864.5	16	121

The biserrula plants were the last to emerge and were often found hidden under the leaves of the large broadleaf weeds but appeared to be healthy. The broadleaf weeds were mostly wards weed and the grass weeds were mostly rye grass.

At the Mount Cooper site plant emergence counts were completed on 29 June 2021. The weeds were predominantly marshmallow (Table 5).

When the site was visited on 5 August 2021 medic plants were growing uniformly up and down the slope. Frano grew well on the top of the slope, but by mid slope was yellow and had reduced growth. Plant emergence counts had been even across the entire slope. Across the wider DLPS project, French serradella has occasionally performed well on deep sandy soils. Planting a test strip of alternative pasture legumes up and down a slope can be used as way determining which areas of your farm is suited to alternative legume species.

Pastures

What does this mean?

Grain protein content, but not grain yield was affected by the pasture treatment that proceeded the wheat crop. Whilst the trials indicate scope to improve grain protein by using pasture species aligned with the soil types, further work is needed to understand the transfer of N between the legume and crop phase.

These demonstration sites compared alternative ley pasture species with strand and barrel medics which are currently the widely used pasture species on the upper EP. Ley pasture species/cultivars need to be well adapted to the soil type in order to be productive, and have high seed set and suitable hardseed levels to regenerate after a crop. At these sites the medics regenerated well. The alternative species French serradella cultivar Margurita failed to regenerate at Lock and Wirrulla. The new early season cultivar Frano may assist with greater seed set in low rainfall environments. The alternative species biserrula did not regenerate at Lock and had moderate regeneration at Wirrulla. Planting strips up and down a slope at Mount Cooper demonstrates a method that can be used to determine which soil types an alternative can be grown on. By planting strips of alternative species you can determine suitability while minimising seed costs and the risk of a whole paddock failing. When trialling alternative species it is important to evaluate their ability to regenerate and not just their performance in the establishment year. The medic/vetch treatment was a method in which vetch can provide more feed in the establishment year. However at Lock medic combined with vetch failed to regenerate. This suggests that instead of using vetch it would be better to increase the sowing rate of medic.

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Dryland Legume Pasture Systems (DLPS): Demonstrations on lower Eyre Peninsula

Andrew Ware
EPAG Research

Location
Butler
Clinton Charlton
Rainfall
Av. Annual: 363 mm
Av GSR: 278 mm
2021 Total: 346 mm
2021 GSR: 228 mm
Yield
2019: 5.3 t/ha dry matter
2020: 2.9 t/ha wheat
2021: 2.5 t/ha dry matter
Paddock history
2020: Wheat
2019: Pasture
2018: Barley
Soil type
Loam
Plot size
10 m x 2 m
Trial design
Complete randomised block design - 3 reps x 2 blocks - sandy and heavy soil
Yield limiting factors
Broadleaf weeds
Livestock
Enterprise type: Sheep
Type of stock/breed: Various

Location
Lipson
Andrew Bates
Rainfall
Av. Annual: 309 mm
Av GSR: 235 mm
2021 Total: 362 mm
2021 GSR: 267 mm
Yield
2020: 3.8 t/ha dry matter
2021: 3.5 t/ha wheat
Paddock history
2021: Wheat
2020: Pasture
2019: Wheat
Soil type
Loamy sand - loamy clay
Plot size
10 m x 2 m x 3 reps

Key messages

- **Medic species appear to be well adapted to be able to produce pasture biomass and regenerate well after a year of cropping on the alkaline soils of the lower Eyre Peninsula (EP).**
- **Vetch species can produce high quantities of biomass in the year of planting and may be best suited to farming systems with more intensive cropping enterprises that have run down pasture seed reserves.**
- **The alternative species evaluated did not appear to be well adapted to the soil type/ environments/ farming systems that they were planted into.**
- **Pasture species must have a level of tolerance to broadleaf herbicides to allow for the removal of broadleaf weeds, which in some situations and soil types is seeing pasture production severely restricted with broadleaf weeds.**
- **Soil type differences did appear to reflect differences in pasture production, particularly getting pastures to establish on sandy soil types, but the work was unable to identify a superior pasture species beyond medic or vetch adapted to the lower EP's sandy soils.**

Why do the trial?

This article will report on findings from two pasture trials conducted on the lower Eyre Peninsula in the 2019-2021 growing seasons. These trials are part of the demonstration component of the Dryland Pasture Legume Systems (DLPS) project developed with the former LEADA committee/AIR EP Medium Rainfall RD&E committee to answer several questions about how pasture performance could be improved in the region.

Demonstration 1: What is the best pasture species/ mix of species to plant in paddocks with differing soil types?

Background

Paddocks across the region often have soil types that vary, ie. changing from heavier flats to sandier rises, with pH varying from below 6 to above 8. Getting pasture species established and maintaining good production levels across this landscape is often challenging.

How was it done?

These trials, in the Butler area, investigated which pasture species was best able to perform on differing soil types, by sowing two replicated pasture species in different parts of the same paddock, one on a sandy rise and one a heavier flat. A total of 16 pasture species/ mixes were sown in each of the trials.

The pastures were sown in 2019, with the same plots over-sown to wheat in 2020 and then pastures were allowed to regenerate in 2021. Establishment counts and peak biomass cuts were taken from the pasture species in spring 2019. Grain yield and quality were measured in 2020. Establishment counts and early spring biomass were measured in 2021.

Trial design
Complete randomised block design - 3 reps x 2 blocks - sandy and heavy soil
Yield limiting factors
nil
Livestock
Enterprise type: Sheep
Type of stock/breed: Various

The pastures were sown in 2019, with the same plots over-sown to wheat in 2020 and then pastures were allowed to regenerate in 2021. Establishment counts and peak biomass cuts were taken from the pasture species in spring 2019. Grain yield and quality were measured in 2020. Establishment counts and early spring biomass were measured in 2021.

2019 pasture production and 2020 grain yields were reported in the EPFSS 2020.

Analysis of collected data was undertaken using GenStat version 19.

What does this mean?

In 2021 high populations of pasture species established on both soil types but there were no significant differences between any of the treatments that were sown in 2019. Most of the pasture that did establish appeared to be some type of medic and may have been the result of seed reserves set prior to 2019.

Biomass cuts taken in September 2021 showed that the highest biomass generally resulted from treatments where medic varieties were established in 2019.

Demonstration 2: Regenerating species

Why do the trial?

Typically, some pasture paddocks relying on regenerating species experience poor establishment, resulting in unproductive paddocks for the remainder of the season. Sometimes it is difficult to forecast when a paddock will establish poorly, and it can be three weeks after the break in the season when this can be determined. If a regenerating pasture paddock has poorly established, is it more profitable to spray off and re-sow a pasture or let what has come up continue?

What was it done?

The trial site was selected at Lipson, in a paddock where regenerating pasture establishment has been less than satisfactory. Three weeks after the break in season, all germinating plants were removed with a knock-down herbicide. Plots of medic (cv Sultan-SU), vetch (cv Timok), and serradella (cv Margurita) were sown in two differing soil types in the same paddock on 14 May 2020. Each pasture species block consisted of 5 x 2 m x 10 m blocks of plots, replicated three times in each of the heavy and sandier soil types. A further plot of self-regenerating pasture (left unsprayed) was also included in a randomised complete block design. Establishment, early biomass, late biomass, and feed value were measured. Results were reported in the EPFSS 2020.

Wheat (cv Scepter) was sown on the two sites on 28 May. The trial was sown with 80 kg/ha DAP and 100 kg/ha urea was applied to both sites.

Table 1. Pasture establishment and biomass production (early September) at Butler, 2021.

Variety/ species (seeding rate kg/ha)	Heavy Flat		Sandy Rise	
	Establishment (plants/m^2)	Biomass (t/ha)	Establishment (plants/m^2)	Biomass (t/ha)
Bartolo bladder clover	156	3.75	99	2.49
Bindaroo button medic	87	3.43	74	2.89
Biserrula (5)	199	3.25	88	2.58
Casbah biserrula	148	3.33	52	3.24
Clover	132	2.48	134	1.99
Margurita French serradella (7.5)	158	3.50	159	2.62
Seraph/PM-250 strand medic	272	3.86	108	2.24
Prima gland clover	118	2.45	47	2.25
SARDI rose clover	124	3.00	106	2.55
Scimitar spineless burr medic	192	3.20	278	2.51
Sultan-SU barrel medic (10)	192	3.88	291	3.27
Sultan-SU (10) + Vetch (10)	190	3.53	203	2.91
Sultan-SU (2.5)	147	2.89	104	1.97
Timok vetch	114	3.37	38	2.20
Toreador disc medic (7.5)	153	4.10	199	2.60
Vetch (40)	126	3.83	61	3.01
LSD (P=0.05)		*0.92*		*0.68*

Table 2. Pre-seeding soil mineral nitrogen results (kg/ha) to 80 cm depth N Lipson, 2021.

	Heavy soil (kg/ha)	Sandy soil (N 0-80 cm)
Vetch	29.5	72.7
Regenerating pasture	41.7	82.2

Table 3. Wheat yield (t/ha) sown into residue of differing 2020 pasture sites at Lipson.

2020 Pasture	Wheat yield 2021 (t/ha)	
	Sandy Site	Heavy Site
Self regenerating	3.26 a	3.24 b
Margurita	3.40 a	3.05 a
Timok	3.50 ab	3.29 b
Sultan-SU	3.73 b	3.25 b

What does this mean?

2021 wheat yields following the lowest producing pasture (Margurita) were lower on the heavy site. On the sandy site, lower wheat yields where recorded when sown into Margurita and the regenerating pasture, indicating that poor producing pastures can have a lasting effect on subsequent wheat yields.

Conclusions from the three years on DLPS demonstrations conducted on Lower Eyre Peninsula support traditional rationale:

- Medic species appear to be well adapted to be able to produce pasture biomass and regenerate well after a year of cropping.
- Vetch species can produce high quantities of biomass in the year of planting and may be best suited to farming systems with more intensive cropping enterprises that have run down pasture seed reserves.
- The alternative species evaluated did not appear to be well adapted to the soil type/ environments/ farming systems that they were planted into.
- Pasture species must have a level of tolerance to broadleaf herbicides to allow for the removal of broadleaf weeds, which in some situations and soil types is seeing pasture production severely restricted with broadleaf weeds.
- Soil type differences did appear to reflect differences in pasture production, particularly getting pastures to establish on sandy soil types, but the work was unable to identify a superior pasture species adapted to Lower Eyre Peninsula's sandy soils beyond medic or vetch.

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Dryland Legume Pasture Systems (DLPS): Harvesting annual medic pods

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Key messages

- **With early desiccation, up to 900 kg of medic pods per hectare was machine harvested at one site, but not the other.**
- **The use of field pea to trestle the medics did not increase medic pod machine harvest yield.**
- **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.**
- **This is preliminary research, and we recommend trialling on a small area or waiting for further research results.**

Why do the trial?

This work investigated if early desiccation of annual medic plants enables a valuable amount of medic pods to be harvested with a conventional crop harvester, and if trestling medics with field peas assists pod harvest.

The cost of seed and low growth of pastures in the establishment year is regularly reported as a constraint to pasture adoption and production of annual medics. Traditionally ley legume pastures are sown using 'germinable' seed after completing the sowing of the cropping program, when the amount of early pasture feed on offer is often low due to emergence after soil temperatures have dropped. Some alternative ley pasture species (eg. French serradella, bladder clover) are amenable to having pods/seeds harvested with a grain harvester, thereby providing 'hard' seed that is suitable for sowing in late summer to establish the pasture earlier on opening rains. In WA and NSW this method using legumes with harvestable seed has provided farmers with a relatively cheap source of seed and increased early feed. However, in adaptation trials on the upper EP, alternative ley legume species have nearly always produced lower dry matter and seed yield than annual medics (EPFSS 2018, p. 153; EPFSS 2019, p. 209 and EPFSS 2020, p. 186). In other work, the DLPS project has found that annual medic pods are also suitable for summer sowing (EPFSS 2020, p. 201 and EPFSS 2021, p. 189). However, medic pods are less easily harvested by a grain harvester because medics drop their pods when they mature. The seed industry harvests medic seeds with a clover (vacuum) harvester. This paper reports experiments examining methods to improve the harvestability of medic pods. In farming systems trials in the DLPS project, medics have increased subsequent grain yields by 0.7-2.9 t/ha (EPFSS 2020, p. 205; EPFSS 2020, p. 213; EPFSS 2021, p. 189. A cheaper source of medic seeds may encourage more sowing of medics and thus benefit to subsequent grain crops.

How was it done?

A pod harvesting trial was established at Minnipa. We grew the strand medic cultivars Seraph and Jaguar (Jaguar was bred by Pristine Forage Technologies for improved pod retention), barrel medic cultivar Sultan-SU, and spineless burr medic cultivar Scimitar. Medics were sown at 10 kg/ha in a factorial combination of field peas at 0, 0.25 and 0.5 X recommended rate. Plots were rolled after planting to assist harvest. A similar trial was sown at Waite, where Seraph and Sultan-SU were sown in a factorial combination of field peas at nil and 0.25 recommended sowing rate in four replicates.

