Eyre Peninsula Farming Systems Summary 2022

SARDI - Minnipa Agricultural Centre

Government of South Australia

Department of Primary Industries and Regions

SARDI

SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE

The research contained in this manual is supported by

GRDC — Grains Research & Development Corporation

SAGIT

AIR EP — Ag Innovation & Research Eyre Peninsula

Government of South Australia — Department of Primary Industries and Regions

SARDI — South Australian Research and Development Institute

SOIL CRC — Performance through collaboration

Australian Government — National Landcare Programme

The University of Adelaide

Future Drought Fund

SA Drought Hub

CSIRO

Australian Government — Department of Agriculture, Water and the Environment

Flinders University

AGT

LongReach Plant Breeders

Thank you to the sponsors of the Eyre Peninsula Farming Systems 2022 Summary

Platinum - SAGIT

Gold - AGT

Bronze - LongReach

Thank you to AIR EP for contributing to the EPFS 2022 Summary

Eyre Peninsula Farming Systems Summary 2022

Editorial Team

Amanda Cook	SARDI, Minnipa Agricultural Centre (MAC)
Fiona Tomney	SARDI, MAC
Nicole Baty	SARDI, MAC
Nigel Wilhelm	SARDI, MAC/Waite
Rhiannon Schilling	SARDI, Waite
Kaye Ferguson	SARDI, Port Lincoln
Amy Keeley	SARDI, Port Lincoln
Brian Dzoma	SARDI, MAC/Waite
Elijah Luo	SARDI, MAC

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.

This manual was compiled by The Printing Press

March 2023

Front Cover: Amanda Cook - MAC. 2022 MAC Barley breeding trials and Yarwondutta Rock

Cover design: Kate Gray - The Printing Press, Port Lincoln 2023

ISBN 1838-5540

SARDI Foreword

On behalf of the Department of Primary industries and Regions (PIRSA), I am delighted to present the 2022 Eyre Peninsula Farming Systems Summary. This annual publication provides valuable insight into the research and development activities undertaken at the Minnipa Agricultural Centre (MAC) and can be used by EP growers and producers as a resource to enable informed, practical decisions that are integral to running a successful farming business.

The release of this publication is timely, with South Australian crop production levels expected to rise to record levels for the 2022-23 growing season with EP being one of the main drivers of the increased tonnage. The 2022 EP cropping season was hindered due to inclement weather however, high rainfall in September and October resulted in an exceptional growing season.

Comparable with growers across the EP, MAC has observed many highlights during this exceptional season; beginning the season with significant soil-stored summer rainfall, an early seasonal break, a mild winter with lower than average rainfall, followed up with well-timed and significant spring rainfall events and a mild finish to the season allowing for good grain fill and high yields. A new plot harvester was a timely and very welcome acquisition. Harvest operations revealed wheat yields approaching 5 t/ha in some paddocks, the yield monitor indicating as high as 8 t/ha in some soil types. The purchase of a Front-End Loader was also a welcome addition making light work of hay movements and general tidy-up duties on the property.

The MAC field day held annually in September 2022 was attended by close to 150 growers, consultants, researchers, and industry representatives across the EP. The programme consisted of a variety of topics including trends in temperature and rainfall on the EP, placement of phosphorus fertilisers, sandy and calcareous soils, herbicide and grass weed management, rotational grain legumes, weed management in pulses, AgTech, virtual fencing and mixed annual legume pasture. Inclement weather conditions unfortunately restricted programme field tours, however the conditions were welcomed and have contributed to what has become an extraordinary season.

Most importantly I want to acknowledge the contributions of the MAC research and farm staff, the EP community for their support and research partners including the Grains Research and Development Corporation (GRDC), the South Australian Grains Industry Trust (SAGIT), AIR EP, 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, CSIRO and the University of South Australia. Your investment into the only low rainfall dryland farming research centre ensures MAC can continue to deliver positive research outcomes for the EP and South Australia.

Peter Appleford

Executive Director SARDI and Major Programs

Government of South Australia

Department of Primary Industries and Regions

SARDI

SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE

SAGIT Foreword 2022

The record crops grown in South Australia in 2022 is a true demonstration of South Australian grain growers' determination and pursuit of excellence. While the area sown has not increased over the past five years, the ability of growers to produce a 12 million tonne crop on the same land size is remarkable and should be applauded.

SAGIT is proud to support the EP Farming Systems Summary, an important resource for Eyre Peninsula's grain growers, who continually look to make sustainable improvements to their businesses.