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 be ready to fall from the plant. We observed when the first flowers appeared and when peak flowering finished. On a weekly basis we used observed daily temperature, forecast daily temperature and climate data to predict our harvest window. Actual desiccation date was chosen by a weather forecast of four fine days after desiccation. Plots were desiccated with Sprayseed at 3 L/ha. Medic pods were harvested with a small plot harvester four days after desiccating. A sample of total pod yield was taken from small quadrats on the day prior to harvesting but samples have not yet been cleaned and weighed.

Pods have been harvested but a range of seed measures are yet to be completed. Seed measures will include percent of seeds harvested, seed to pod ratio, percent viable seed and seed softening studies.

What happened?

Figure 1 shows Seraph medic pods four days after desiccating. High pod yields (900 kg pods/ha) were obtained at Waite and lower yields (up to 110 kg pods /ha) at Minnipa (Table 1).

Figure 1. Seraph medic pods on medic plants ready to harvest, four days after desiccating.

Table 1. Machine harvested pod yield (kg/ha) and bulk density of annual medic cultivars. Samples for total pod yield have yet to be processed.

Cultivar	Species	Pod yield (kg/ha)		Bulk density (kg/m^3)
		Waite	Minnipa	
Seraph	strand medic	906	110	460
Jaguar	strand medic	Not included	73	310
Sultan-SU	barrel medic	895	24	230
Scimitar	spineless burr medic	Not included	8	330

The field pea treatments did not affect pod yield. Minnipa had strong winds the day before harvest, which may have reduced pod yields. Elsewhere in the DLPS project (EPFSS 2020 p. 211) 120 kg/ha (30 kg seed) was harvested from fully senesced Jaguar medic (pod holding) compared to nil from Seraph, in the absence of desiccation. We speculate that early desiccation and favourable conditions until harvest allowed higher medic pod harvest yield to be achieved.

The bulk density (kg/m^3) of medic pods is low (230-460). Seraph has very small spines resulting in its higher bulk density than Jaguar. The very short spines of Seraph may assist the flow of pods through planting equipment.

What does it mean?

Up to 900 kg of medic pods/ha were able to be harvested at Waite, but not at Minnipa. Early desiccation was the likely key to success and was used at both sites, but environmental conditions only favoured pod retention/ harvestability at one site. The DLPS project has reported the successful establishment of medic pastures with summer sowing of 30 kg pods/ha (EPFSS 2020, p. 201; EPFS 2021, p. 189). This suggests that a one hectare seed nursery paddock could potentially produce enough pod to summer sow up to 30 hectares. The findings indicate that it is possible to harvest medic pods, however further research is required to determine if medic pods can be reliably harvested. We also need to complete our processing of per-plot harvester samples to determine what percentage of pods were harvested. This is preliminary research, and we recommend waiting for further research results or trialling on a small area.

GDD are widely used to estimate growth and development of crops, pests and diseases. GDD is the sum of mean daily temperature (add together the maximum and minimum temperature and divide that value by two). Observation of pods in the field agreed with 900 GDD for pods ready to fall made by Gallardo *et al.* (2003) for plants growing in a controlled environment room and on this basis, we assume seeds 400 GDD are viable.

An important measure will be percent viable seed. However we are unable at this time to report percent viable seed as freshly harvested medic seed are dormant (embryo dormancy) which breaks down with the heat of summer. For this work we have used GDD to determine harvest date which we suggest being used when harvesting medic pods. If you opportunistically decide to attempt to harvest medic pods, we suggest you use guides for desiccating pulses or canola to determine desiccation time.

The bulk densities are provided to allow you to determine storage requirements. The bulk density (kg/m3) of medic pods is low (230-460) compared to wheat (800) and barley (680). The bulk density of Seraph (460) is similar to oat (450), but the other cultivars are lower (230-330).

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. Pods need to be sown/broadcast before the end of February to allow them to soften with the fluctuating temperatures in autumn. Medic pods soften more on the soil surface than if buried and hence they can be broadcast which means the planting operation is quick and cheap. It also means that it does not leave the field vulnerable to wind erosion as do alternative species that need to be sown (hardseeded French Serradella and bladder clover need to be sown at 0.5-1 cm as they are have an unusual softening process whereby light inhibits softening).

Research to establish recommended sowing rates of medic pods is needed. However basic science studies on the softening of medic pods can be used to provide preliminary recommendations. In the DLPS project, fresh medic pods were found to have 20% soft seed by the end of 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 first, second and third summer after harvest respectively. Spineless burr medics have a seed to pod ratio of 0.5 and the minimum sowing rates are 50, 25 and 17 kg pods/ha for pods sown in the first, second and third summer respectively.

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Acknowledgments

This project is supported by funding from the Australian Government Department of Agriculture, Water and the Environment (DAWE) as part of its Rural R&D for Profit program, the Grains Research and Development Corporation (GRDC), Meat and Livestock Australia (MLA) and Australian Wool Innovation (AWI). The research partners include the South Australian Research and Development Institute, Murdoch University, the Commonwealth Scientific and Industrial Research Organisation, the WA Department of Primary Industries and Regional Development, NSW Department of Primary Industries and Charles Sturt University, as well as grower groups.

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Section 8

Disease

Eyre Peninsula Cereal Disease Survey 2021

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[1]SARDI, Waite; [2]University of Adelaide Affiliates

Key messages

- **Foliar diseases had minimal impact on cereals on the Eyre Peninsula in 2021.**
- **The survey, particularly the DNA results, shows that disease inoculum is widespread on the EP, but that weather conditions limited disease development in 2021.**
- **No high priority exotic plant disease was found.**

Why do the survey?

- To determine the incidence and severity of endemic leaf diseases of cereal and pulse crops in South Australia.
- Contribute to "proof of area freedom" from five high priority exotic grain diseases. This provides confidence that the region is free of those exotic diseases.

How was it done?

Under the new surveillance program, 60 paddocks will be surveyed each year from 2021-2023. To maximise the statistical value of data in any one year, only two crop types will be surveyed per year, one pulse and one cereal. In SA, surveys will target wheat, barley, faba bean and lentil across the life of the project. In 2021, wheat and faba bean crops were surveyed during spring. Crops were located in the medium and high rainfall zones where foliar diseases are a common issue across seasons. A total of 60 crops, 40 wheat and 20 faba bean, were surveyed across South Australia. The number of crops sampled per region was based on the area sown of each crop type in each region. In 2021, only wheat was sampled on the Eyre Peninsula (EP). The location of paddocks sampled is indicated in Figure 1.

Agronomists who assisted with paddock nomination in 2020 were again asked to nominate paddocks in 2021. These agronomists had previously been selected using a stratified random sampling approach. Paddock information was collected, including property owner contact details, GPS coordinates, sowing date, 2021 crop type and variety, 2021 fungicide applications (products and timing), and a three-year paddock history.

Wheat paddocks were sampled at flowering to mid grain filling. A paddock sample consisted of 50 plants collected along a single V-shaped transect. Transects started a minimum of 50 m away from the fence line with 5 whole plants collected at 10 locations approximately 50 m apart. Plants were transferred back to the laboratory for disease rating.

Biosecurity protocols were followed to ensure no transfer of pests, weeds or diseases from one paddock to the next. This included not taking vehicles into paddocks and boot disinfection between each paddock.

Presence/absence of major endemic and priority exotic diseases (Table 1) was recorded for whole samples for each paddock, and severity of disease on the stem, upper three leaves (Flag, F -1 and F -2) and head of each plant were assessed visually.

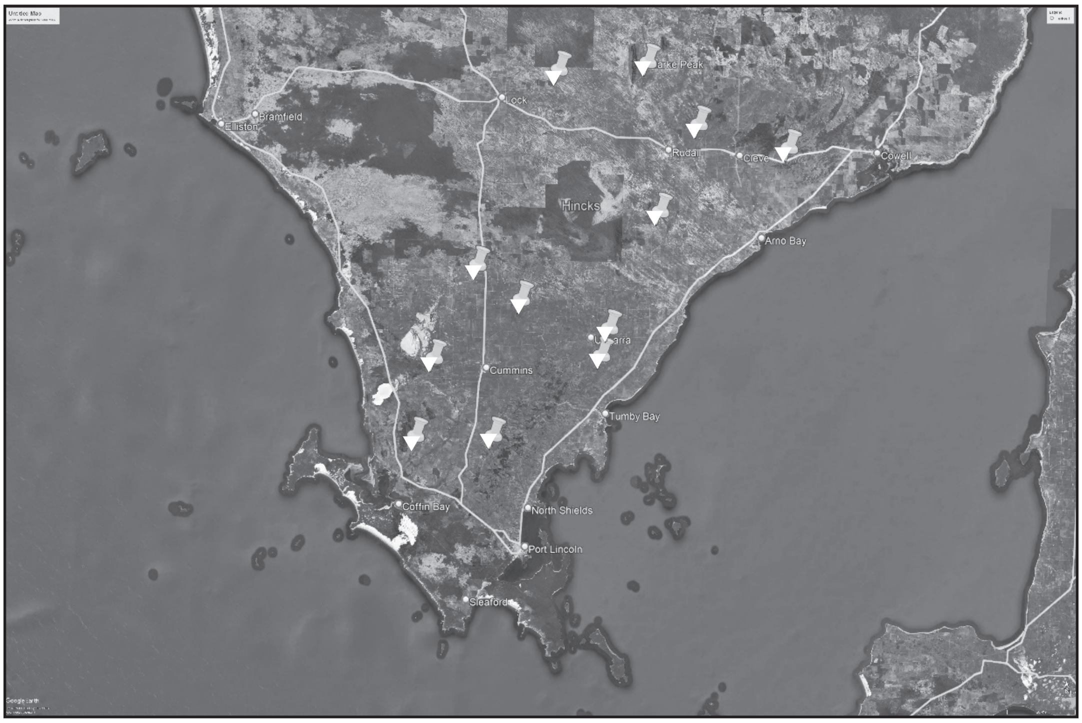

Figure 1. Location of wheat paddocks sampled for foliar diseases on the Eyre Peninsula in 2021.

Table 1. Diseases assessed in SA wheat crops in 2021.

	Disease
Endemic	Septoria tritici blotch (STB), powdery mildew (PM), stripe rust, stem rust, leaf rust (LR), yellow leaf spot (YLS), barley yellow dwarf virus (BYDV) eyespot, crown rot, flag smut
Exotic	Wheat blast, wheat leaf blight, wheat stem rust UG99

Table 2. Pathogens targeted using qPCR tests in SA wheat samples in 2021.

Pathogen	**Disease**
Bipolaris sorokiniana	Common root rot, spot blotch, black point
Eutiarosporella tritici-australis	White grain disorder/disease
Eutiarosporella darliae/pseudodarliae	White grain disorder/disease
Fusarium culmorum	Crown rot
F. graminearum	Fusarium head blight
F. pseudograminearum	Crown rot
Oculimacula yallundae	Eyespot
Pyrenophora teres f. maculata	Spot form net blotch
Pyrenophora tere f. teres	Net form of net blotch
Ramularia collo-cygni	Ramularia leaf spot
Puccinia sp.	Rusts including leaf, stripe and stem
Stagonospora nodorum	Septoria nodorum blotch
Gaeumannomyces tritici	Take-all
Pyrenophora tritici-repentis	Yellow leaf spot
Zymoseptoria tritici	Septoria tritici blotch

The whole sample comprising 50 whole plants from crown above was then milled and a subsample was tested using PREDICTA B. PREDICTA B is a qPCR testing platform designed for testing soil samples for the presence of soilborne diseases, however a suite of crown and foliar disease tests has also been developed (Table 2) and provides an opportunity to detect disease presence in the absence of symptoms i.e. latent infections. The DNA tests also allow capture of asymptomatic disease infection on the lower leaves, as the DNA tests were applied to the whole plant, whereas visual disease severity scores were only made on yield-critical plant parts as described above. Identifying asymptomatic pathogen infection or diseases commonly affecting lower plant plants through DNA tests is likely important for diseases such as YLS.

What happened?

In general, foliar disease expression was relatively low on the EP in 2021, as was the case in 2020. This was generally the case across SA, with the exception of a few crops in the South East (SE) affected by either Septoria tritici blotch or eyespot.

As in 2020, no exotic diseases were detected across SA. Endemic diseases stem rust and stripe rust were also not observed.

The most commonly detected disease was STB, which was present in all regions. Of the four surveyed regions, the EP had the lowest incidence of paddocks with STB, likely due to relatively dry conditions throughout much of the growing season in the mid EP i.e. Cleve, Lock, Wharminda. Although the lower EP (LEP) received higher rainfall, incidence of STB was still low.

Severity of STB across the state was also low. Average leaf area affected (LAA) for the flag leaf did not exceed 2% in any sample from SA and 70% of samples had no STB disease on the flag leaf. Of the three (out of 12) EP samples with STB, only one had disease in the flag leaf and severity for this sample averaged 0.6%. Severity was higher in Flag -1 (Table 3) and Flag -2 across SA (Table 4), although still relatively minor. Only four samples across SA had disease on the Flag -1 leaf in excess of 5% LAA; one of these came from the lower EP, a sample with 7% LAA on Flag -1 and 3 others from the SE. One sample in SA had STB disease above 10% on the Flag-1 leaf; from a cv. Rockstar (rated MSS) crop which received a single fungicide spray late in the growing season and had 16% LAA.

Table 3. Number of paddocks in each disease category for the South East (SE), Eyre Peninsula (EP), Lower/Mid/Upper North (MN) and Yorke Peninsula (YP) cropping regions in 2021. Each category is the average leaf area affected (%) by STB of Flag-1 leaves.

	Leaf area affected by STB				
Region	**0-5%**	**5-10%**	**10-25%**	**25-50%**	**>50%**
SE	4	2	1	0	0
EP	11	1	0	0	0
MN	14	0	0	0	0
YP	7	0	0	0	0

Table 4. Number of paddocks in each disease category for SA cropping regions in 2021. Each category is the average leaf area affected (%) by STB of Flag-2 leaves.

	Leaf area affected by STB				
Region	**0-5%**	**5-10%**	**10-25%**	**25-50%**	**>50%**
SE	2	1	2	1	1
EP	11	0	0	1	0
MN	14	0	0	0	0
YP	4	1	1	1	0

Table 5. Wheat paddocks with foliar diseases (% of paddocks sampled) across SA regions in 2021. The number in brackets is the number of paddocks sampled for each region.

Region	YLS	Leaf Rust	STB	Powdery Mildew	Crown Rot	Eyespot	BYDV
SE (7)	14	57	100	0	43	71	0
EP (12)	0	0	25	8	0	0	0
MN (14)	7	7	57	0	0	7	0
YP (7)	0	0	86	14	29	0	14

Septoria tritici blotch was most common on the Flag -2 leaf (Table 4). Of the three EP samples with STB, only one had disease in the Flag -2 leaf at a level with potential to cause yield loss, a cv. Vixen (rated S) crop on the lower EP with 25% LAA, which received two fungicide applications including one in early July. Disease severity in Flag -2 leaf was greater in the SE and Yorke Peninsula (YP) regions.

Leaf rust was observed in 3/7 paddocks in the SE and 1/14 paddocks in the Lower/Mid/Upper North (MN), but was not observed on the EP or YP. Eyespot was observed in 5/7 paddocks in the SE, but not in any other region. However, DNA testing confirmed the presence of low levels of eyespot in one sample from the EP, and three samples from the MN. Unlike in 2021, powdery mildew was not widespread across the paddocks sampled on the EP, although one paddock on the lower EP had moderate disease incidence within the paddock but at very low severity (<3% of any plant part). Disease incidence by region is presented in Table 5 (diseases which were not observed in any region are omitted).

DNA testing revealed that pathogen inoculum was more widespread than indicated by disease symptoms. Inoculum of YLS was present in 10/12 paddocks on the EP even though no symptoms were recorded in any sample in the visual disease assessment. YLS frequently affects lower plant parts early in the growing season and does not progress if managed effectively or if weather does not favour disease development (rain splash). The disease was likely present in lower leaves of samples only, however this is difficult to distinguish visually later in the season when lower leaves have senesced. YLS was more common on the EP than in the other regions surveyed.

Eyespot inoculum was only detected in one sample from near Ungarra, while crown rot was detected in five samples, all of which had wheat cropped in the previous two years.

What does this mean?

Foliar disease severity across SA was generally low in 2021 including on the EP. STB was widespread across SA, whilst YLS and crown rot inoculum was also commonly detected on the EP. These three diseases should be considered when planning crop choice and management for 2022. Septoria, powdery mildew and eyespot likely caused yield loss in a very limited number of paddocks across SA, despite significant management efforts in these paddocks. These samples were mostly from the SE, although powdery mildew also continues to present an issue in parts of the LEP.

No high priority exotic plant pathogens were detected during the survey.

Disease surveys will continue in 2022 with lentil and barley likely to be assessed.

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Fungicide resistant wheat powdery mildew - management and resistance testing

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Location
Bute
Northern Yorke Peninsula
Rainfall
2021 Total: 346 mm
2021 GSR: 234 mm
Soil type
Loamy sand
Paddock history
2020: PBA Jumbo 2 lentil
2019: Compass barley
Plot size
10 m x 1.5 m x 3 reps

Key messages

- **Varietal resistance plays an important role in managing wheat powdery mildew.**
- **Frequency of powdery mildew resistance mutation in wheat increased from 2019 to 2021.**
- **Group 11 QoI resistance mutation has been detected at lower levels in the central Yorke Peninsula and Mid North regions in 2021.**
- **The application of group 11 QoI fungicides increased the frequency of resistance mutation from 19% in the untreated control to 48.5% across QoI treatments.**
- **The presence of group 11 resistance mutations meant that the performance of group 3 + 11 fungicide mixtures was generally not any better than the straight group 3 (DMI triazole) fungicides.**
- **Group 7 SDHI fungicides did not provide any additional control to the standalone group 3 DMI fungicides when applied in product mixtures. This is due to poor efficacy of group 7 fungicides on wheat powdery mildew.**
- **Mutation at Cyp51 is a gateway mutation which infers that reduced sensitivity to the group 3 DMI fungicides is likely. High frequency of the Cyp51 mutation has commonly been encountered at trial sites, yet the group 3 DMI fungicides are currently providing the best fungicidal control, albeit incomplete control.**

Why do the trial?

Wheat powdery mildew (WPM) can cause up to 25% yield loss in Australia. Wheat varieties that are commonly being grown have poor varietal resistance, with many having ratings of susceptible to very susceptible (SVS), and only a few varieties rated as moderately susceptible to susceptible (MSS) or moderately susceptible (MS). Scepter^A is now a very common wheat variety and it has a SVS rating. Consequently, there is a heavy reliance on foliar fungicides for WPM control. Fungicide options for WPM and other diseases have relied heavily on the DMI group 3 (triazole) products such as tebuconazole and epoxiconazole, and these are the basis of many fungicide mixes, putting pressure on resistance development. In more recent years, there has also been increasing use of the QoI group 11 (strobilurin) actives in mixtures with DMI fungicides in products such as Amistar Xtra® (azoxystrobin + cyproconazole), but control from these fungicides has been variable due to QoI resistance developing in some of the same populations. New generation fungicides which contain a group 7 (SDHI) active ingredient, such as Aviator Xpro and Elatus Ace, were expected to provide improved control of WPM, particularly WPM populations with reduced sensitivity or resistance to group 3 DMI and 11 QoI fungicides.

However, findings from 2020 indicate the group 7 SDHI actives have poor efficacy on WPM, with most of the control from these fungicides being derived primarily from the group 3 DMI mix partner (Trengove *et al* 2021). In terms of fungicide resistance risk the DMI group 3 are medium risk, whilst the SDHI group 7 and QoI group 11 fungicides are medium-high and high risk for development of fungicide resistance (AFREN Fungicide Resistance Workshop), (FRAC Code List ©*2021).

Trials were initiated in 2020 and 2021 as part of SAGIT project TC120 to better understand best practice management of WPM given emerging fungicide resistance issues.

How was it done?

Five trials were established in 2020 and six in 2021. Each of the trials had a particular focus and the main varieties used (excluding the variety trial) were ScepterA and Chief CL PlusA in 2020 and Chief Cl PlusA in 2021. The focus of the 2021 trials were:

1. Varietal resistance and post emergent fungicides
   - Four varieties with disease ratings for WPM ranging from MS to SVS and four fungicide strategies, plus two new lines with no fungicide applied.
2. Pre-emergent fungicides
   - Six pre-emergent fungicides +/– post emergent fungicide.
3. Post-emergent fungicides
   - A range of post emergent fungicide treatments applied at the full label rate at both GS32 and GS39.
4. Fungicide timing
   - Fungicide applied at four timings (GS14, 32, 39 and/or 71) in 10 timing combinations.
5. Fungicide sequencing
   - A trial focused on controlling resistant powdery mildew using 12 combinations of pre-emergent and post emergent fungicides from a range of fungicide groups.
6. Fungicide coverage
   - A trial investigating the application rate of two fungicides and a control treatment and two water application rates 100 and 200 L/ha.

Post emergent fungicide treatments were applied using 015110 pre orifice nozzles in 100 L/ha of water.

The 2021 trials were located at a site on a sand hill north of Bute, northern Yorke Peninsula, where WPM has been frequently observed. Nearby sites were identified in a 2019 survey with reduced sensitivity to group 3 DMI and resistance emerging to group 11 QoI fungicides. This paper will only present results from the variety and product trials established in 2021 at this site.

Powdery mildew assessments were made during the growing season using either a canopy score of 0 - 5 (0 = no infection, 1 = low infection, 2 = low-moderate infection, 3 = moderate infection, 4 = high infection, 5 = severe infection) or pustule count on specific plant parts. Where pustules merged, an individual pustule was counted as an area of 2 mm^2. WPM samples were collected from the fungicide product trial on 27 September and these were submitted to the Centre for Crop and Disease Management (CCDM) for fungicide resistance testing.

A survey of WPM was collected from the northern Yorke Peninsula (NYP -30 paddocks), central Yorke Peninsula (CYP - 11 paddocks) and Mid North (MN - 10 paddocks). Agronomists working in these regions supplied location details of WPM infections. Sampling was performed on 23 and 24 Sept. Several WPM infected leaves were collected from each location and submitted to CCDM for resistance testing.

What happened?

In the NYP region, the 2021 season was characterised by a dry start and late May break, followed by a wet early winter period (Figure 1). The region then experienced a dry late winter and early spring. Wheat powdery mildew developed later in the 2021 season compared with 2020. WPM infection developed through the latter part of August as the crop approached GS39, whereas in 2020 infection occurred from GS14 in late June. Different seasonal conditions likely explain the differences in disease development between these years.

WPM spores germinate best at high levels of humidity (>95%) with a temperature range of between 10 to 22°C. Disease development will rapidly decline when temperatures exceed 25°C and humidity lowers however spores can still germinate when humidity declines below 50% due to their high moisture content. Under higher rainfall or free moisture conditions (i.e., rainfall) the moisture can both wash the spores from the leaves or inhibit spores from germinating by causing them to burst.

Varietal resistance to wheat powdery mildew

Varietal resistance is an important part of powdery mildew management. A total of six varieties were included in this trial in 2021 with a range of resistance levels to determine the benefit of varietal resistance and its interaction with fungicide use. The varieties included Grenade CL PlusA (MS), MaceA (MSS), ScepterA (SVS) and Chief CL PlusA (SVS). Scepter and Chief CL PlusA were both chosen as they have commonly been grown in the area and field observations indicate that Chief CL PlusA may be more susceptible than ScepterA, despite both being rated SVS. Two new lines, Calibre (RAC2721) rated S and IGW6683 with provisional rating of R were also included although no fungicide treatments were applied to these. This was to test their ratings against the WPM population at this site and against known commercial cultivars.

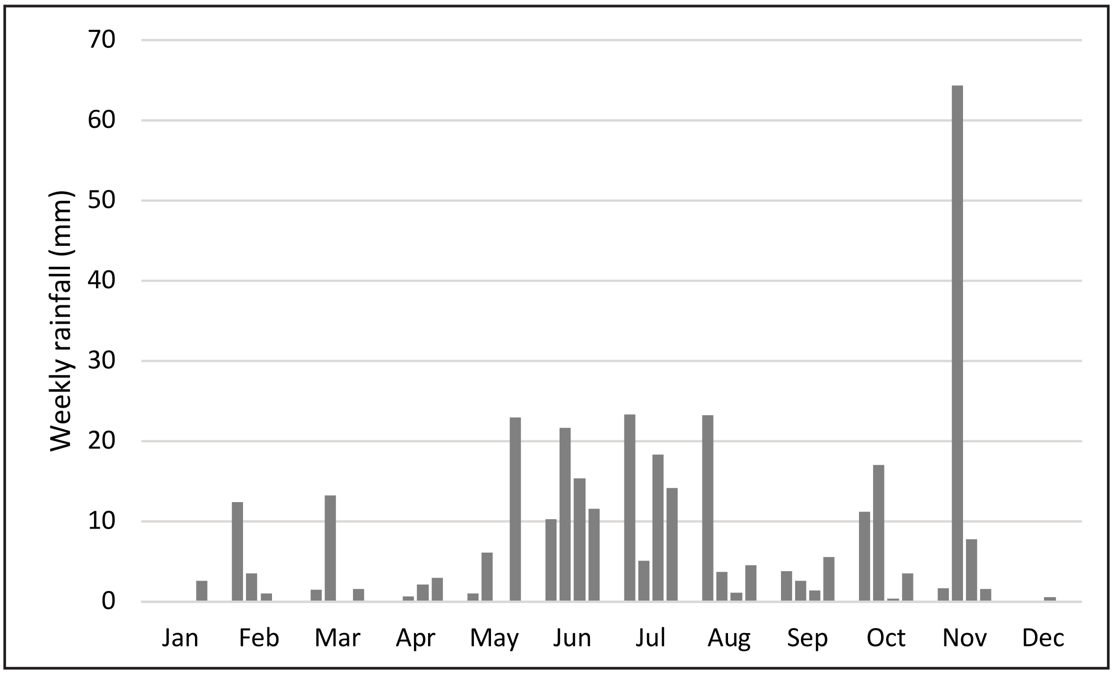

Figure 1. Weekly rainfall at Bute, 2021. April to October rainfall 234 mm, 2021 annual rainfall 346 mm.

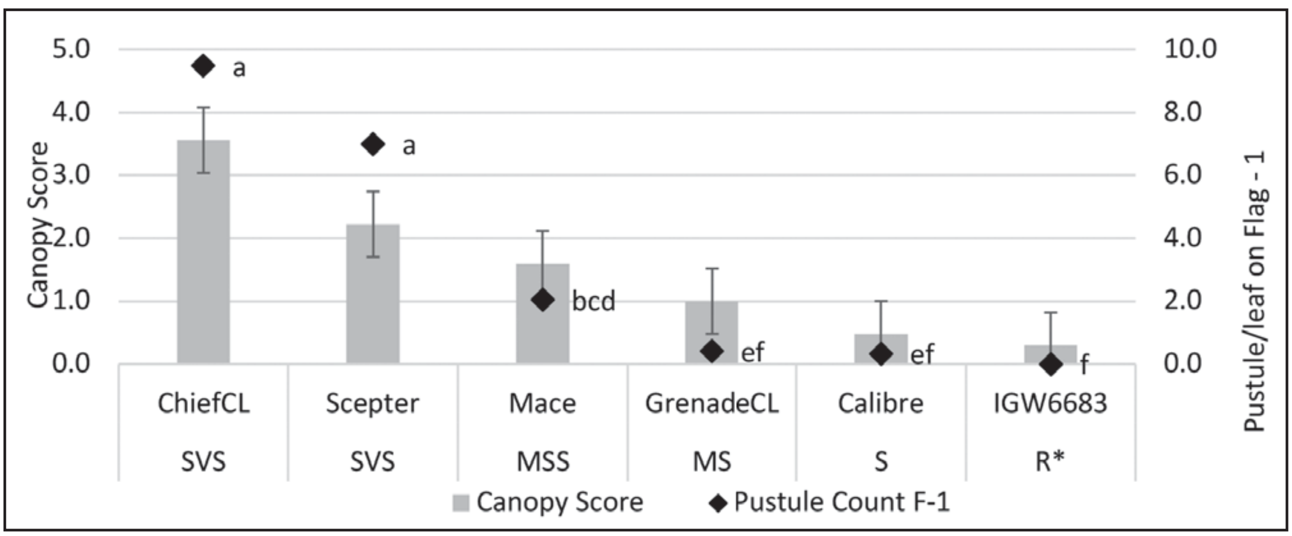

Figure 2. Powdery mildew canopy score (0 = no powdery mildew to 5 = severe infection, grey bars) and number of pustules on the leaf flag - 1 (black diamonds) for the nil fungicide treatments in the variety * fungicide trial at Bute on 22 Sept 2021. Letters denote significant differences between pustule count (Pr(F) <0.001) and error bars show LSD 0.05 for canopy score.

Powdery mildew build-up occurred late in the 2021 winter however, varietal resistance played an important role in the level of infection in the crop canopy (Figure 2). For the four main varieties, increasing the rating from SVS (Chief CL PlusΦ) to MS (Grenade CL PlusΦ) reduced the number of pustules on the leaf flag -1 (F -1) by 96%. Calibre Φ incurred less WPM infection than expected given its resistance rating, with results at this site placing it between the MS and R varieties, rather than its current S rating. However, WPM has large genetic diversity, with many different pathotypes likely to be encountered across the cropping regions, meaning that varietal resistances can perform differently depending on which pathotype is present. In accordance with its R rating, IGW6683 performed very well at resisting WPM infection. No WPM infection was recorded on this variety at all, except in one small 4 m^2 hotspot in the third replicate of the trial. In this hotspot, the average canopy score was 1.5, but there was no infection on the F -1 on September 22. Tara Garrard and Hugh Wallwork (SARDI) collected a sample of this isolate for culturing and testing in the glasshouse, with their results indicating that where this pathotype is dominant IGW6683 is likely to perform more like an SVS, rather than R. This example highlights the scale of genetic diversity that can be encountered in the field.

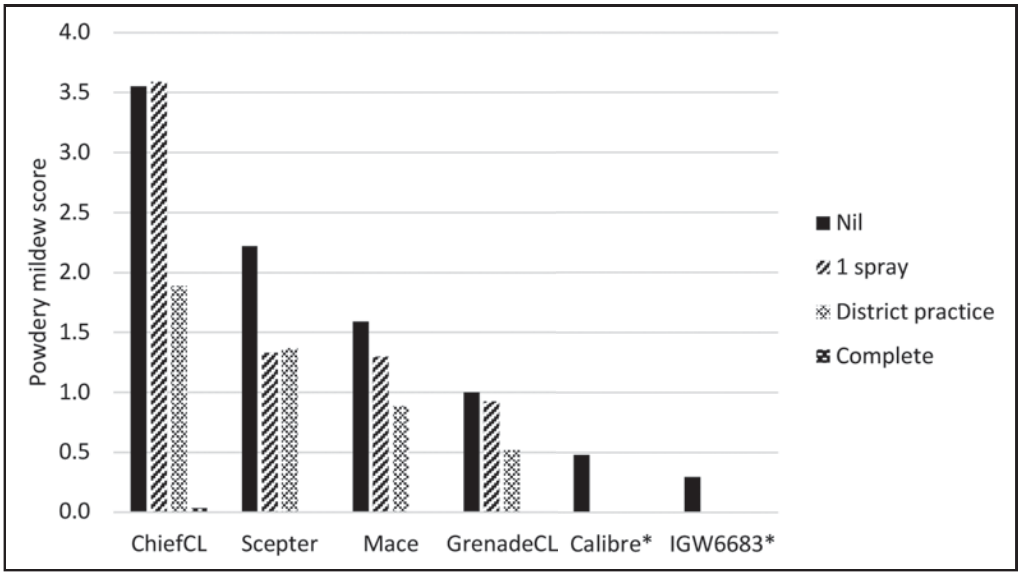

Figure 3. Powdery mildew canopy score (0 = no powdery mildew to 5 = severe infection) in the variety * fungicide trial at Bute on 22 Sept 2021 (LSD 0.05 = 0.2). Nil = no fungicide, 1 spray = Amistar Xtra 800mL/ha applied at GS39, District practice = Epoxiconazole125 500mL/ha applied at GS32 followed by Amistar Xtra 800 mL/ha applied at GS39, Complete = complete control. *Calibre and IGW6683 only received Nil treatment.

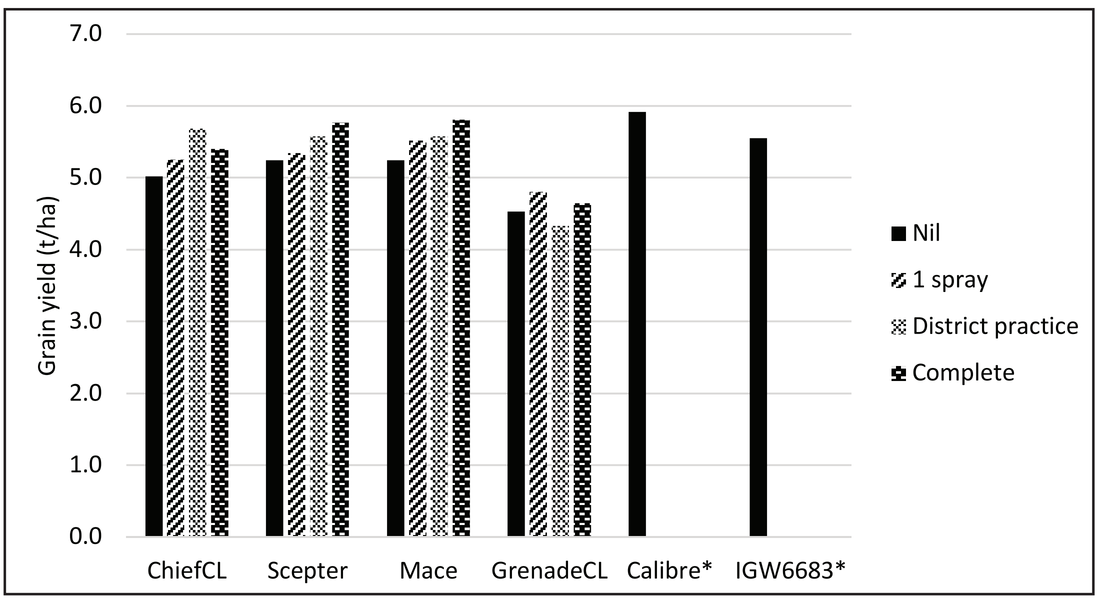

Figure 4. Grain yield (t/ha) for the variety * fungicide trial at Bute 2021 (LSD 0.05 = 0.51). Nil = no fungicide, 1 spray = Amistar Xtra 800 mL/ha applied at GS39, District practice = Epoxiconazole125 500 mL/ha applied at GS32 followed by Amistar Xtra 800 mL/ha applied at GS39, Complete = complete control. *Calibre and IGW6683 only received Nil treatment.

Varietal resistance has a significant effect on fungicide performance. In the variety Chief CL Plus⌽, which was shown to have the highest level of susceptibility to WPM, a one spray strategy (Amistar Xtra @ 800 mL/ha applied at GS39) did not significantly reduce the canopy score but the district practice treatment (Epoxiconazole125 @ 500 mL/ha applied at GS32 followed by Amistar Xtra @ 800 mL/ha applied at GS39) reduced the infection score to 1.9 (low-moderate) (Figure 3). Scepter⌽ was less susceptible to this WPM population, with the single spray strategy reducing the canopy score of infection from 2.2 (low-moderate) to 1.3 (low). This was equivalent to the district practice treatment. In comparison, the variety tested with the best currently available resistance, Grenade CL Plus⌽, had a lower canopy score in the nil fungicide treatment than the other varieties that were treated with a two-fungicide strategy, as did Calibre ⌽ and IGW6683.

The level of powdery mildew in the canopy was lower than the previous year, but some effect on grain yield was still apparent (Figure 4). Grain yields for Chief CL Plus, Scepter⌽ and Mace⌽ increased by 0.6-0.7 t/ha (11-13%) with fungicides whereas in the more resistant variety Grenade CL Plus⌽ there was no yield response. In 2020 the yield response in Chief CL Plus⌽ was also 0.7 t/ha (or 17%).

Resistance of wheat powdery mildew to fungicides and post-emergent fungicide performance

Wheat powdery mildew fungicide resistance was confirmed on the northern Yorke Peninsula (NYP) in 2019. The frequency of an indicator for the reduced sensitivity of group 3 DMI fungicides (the gateway mutation at Cyp51) ranged from 2 to 99%, while the group 11 (QoI) resistance mutation was up to 56% in one paddock, but with more than half of tested paddocks with no QoI resistance mutation (Table 1). A second survey was conducted in 2021 and the geographical spread of mutations associated with fungicide resistance on the central Yorke Peninsula (CYP), NYP and the mid north (MN) was assessed (Figure 5). For the NYP, CYP and MN the average level of the QoI resistance mutation was 33, 12 and 10% respectively with a large range in frequencies in each of the areas (Table 1). It shows that there has been a significant increase in the frequency of this mutation on the NYP since the first survey in 2019. All paddocks tested in this region now record at least a low level of the resistance mutation, and the median has increased from 0 to 19%. This is consistent with QoI resistance development in other pathogens, where once resistant individuals have been selected, resistance development occurs quickly with ongoing QoI fungicide selection pressure. The analysis of the NYP samples revealed a higher frequency of the resistance mutation compared with nearby regions, and this is consistent with anecdotal observations from agronomists where WPM control has been more difficult in this region. Frequencies of the QoI resistance mutation in 2021 on the CYP and MN is more comparable with the levels on the NYP in 2019. These results demonstrate where the CYP and MN might be in two years' time with ongoing QoI fungicide use. There is a large amount of variability within each region too, as shown by the range from minimum to maximum between paddocks, this may possibly be explained by fungicide applications within individual paddocks.

Table 1. Average, median, minimum and maximum frequency of the G143A mutation in the wheat powdery mildew strobilurin (QoI) target Cytb from paddocks across the central Yorke Peninsula (CYP), northern Yorke Peninsula (NYP) and the mid north of SA (MN).

Area	***# of samples***	***Average frequency (%)***	***Median Frequency (%)***	***Minimum frequency (%)***	***Maximum frequency (%)***
NYP 2019	17	13	0	0	58
NYP 2021	30	33	19	2	90
CYP 2021	11	12	5	1	38
MN 2021	10	10	1	0	90

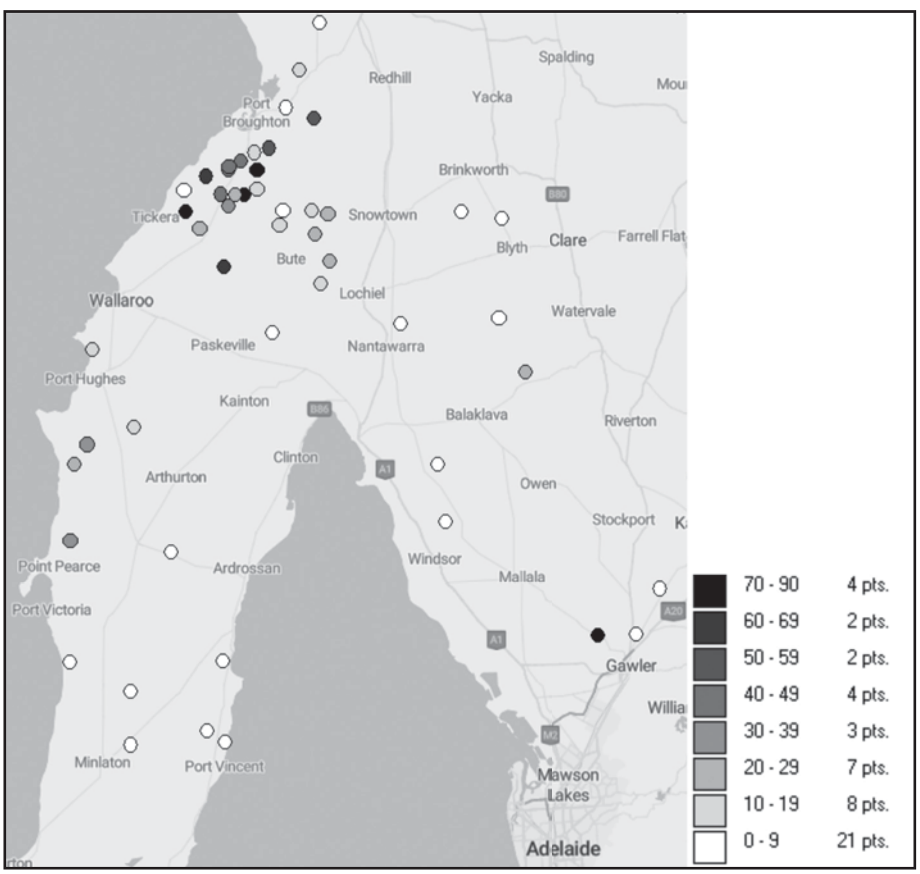

Figure 5. Sample locations and frequency of the G143A mutation in the wheat powdery mildew strobilurin (QoI) target Cytb for paddocks across the central Yorke Peninsula, northern Yorke Peninsula and the mid north of SA in 2021, number of points in the legend show number of paddocks sampled in that range.

At the 2020 trial site SE of Bute there was low level of the QoI resistance mutation with a frequency of 0.5% in the untreated control. The application of Tazer Xpert, containing QoI fungicide azoxystrobin increased the frequency of the resistance mutation to 9% (data not shown). However, the effect of QoI application was inconsistent at this site in 2020, with other QoI treatments having no effect on increasing resistance frequency. In contrast, at the 2021 trial site north of Bute, the untreated had 19% QoI resistance frequency (Figure 6). The application of any fungicide treatment containing a group 11 QoI increased the resistance mutation frequency significantly, to an average of 49%. As expected, the application of group 3 DMI and group 7 SDHI fungicides did not affect the frequency of the QoI resistance mutation.

At the 2021 trial site, an indicator for reduced sensitivity to group 3 DMI fungicides (gateway mutation at the DMI target Cyp51) was not affected by fungicide treatment and the average frequency was 87%. In comparison the average frequency at the 2020 trial site was 70%. Due to the limitation with this target, it is not possible to say which of these samples had isolates which may have caused any field failures.

The presence of fungicide resistance and reduced sensitivity will have a significant impact on fungicide performance. In 2020, the group 3 fungicides ranged in performance from 15 - 73% control of WPM on flag leaf - 1, and group 3 + 11 mixtures ranged from 73 - 84% control (Figure 7). Straight azoxystrobin (not registered) was included for research purposes in the post emergent fungicide trial to evaluate the individual group performance, and this produced 64% control. By contrast, the relative performance of these fungicides tended to be poorer in 2021, particularly for treatments containing the QoI fungicide azoxystrobin. The group 3 DMI control ranged from 0 – 62%, and 41 - 67% control from the group 3 + 11 mixtures (Figure 7). Control from the straight azoxystrobin treatment was only 15% in 2021. The general decline in performance from treatments containing the group 11 azoxystrobin can be attributed, at least partly, to the increasing frequency of the QoI resistance mutation at this site. It is likely that the ongoing use of this fungicide group will continue to increase the resistance frequency in the future.

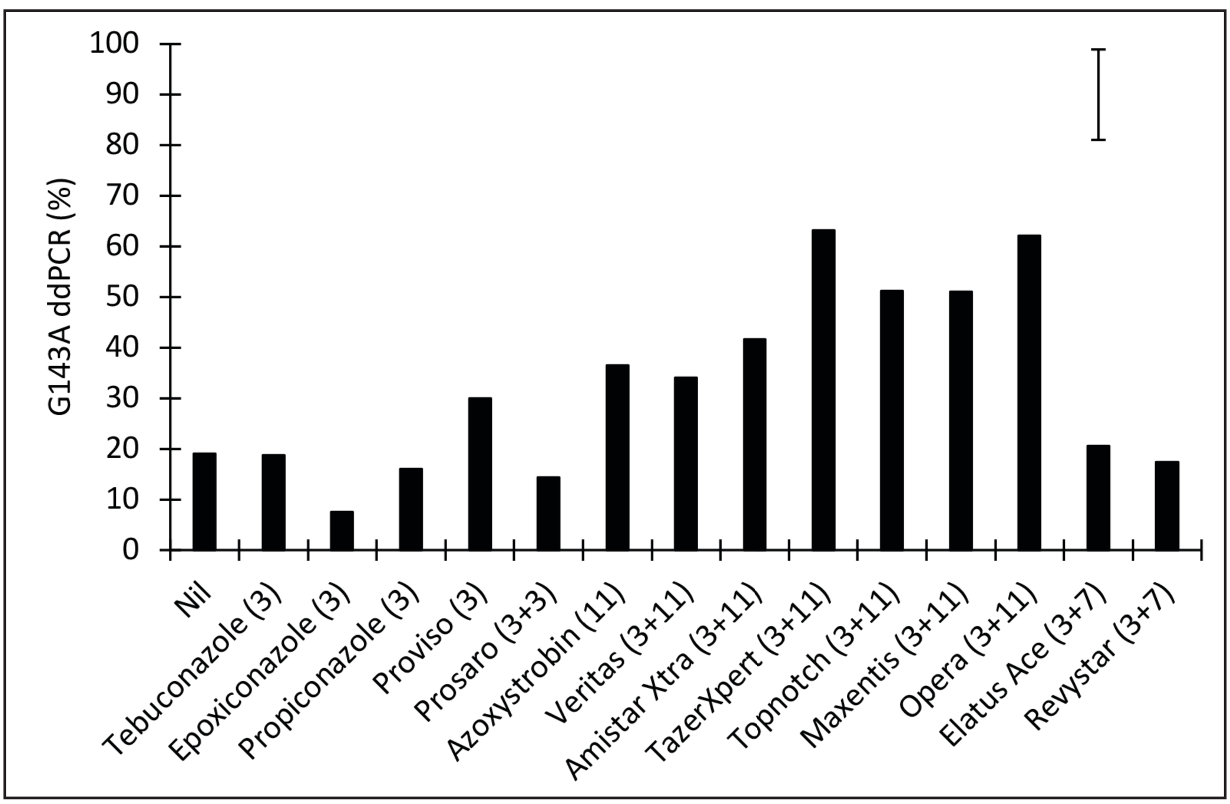

Figure 6. Frequency of the G143A mutation in wheat powdery mildew Cytb (strobilurin resistance) from the 2021 fungicide product trial. Bar shows LSD=0.05.

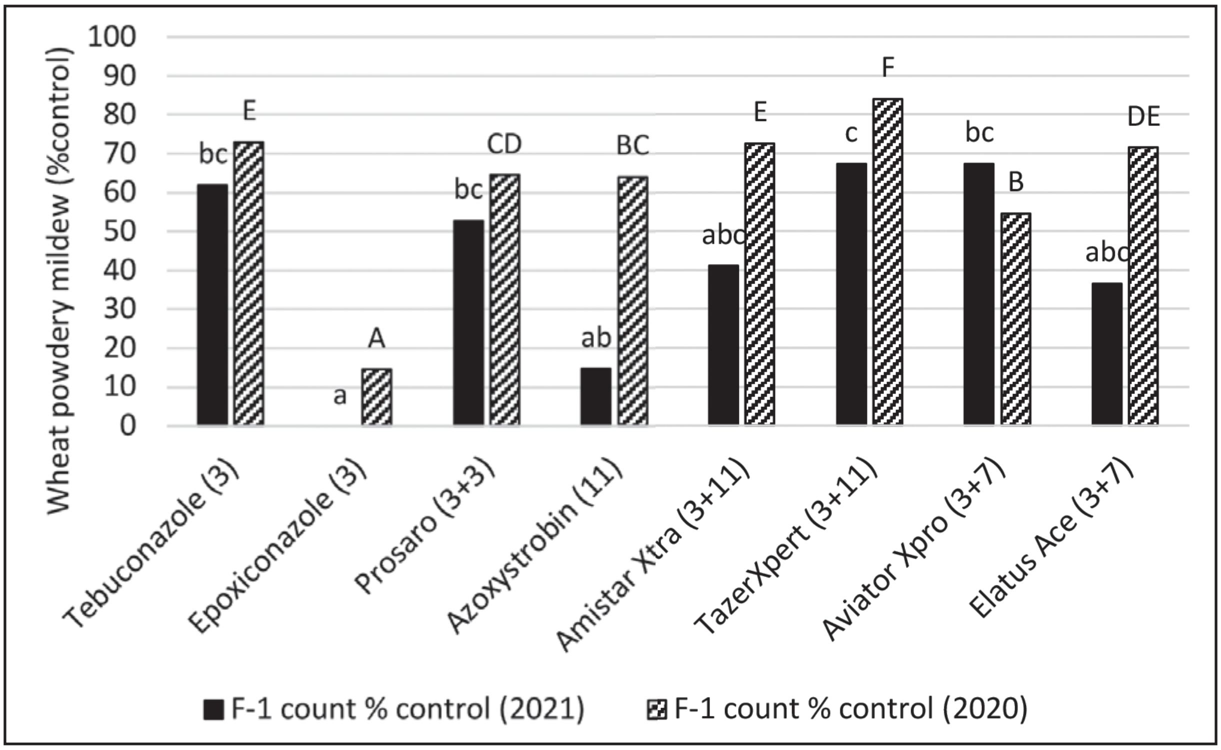

Figure 7. Effectiveness of products against WPM (% reduction from the control in pustules on Flag-1) for the post emergent product trial in years 2020 and 2021 at Bute. Lower and upper letters represent significant differences for 2021 and 2020, respectively.

What does this mean?

Fungicide resistant mutations in WPM are widespread in SA, it is therefore important to make assessments of individual fungicides in context of the resistance status at the site. However, it is also important to consider that powdery mildew is a population, and the population can shift with use of different fungicides.

At Bute in 2021, of the group 3 fungicides, epoxiconazole had the poorest efficacy, not being significantly better than the untreated control for pustule number on the leaf, flag -1 (F -1) (Figure 8). This is a similar result to 2020 (Figure 7). Of the other group 3 fungicides, tebuconazole, propiconazole, and Proviso (prothioconazole) performed similarly to each other, reducing the canopy score to an average of 2.0. The fungicide Prosaro, effectively contains a full label rate of two fungicides, prothioconazole and tebuconazole, the effect of this is additive with Prosaro producing the best control of the straight group 3 treatments, with a canopy score of 0.9 although this difference did not occur in the F -1 pustule number (Figure 8).

Of the group 3 + 11 mixtures, Veritas, Amistar Xtra, Tazer Xpert, Topnotch and Opera all performed similarly with an average canopy score of 2.1, which is no better than the straight group 3 DMI performance. Opera contains the group 11 fungicide pyraclostrobin applied at 85 g ai/ha at full label rate. Veritas delivers 76 g ai/ha azoxystrobin when applied at the full label rate. The other three have azoxystrobin applied between 120 and 160 g ai/ha at full label rate. This indicates that pyraclostrobin is performing in a similar manner to azoxystrobin. The fungicide Maxentis (prothioconazole + azoxystrobin) had the greatest efficacy in terms of canopy score, but it is not clear why this occurred as prothioconazole did not perform better than the other group 3 fungicides.

The next generation of fungicides include the new group 7 (SDHI) active ingredients. In both years, 2020 and 2021, these fungicides performed in a similar manner to the straight group 3 fungicides. In both years a straight group 7 active ingredient (not registered) was included in the trials and performed poorly (data not presented). This indicates that the group 3 mix partner in these new fungicides is providing the control of powdery mildew and further development of group 3 reduced sensitivity will reduce the efficacy of these products also.

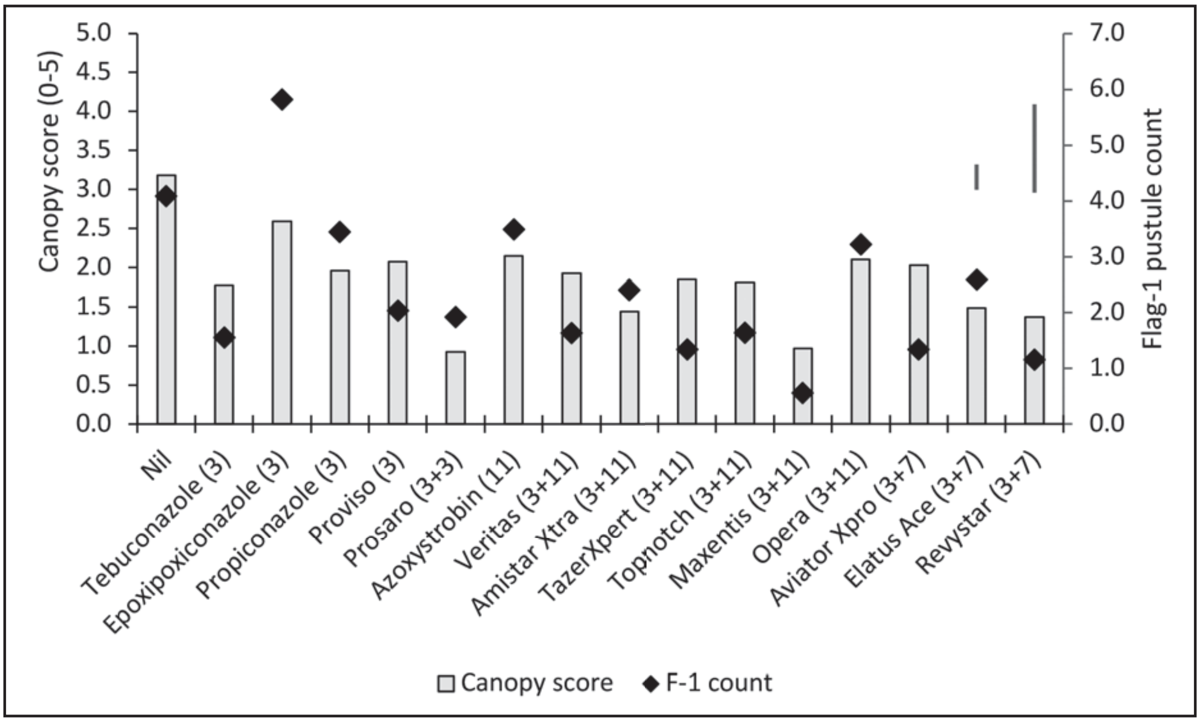

Figure 8. Canopy score (grey bars) and F-1 pustule count (black diamonds) for the post-emergent fungicide trial at Bute on 22 Sept 2021. LSD (0.05) = 0.3 (left) and 1.6 (right) for the canopy score and F-1 pustule count, respectively.

References

Trengove, S., Sherriff, S., Bruce, J. and Lopez Ruiz, F. (2021). Management of powdery mildew on fungicide resistant wheat, 2021 GRDC Adelaide Grains Research Update.

FRAC Code List ©*2021: Fungal control agents sorted by cross resistance pattern and mode of action (including coding for FRAC Groups on product labels), Fungicide Resistance Action Committee

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 SAGIT (project - TC120), the authors would like to thank them for their continued support. The input during this project from Michael Brougham, Hugh Wallwork, Tara Garrard and Nick Poole is gratefully acknowledged.

⦶ Varieties displaying this symbol beside them are protected under the Plant Breeders Rights Act 1994.

Trengove Consulting

SAGIT

Brianna Guidera, Rhaquelle Meiklejohn, Ian Richter and Sue Budarick doing Resilient EP soil characterisations at Kimba, October 2021.

Managing *Septoria tritici* blotch in the low and medium rainfall zones

Tara Garrard[1,2]
[1]SARDI, Waite; [2]University of Adelaide Affiliate-Associate Lecturer

Location
Hart Field Day site
Mid North of South Australia
Rainfall
Av. Annual: 405 mm
Av. GSR: 297 mm
2021 Total: 401 mm
2021 GSR: 231 mm
Soil type
Clay loam
Paddock history
2021: Wheat
2020: Oats
2019:
Plot size
12 m x 1.7 m x 6 reps

Location
Booleroo Centre
Upper North of South Australia
Rainfall
Av. Annual: 391 mm
Av. GSR: 277 mm
2021 Total: 334 mm
2021 GSR: 217 mm
Soil type
Red loam
Paddock history
2021: Wheat
2020: Lentils
Plot size
12 m x 1.7 m x 6 reps

Key messages

- **Understanding yield losses caused by Septoria tritici blotch in the low and medium rainfall zones is critical in disease management decision making.**
- **Trials run at Booleroo Centre (LRZ) and Hart (MRZ) in the 2021 growing season showed no significant yield loss due to the disease in varieties rated from SVS through to MR.**

Why do the trial?

Previous research on *Septoria tritici* blotch (STB) in wheat has been targeted at the high rainfall zone where yield losses from the disease are high. However, the prevalence of the disease is widespread and there is less known about the yield losses and economics of disease management in the low and medium rainfall zones. Developing our understanding of seasons where yield losses are significant will aid growers in decision making when managing the disease.

GRDC have invested in research on STB of wheat in the low and medium rainfall zones in the Southern Region (GRDC project: DJP2104-004TRX). Agriculture Victoria and SARDI are working together with input from FAR Australia and NSWDPI to conduct this work. The research aims to better understand the disease outside of the high rainfall zone (HRZ) to enable smarter integrated disease management strategies and to lower unnecessary chemical inputs.

Integrated disease management (IDM) work into STB includes spore trapping and stubble monitoring to better understand the epidemiology of the pathogen. This monitoring requires multiple seasons of data before results can be meaningful. This data will therefore be presented in future years as well. Plot trials have focused on better understanding the interaction between variety disease resistance rating and yield loss, as well as optimal fungicide timing. The yields from variety trials from the 2021 season are presented in this paper.

How was it done?

The yield loss by variety trials will be run for the three years of the project, but only the first year of trials have been completed so far.

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: Impalaⓟ SVS, Scepterⓟ S, Hammer CL Plusⓟ MSS, LRPB Lancerⓟ MS, Orionⓟ MRMS and Sunlambⓟ MR.

Trials were designed by Statistics for the Australian Grains Industry (SAGI) South and involved disease-inoculated plots and disease-controlled plots to develop plus and minus disease for each variety. Treatments were replicated six times and were blocked by disease treatment, plots were 10 m x 1.5 m. 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 GS31 and 39. The GS31 spray consisted of Elatus Ace (250 grams active ingredient/L propiconazole + 40 gai/L benzovindiflupyr) @ 500 mL/ha and the GS39 spray was epoxiconazole (500 gai/L) @125 mL/ha. Disease assessments were conducted at flowering by assessing percentage of leaf area infected on each leaf of 10 plants/plot. Preliminary single site statistical analysis was conducted with Genstat 20.

Table 1: STB mean whole plot disease severity - calculated from % leaf area at Hart Field Site and Booleroo in 2021.

Rating	Variety	Mean disease severity %			
		Hart Field Site		Booleroo Centre	
		+ Disease	- Disease	+ Disease	- Disease
SVS	Impala⟨PBR⟩	11.3	0.0	0.09	0.00
S	Scepter⟨PBR⟩	8.7	0.0	0.11	0.00
MSS	Hammer CL Plus⟨PBR⟩	2.2	0.0	0.00	0.00
MS	LRPB Lancer⟨PBR⟩	1.7	0.0	0.00	0.00
MRMS	Orion⟨PBR⟩	1.1	0.0	0.02	0.00
MR	Sunlamb⟨PBR⟩	0.1	0.0	0.02	0.00

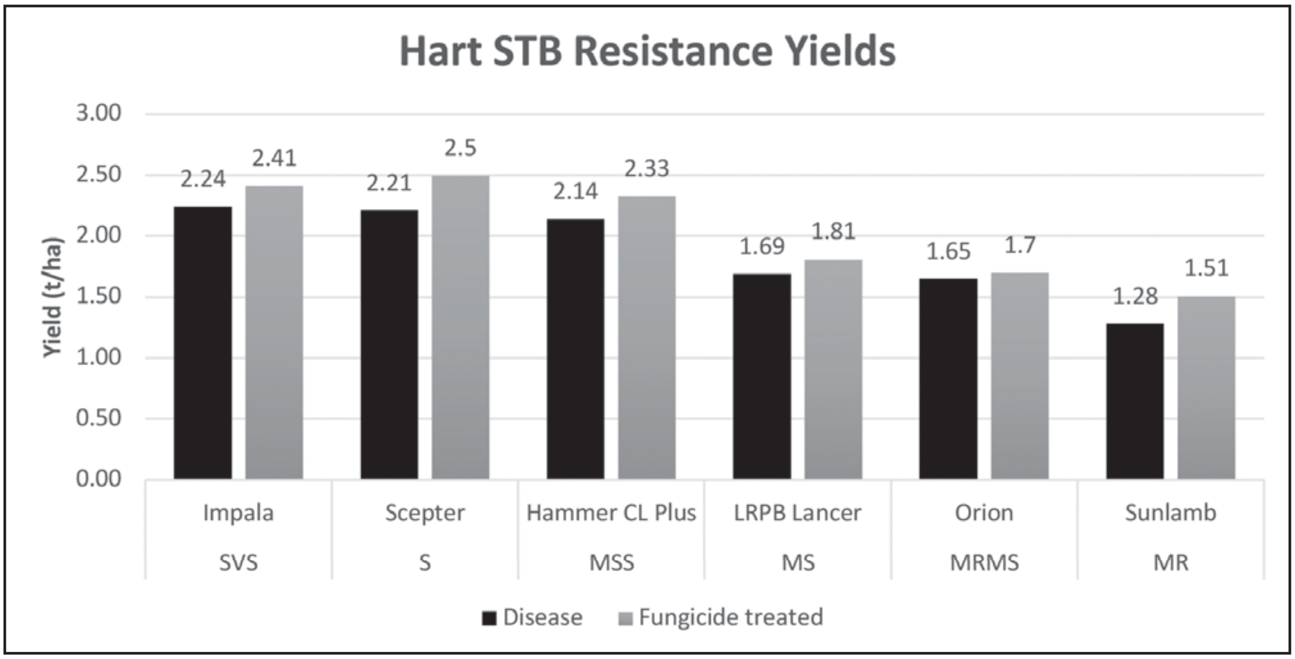

Figure 1. Mean yields of 6 wheat varieties associated with STB and its control at Hart Field Site in 2021. No significant differences were detected.

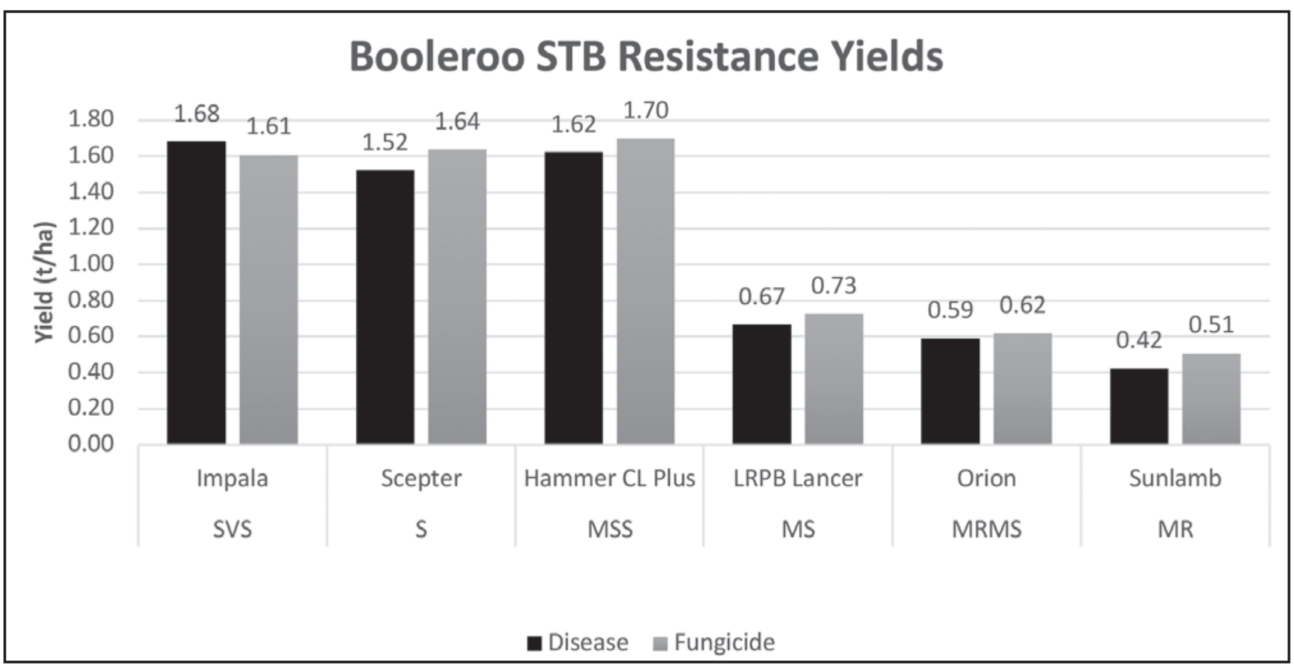

Figure 2. Mean yields of 6 wheat varieties associated with STB and its control at Booleroo Centre in 2021. No significant differences were detected.

What happened?

Conditions at both Booleroo Centre and Hart Field Site were not conducive for extensive disease development in the 2021 growing season. This was likely due to below average rainfall in early spring, which is critical for STB disease development in the upper canopy. As a result, disease levels were barely detectable at the Booleroo site and at Hart, the SVS variety Impala had only 11.3% disease (Tables 1) and the rest of the varieties even less. Growing season rainfall (April to October) was 217 mm at Booleroo and 232 mm at Hart.

Grain yields at Hart appeared slightly higher in the minus-disease plots than in the plus-disease plots (Figure 1). However, statistical analysis found no significant differences in the trial. Booleroo yields were very variable but minus-disease yields were slightly lower than plus-disease yields in all varieties except Impala (Figure 2). There were no significant differences in yields at the site.

These trials provide growers with the first year of trial data for STB disease development in low and medium rainfall zones. In the 2021 season, conditions were not conducive to disease development at these locations and resulted in no statistically significant yield losses. This is important data to inform decision making, as in 2021, fungicide sprays would not have been economic in these areas as yield differences were not significant.

These trials are also being run at medium and low rainfall sites in Victoria. It is expected that after three years of trials, there will be multi-environment data that is able to give growers information about which seasons, varieties and situations are conducive for STB yield losses.

What does this mean?

In 2021 at the low and medium rainfall sites tested, seasonal conditions were not conducive for enough disease development to result in significant yield loss, even in SVS and S varieties. Further years of data will better develop our understanding of which years provide conducive disease development so that fungicide use can be targeted to these seasons.

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. The authors would also like to acknowledge the collaborators on the STB project including Agriculture Victoria, FAR Australia, Hart Field Site Group, Upper North Farming Systems, Birchip Cropping Group and AgXtra.

Brian Dzoma and Fiona Tomney at SARDI EP Farmer Meetings, March 2022.

THE UNIVERSITY of ADELAIDE

GRDC GRAINS RESEARCH & DEVELOPMENT CORPORATION

Government of South Australia
Department of Primary Industries and Regions

SARDI
SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE

Wheat	Rust			*Septoria tritici* blotch	CCN Resistance	Yellow leaf spot	Eyespot	Powdery mildew	Root lesion nematodes		Crown rot	Common root rot	Flag smut	Black point ‡	Quality in SA
	Stem	Stripe	Leaf						*P. neglectus*	*P. thornei*					
Accroc	MS	RMR	S	MRMS	S	MR	MSS	MRMS	S	S	SVS	S	SVS	MRMS	Red Feed
Anapurna	MSS	RMR	MS	MRMS	MRMS	MRMS	–	RMR	MS	MS	SVS	MSS	R	S	Red Feed
Ascot	MRMS	MSS	RMR	S	MR	MRMS	S	S	S	S	S	MS	MRMS	MSS	APW
Ballista	MR	MSS	S	SVS	MRMS	MSS	S	SVS	S	MS	SVS	MS	SVS	MRMS	AH
Bennett	MRMS	S	S	MSS	S	MRMS	MSS	R	S	S	VS	S	SVS	MSS	ASW
Calabro	MS	RMR	MSS	MRMS	S	MR	–	RMR	S	MS	SVS	MSS	RMR	MS	Red Feed
Calibre	MR	MS	MSS	S	MRMS	MRMS	–	S	S	MS	S	-	-	-	AH
Catapult	MR	MRMS/ SVS	S	MSS	R	MRMS	S	S	S	MS	MSS	MS	MS	MS	AH
Chief CL Plus	MR	SVS	MR	MSS	MS	MRMS	S	SVS	MRMS	MSS	MSS	MS	SVS	MS	APW
Cutlass	R	MSS	RMR	MSS	MR	MSS	S	MSS	MSS	MSS	S	MS	MS	MS	APW
Denison	MS	MSS	S	MSS	MS	MRMS	S	S	S	S	S	MS	MS	MS	APW
Emu Rock	MS	SVS	SVS	SVS	S	MRMS	MSS	MSS	MSS	S	MSS	MS	MS	MSS	AH
Forrest	RMR	RMR	S	MS	S	MRMS	MS	S	VS	SVS	SVS	MS	MR	MR	APW
Grenade CL Plus	MR	MRMS	S	S	R	S	S	MSS	MSS	S	S	MS	MR	MSS	AH
Hammer CL Plus	MR	MS	S	MSS	MRMS	MRMS	S	MSS	MSS	S	MSS	MSS	RMR	MRMS	AH
Illabo	MRMS	MRMS	S	MSS	MRMS	MS	–	R	S	MSS	S	MSS	R	MRMS	AH
Impala	MR	MRMS	SVS	SVS	MSS	MSS	MSS	R	SVS	S	MSS	MSS	S	MS	Soft
Kittyhawk	MRMS/S	MR	MR	MRMS	S	MRMS	S	MS	S	S	SVS	S	RMR	MRMS	AH
Longsword	MR	R/S	MR/S	MSS	MRMS	MRMS	S	MSS	MRMS	MRMS	MSS	MS	MRMS	MS	Feed
Mace	MRMS	SVS	S	SVS	MRMS	MRMS	S	MSS	MS	MS	S	MS	S	MRMS	AH
Manning	MR	RMR	MSS	MR	S	MRMS	MS	MS	MSS	S	VS	SVS	R	S	Feed
Nighthawk	RMR	MRMS	MSS	MSD	MS	MS	–	SVS	MSS	MS	MSS	MSS	MSS	MS	APW
Orion	MR	MS	R	MRMS	MS	MSS	S	SVS	MS	S	MSS	MSS	S	S	Soft / Hay
Razor CL Plus	MR	MS	S	SVS	MR	MSS	S	MSS	S	MS	S	MSS	RMR	MS	ASW
Revenue	RMR ^	RMR	VS	MSS	S	MRMS	S	R	S	S	S	SVS	S	MS	Feed
Rockstar	MR	S	S	S	MSS	MRMS	S	SVS	MRMS	MS	S	MSS	VS	MSS	AH
Scepter	MRMS	MSS	MSS	S	MRMS	MRMS	S	SVS	S	MSS	MSS	MS	MSS	MS	AH
Sheriff CL Plus	MS	S	SVS	S	MS	MRMS	S	SVS	MRMS	MRMS	S	MSS	S	MS	APW
Trojan	MRMS	SVS	MR#	MS	MS	MSS	MS	S	MSS	MSS	MS	MS	SVS	MS	APW
Valiant CL Plus	RMR	MSS	S	S	MSS	MRMS	–	VS	S	S	S	–	–	–	AH
Vixen	MRMS	S	SVS	S	MSS	MRMS	S	SVS	MRMS	MS	S	MSS	SVS	MSS	AH
Zanzibar	VS	RMR	SVS	S	MSS	MS	–	MRMS	S	MS	S	S	SVS	MRMS	Red Feed

‡ - Black point is not a disease but a response to certain humid conditions.
R = resistant, MR = moderately resistant, MS = moderately susceptible, S = susceptible, VS = very susceptible, ^ = some susceptible plants, /* = Reaction to less common strains
Tolerance levels are lower for durum receivals
*SVS to a pathotype identified near Bute in 2021

Durum	Rust			*Septoria tritici* blotch	CCN Resistance	Yellow leaf spot	Eyespot	Powdery mildew	Root lesion nematodes		Crown rot	Common root rot	Flag smut	Black point ‡	Quality in SA
	Stem	Stripe	Leaf						*P. neglectus*	*P. thornei*					
Artemis	MR ^	MR	RMR	MRMS	MS	MRMS	–	S	MS	MR	VS	MS	MRMS	MS	Durum
Aurora	RMR	MR	R	MR/S	MSS	MRMS	S	MSS	MRMS	RMR	VS	MSS	R	MS	Durum
Bitalli	RMR	MRMS	MR	MRMS	MSS	MRMS	–	S	MSS	RMR	SVS	MS	R	MS	Durum
Saintly	MR	MS	MRMS	S	MS	MRMS	MS	MSS	MRMS	MR	VS	MS	R	MS	Durum

Triticale	Rust			*Septoria tritici* blotch	CCN Resistance	Yellow leaf spot	Eyespot	Powdery mildew	Root lesion nematodes		Crown rot	Common root rot	Flag smut	Black point ‡	Quality in SA
	Stem	Stripe	Leaf						*P. neglectus*	*P. thornei*					
Fusion	R	S	RMR	MR	R	MRMS	MS	R	RMR	MSS	MSS	S	R	MSS	Triticale
KM10	R	S	MR/S	MR	S	MR	–	R	RMR	MS	MS	MRMS	R	MRMS	Triticale
Kokoda	R	RMR#	RMR	RMR	MR	MR	–	R	MRMS	MS	MS	S	R	MS	Triticale
Normandy	R	RMR	RMR	RMR	MR	MR	–	R	RMR	MS	MR	MS	R	MRMS	Triticale
Razoo	MS	MSS	RMR	RMR	MS	MR	–	R	R	MSS	MS	–	–	–	Triticale
Wonambi	R	S	R	MR	MS	MR	–	R	MR	MS	MSS	MSS	R	–	Triticale
Joey	S	MSS	RMR	RMR	MS	MR	–	R	MR	MSS	MRMS	MRMS	R	MS	Triticale

‡ - Black point is not a disease but a response to certain humid conditions.

R = resistant, MR = moderately resistant, MS = moderately susceptible, S = susceptible, VS = very susceptible, ^ = some susceptible plants, /* = Reaction to less common strains
Tolerance levels are lower for durum receivals

Barley	Leaf rust*	Net form net blotch*	Spot form net blotch*	Scald*	CCN Resistance	Powdery mildew	Eyespot*	Covered smut	Common root rot	Root lesion nematodes		Black point
										P. neglectus	*P. thornei*	
Beast	MS-S	MR-S	MS	SVS	MR	MSS	-	R	S	MRMS	MRMS	MSS
Commander	MS-S	S-VS	MSS	MSS-SVS	R	MS	-	RMR	MSS	MRMS	MRMS	MSS
Commodus CL	MRMS-SVS	MR-MSS	MSS	MSS-SVS	R	MS	-	R	S	MRMS	S	MSS
Compass	SVS	MRMS-S	MS	MSS-SVS	R	MS	MS	R	MS	MRMS	MR	MSS
Cyclops	SVS-VS	MR-MS	MS-S	R-S	S	MSS	-	-	-	S	MRMS	MS
Fathom	MRMS-S	MSS-SVS	RMR	R-S	R	MRMS	MRMS	MR	MSS	MRMS	MR	MSS
Laperouse	MS-SVS	MR-MSS	MRMS	MSS-VS	S	MS	-	R	MSS	MR	MR	MSS
Leabrook	S-VS	MR-MS	MS	R-SVS	MR	MS	-	R	MS	MRMS	RMR	MSS
Maximus CL	MS-S	R-MS	MS	R-SVS	R	MS	-	MS	S	MRMS	MR	MSS
Minotaur	S-VS	R-MS	S	VS	R	S	-	-	-	MRMS	MR	MS
Oxford	MR-MS	MR-VS	S	MR-VS	S	RMR	MRMS	MRMS	MSS	MR	MR	MR
Planet	MRMS-MS	MR-SVS	SVS	R-S	R	R mlo	S	R	MSS	MRMS	MR	MRMS
Rosalind	MR-MS	R-MRMS	MSS	MR-S	R	MSS	MS	MRMS	S	MRMS	MR	MSS
Scope	MS-SVS	R-MR	MS-S	MRMS-SVS	S	RMR	MS	MS	MS	MRMS	MRMS	MS
Spartacus CL	MR-S	S-VS	S	R-SVS	R	MSS	MS	MS	MSS	MRMS	MRMS	MSS
Westminster	MR-MRMS	R-S	S	R-S	-	R mlo	-	MR	MSS	MRMS	MS	MRMS

R = Resistant, MR = Moderately Resistant, MS = Moderately Susceptible, S = Susceptible, VS = Very Susceptible, – = Uncertain
* Due to multiple strains of these pathogens, the table provides a range of reactions that may be observed. Different ratings are separated by a -
mlo - These varieties carry durable resistance

Oats	Rust		CCN		Stem nematode		Bacterial blight	Red leather leaf	BYDV*	*Septoria avenae*	End Use
	Stem*	Leaf*	Resistance	Tolerance	Resistance	Tolerance					
Bannister	S	MSS	MR	I	MRMS	MT	S	MS-SVS	MS	MRMS	Grain
Bilby	S	MS	VS	-	S	MI	SVS	MR-S	S	S	Grain
Brusher	SVS	MS/MRMS/RMR	MR	MI	S	MT	S	MR-SVS	SVS	MSS	Hay
Durack	S	MR/S	MRMS ^	MI-MT	S	MI	S	SVS	MSS	S	Grain/Hay
Forester	R-S	MR-MS	MS	MI	S	I	MS-S	MR	MR-S	S	Hay
Glider	MR-S	MS-S	MS	I	R	MT	R	MRMS	MR-S	MSS	Hay
Kingbale	S	MRMS	R	-	MR	MT	MSS	MRMS-S	MS	MSS	Hay
Koorabup	S	MSS	MRMS	-	S	I	S	MS-SVS	MS	MRMS-SVS	Hay
Kowari	S	S	S	-	S	I	MSS	MR-S	S	MRMS-S	Grain
Mitika	S	S	VS	I	S	MT	MSS	R-SVS	SVS	MR-S	Grain
Mulgara	S	MR/MS	R	MT	R	MT	MSS	MS-SVS	MSS	SVS	Hay
Tungoo	S	MR	R	MT	R	T	MR-MSS	RMR-MSS	MS	MR-S	Hay
Wallaroo	S	S	R	MT	MS	MI	S	MR-VS	MS	S	Hay
Williams	S	MRMS	VS	I	S	MT	MSS	MR-MS	MSS	MSS	Grain/Hay
Wombat	MS-SVS	SVS	R	T	MS	MT	MS-S	S	MR	MSS	Grain
Wintaroo	S	MRMS/S	R	MT	MR	MI	S	MR-S	MSS	MSS	Hay
Yallara	S	S	R	I	MS	MI	MS	VS	MSS	MSS	Grain/Hay

T = Tolerant, MT = Moderately Tolerant, MI = Moderately Intolerant, I = Intolerant, VI = Very Intolerant, – = Uncertain

* = Due to multiple strains of these pathogens, the table provides a range of reactions that may be observed. Different ratings are separated by a -

Chemical product trademark list

Knock Down + Spikes

Alliance - registered trademark of Crop Care Australasia Pty Ltd
Boxer Gold - registered trademark of Syngenta Australia Pty Ltd
BroadSword - registered trademark of Nufarm Australia Limited
Brodal Options - registered trademark of Bayer
Bromicide 200 - registered trademark of Nufarm Australia Limited
BS1000 - registered trademark of Nufarm Australia Limited
Buttress- registered trademark of Nufarm Australia Limited
Goal - registered trademark of Dow Agrowsciences
Gramoxone - registered trademark of Syngenta Group Company
Hammer - registered trademark of FMC Corporation
Hasten - registered trademark of Vicchem
Hot-Up spray additive - registered trademark of Vicchem
Jetti Duo - registered trademark of Imtrade Australia Pty Ltd
Kyte 700 WG - registered trademark of Nufarm Australia Limited
Liase - registered trademark of Nufarm Australia Limited
Nail 240EC - registered trademark of Crop Care Australasia Pty Ltd
Nuquat - registered trademark of Nufarm Australia Limited
Revolver- registered trademark of Nufarm Australia Limited
Roundup Attack - registered trademark of Monsanto Australia Limited.
Roundup PowerMax - registered trademark of Monsanto Technology LLC used under licence by Nufarm Australia
Roundup Ultra MAX - registered trademark of the Bayer Group
Spray Seed - registered trademark of Syngenta Group Company
Striker - registered trademark of Nufarm Technologies USA Pty Ltd
TriflurX - registered trademark of Nufarm Australia Limited
Volley SG - registered trademark of Sipcam Australia
Voraxer - registered trademark of BASF
Weedmaster DST - registered trademark of Nufarm Australia Ltd

Cereal Broad Leaf

2,4-D amine - registered trademark of Dow AroSciences
Agritone 750 - registered trademark of Nufarm Australia Limited
Ally - registered trademark of Du Pont (Australia) Ltd or its affiliates
Amicicde625 - registered trademark of Nufarm Australia Limited
Archer - registered trademark of Nufarm Australia Limited
Broadside - registered trademark of Nufarm Australia Limited
Broadstrike - registered trademark of the Dow Chemical Company or an affiliated company of DOW
BromicideMA - registered trademark of Nufarm Australia Limited
Dual Gold - registered trademark of a Syngenta Group Company
Ecopar - registered trademark of Sipcam Pacific Australia Pty Ltd
Lexone - registered trademark of Du Pont (Australia) Ltd or its affiliates
Logran 750WG - registered trademark of Syngenta Group Company
Lontrel - registered trademark of Dow AroSciences
Lontrel Advanced 600 - registered trademark of Corteva Agriscience
LV Ester 680 - registered trademark of Crop Care Australasia. Pty Ltd
LVE MCPA - registered trademark of Dow AroSciences
Tigrex - registered trademark of the Bayer Group
Velocity - registered trademark of the Bayer Group

Clearfield Chemical

Intervix - registered trademark of BASF

Adjuvants

Bonza - registered trademark of Nufarm Australia Limited
Chemwet 1000 - registered trademark of Nufarm Australia Limited
Hasten - registered trademark of Victorian Chemical Company Pty. Limited

Kwicken - registered Trademarks of Third Party SST Australia Pty Ltd
LI 700 - registered trademark of United Agri Products.
Spreadwet - registered trademark of SST Australian Pty Ltd

Grass Selective

Avadex Xtra - registered trademark of Nufarm Australia Limited
Clethodim - registered trademark of Syngenta Group Company
Elantra Xtreme - registered trademark of Sipcam Pacific Australia Pty Ltd
Factor –-registered trademark of Crop Care Australasia Pty Ltd
Hoegrass - registered trademark of the Bayer Group
Luximax - registered trademark of BASF
Mateno Complete - registered trademark of the Bayer Group
Monza - registered trademark of Monsanto Technology LLC used under license by Nufarm Australia Limited
Overwatch - registered trademark of FMC Australia
Propyzamide - 4 Farmers Australia Pty Ltd
Raptor - registered trademark of BASF
Reflex - registered trademark of Syngenta Group Company
Rustler - registered trademark of Cheminova Aust. Pty Ltd.
Sakura - registered trademark of Kumiai Chemical Industry Co. Ltd
Select - registered trademark of Arysta Life Sciences and Sumitomo Chemical Co. Japan
Targa - registered trademark of Nissan Chemical Industries, Co Japan
Ultro 900 - registered trademark of ADAMA
Verdict - registered trademark of the Dow Chemical Company or an affiliated company of DOW

Broadleaf

Aspect Options - registered trademark of Sipcam Australia
Flagship - registered trademark of ADAMA
Biffo - registered trademark of Nufarm Australia
Terrain - registered trademark of Nufarm Australia
Associate - registered trademark of Nufarm Australia
Sharpen - registered trademark of BASF
Amicide Advance -registered trademark of Nufarm Australia
Thistle Killem - registered trademark of Orion Agriscience

Insecticide

Alpha Duo - registered trademark of Syngenta Group Company
Astound Duo - registered trademark of Nufarm Australia Limited
Dimethoate - registered trademark of Nufarm Australia Limited
Dominex Duo - registered trademark of Crop Care Australasia Pty Ltd
Karate Zeon - registered trademark of Syngenta Group Company
Lemat - registered trademark of the Bayer Group
Lorsban - registered trademark of Dow Agrowsciences

Fungicide

Amistar Xtra - registered trademark of Syngenta Group Company
Baytan - registered trademark of the Bayer Group
Cruiser Maxx - registered trademark of a Syngenta Group Company
Elatus Ace - registered trademark of Syngenta Group Company
EverGol - registered trademark of the Bayer Group
Gaucho - registered trademark of the Bayer Group
Helix - registered trademark of a Syngenta Group Company
Impact - registered trademark of Cheminova A/S Denmark
Jockey - registered trademark of the Bayer Group
Maxentis - registered trademark of the Bayer Group
Opera - registered trademark of BASF
Prosaro - registered trademark of the Bayer Group
Proviso - registered trademark of ADAMA
Rancona Dimension - registered trademark of UPL
Raxil - registered trademark of the Bayer Group
Stayer - registered trademark of the Bayer Group
Tazer Xpert - registered trademark of Nufarm Australia Limited
Topnotch - registered trademark of ADAMA
Uniform - registered trademark of a Syngenta Group Company
Veritas - registered trademark of ADAMA
Vibrance - registered trademark of a Syngenta Group Company

Acronyms and abbreviations

ABA	Advisory Board of Agriculture
ABARES	Australian Bureau of Agriculture and Resource Economic and Sciences
ABS	Australian Bureau of Statistics
ADWG	Average daily weight gain
AFPIP	Australian Field Pea Improvement Program
AGT	Australian Grain Technologies
AH	Australian Hard (Wheat)
AIR EP	Agricultural Innovation and Research Eyre Peninsula
AM fungi	Arbuscular Mycorrhizal Fungi
APSIM	Agricultural Production Simulator
APW	Australian Prime Wheat
AR	Annual Rainfall
ASW	Australian Soft Wheat
ASBV	Australian Sheep Breeding Value
AWI	Australian Wool Innovation
BCG	Birchip Cropping Group
BYDV	Barley Yellow Dwarf Virus
CCN	Cereal Cyst Nematode
CfoC	Caring for our Country
CLL	Crop Lower Limit
DAFF	Department of Agriculture, Forestry and Fisheries
DAS	Days After Sowing
DAP	Di-ammonium Phosphate (18:20:00)
DCC	Department of Climate Change
DEWNR	Department of Environment, Water and Natural Resources
DGT	Diffusive Gradients in Thin Film
DM	Dry Matter
DMD	Dry Matter Digestibility
DOMD	Dry Organic Matter Digestibility
DPI	Department of Primary Industries
DSE	Dry Sheep Equivalent
DUL	Drained Upper Limit
EP	Eyre Peninsula
EPFS	Eyre Peninsula Farming Systems
EPFSS	Eyre Peninsula Farming Systems Summary
EPL	Eyre Peninsula Landscapes Board
EPR	End Point Royalty
FDF	Future Drought Fund
GA	Gibberellic Acid
GM	Gross Margin
GRDC	Grains Research and Development Corporation
GS	Growth Stage (Zadocks)
GSR	Growing Season Rainfall
HLW	Hectolitre Weight
IP	Inclusion Plates
IPM	Integrated Pest Management
LEP	Lower Eyre Peninsula
LSD	Least Significant Difference
LW	Live weight
MAC	Minnipa Agricultural Centre
MAP	Monoammonium Phosphate (10:22:00)
ME	Metabolisable Energy
MED	Molar Ethanol Droplet
MIR	Mid infrared
MLA	Meat and Livestock Australia
MRI	Magnetic Resonance Imaging
NDF	Neutral Detergent Fibre
NDVI	Normalised Difference Vegetation Index
NLP	National Landcare Program
NRM	Natural Resource Management
NVT	National Variety Trials
OM	Organic Matter
PAWC	Plant Available Water Capacity
P	Probability
PBI	Phosphorus Buffering Index
pg	Picogram
PGR	Plant growth regulator
PIRSA	Primary Industries and Regions South Australia
PM	Powdery Mildew
RD&E	Research, Development and Extension
RDTS	Root Disease Testing Service
SAGIT	South Australian Grains Industry Trust
SANTFA	South Australian No Till Farmers Association
SARDI	South Australian Research and Development Institute
SASAG	South Australian Sheep Advisory Group
SBU	Seed Bed Utilisation
SED	Standard Error Deviation
SGA	Sheep Genetics Australia
SMP	Soil Moisture Probe
SU	Sulfuronyl Urea
TE	Trace Elements
TOS	Time of Sowing
TT	Triazine Tolerant
UAN	Urea Ammonium Nitrate (42.5:0:0:0)
UNFS	Upper North Farming Systems
WAS	Weeks After Sowing
WP	Wilting Point
WUE	Water Use Efficiency
YEB	Youngest Emerged Blade
YP	Yield Prophet

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Growers attanding the Minnipa Agricultural Centre Field Day, September 2021

NOTES:

NOTES:


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