Through dedicated investment in research and development, advances in grain production can continue to be made. Those who work in this industry know how readily SA grain growers adopt new technologies and make improvements based on research outcomes to ensure their farms are productive and profitable.

Providing easy access to research outcomes that drive continued improvement and boost yields is essential for ongoing success. Information of direct relevance to EP growers enhances their knowledge and understanding of local cropping constraints and opportunities to address them.

Included in this year's summary are outcomes and updates on EP projects funded by SAGIT, which on average, invests $2 million annually 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 terms of projects with on-the-ground activity on EP, SAGIT is funding several initiatives. This includes ongoing work into Group A resistant barley grass, led by Amanda Cook, SARDI, the Minnipa Agricultural Centre and the University of Adelaide.

A two year project which started in 2022 is looking at managing crown rot on the upper EP, with the aim of increasing the amount and consistency of grain for export and improving the ability of farmers and advisers (and researchers) to understand trials and demonstrations. Being able to interpret results and implement changes in local farming systems will lead to the adoption of novel ways of managing crown rot.

SAGIT is also committed to supporting projects through the Soil Cooperative Research Centre, many of which have direct relevance to EP farming systems, for example, improving calcareous soils.

In addition, SAGIT is proud to support career pathways for agricultural graduates. There are currently four projects designed to provide internship opportunities across applied and field research, with one of these on the EP designed to improve the local capacity for grains research, development and extension. In addition, SAGIT is funding the appointment of a Lead Agriculture Teacher role to mentor and support secondary school teachers, including those in EP schools, and to engage students with meaningful food and fibre production content.

Of course, there are many more SAGIT-funded projects that have applications 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 current SAGIT Snapshot, which can be viewed and downloaded via sagit.com.au/2022-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. Our Trustees and management team 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 2023.

Yours sincerely,

Max Young
Chairman

GRDC Foreword

The start of the 2022 season saw historically high input prices and most growers spent record amounts on getting the crop in the ground and through winter, adding to risk profiles. The wet spring then increased disease risks and left many growers on the Eyre Peninsula (EP) and elsewhere wondering if they should've applied more fungicide and nitrogen fertiliser. Fortunately, a favourable season overall (despite waterlogging on the lower-EP) resulted in exceptional yields and relatively high grain prices contributed to resounding profits for most crops.

The Grains Research and Development Corporation (GRDC) invests levy payer and government funds into research, development and extension to ensure growers on the EP remain productive, profitable and sustainable. Nationally, the winter crop production in 2022 is expected to be close to record. GRDC's diverse investments in pre-breeding, crop protection, soils, nutrition, agronomy and ag tech, have helped contribute to the industry's success.

GRDC ensures its investments are regionally relevant through feedback and insights from GRDC Southern Panel members from the EP – including current members Andrew Ware and Michael Treloar. GRDC's National Grower Network meetings run across the southern region, and local partners such as Agricultural Innovation and Research EP (AIR EP) and the SARDI Minnipa Agricultural Centre also contribute input to ensure research is relevant to the EP. GRDC's many investments on the EP are reported in this publication, which provides examples of how GRDC helps bring together a range of partners to address constraints or develop opportunities for grain growers.

In general, EP growers have been leaders in the adoption of soil amelioration across the southern region. The investment 'Increasing production on sandy soils in the low-medium rainfall areas of the southern region' had its final experimental season in 2022, and spring masterclasses including those on the EP summarised a huge amount of information about diagnosing crop constraints on sandy soils, the range of amelioration options, and the whole-farm economic implications of these. The research, led by the Commonwealth Scientific and Industrial Research Organisation (CSIRO), Department of Primary Industries and Regions South Australia (PIRSA) and the University of South Australia, showed how strategic tillage (e.g. deep ripping) helped close the yield gap at half of the trial sites over a number of years. Soil disturbance, near row sowing and wetting agents were also effective at overcoming water repellency and improving establishment. Additional extension workshops and validation trials supported by GRDC are planned as part of a collaboration with AIR EP, through the SA Drought Hub.

The investment 'Practical tactics to improve ground cover and ensure soil preservation following successive low rainfall seasons' continued to monitor two case study sites on the EP. This information will help growers make informed decisions to manage ground cover and reduce loss from sandy soils following dry conditions.

Ongoing collaborative research continues to focus on calcareous soils which limit yields and profits across large parts of the EP. Together with the Cooperative Research Centre for High Performance Soils, this GRDC investment builds on previous research into improvements in soil structure, crop nutrition, microbiological activity and management of root disease on these problematic soils. Research partners include PIRSA, New South Wales Department of Primary Industries, and CSIRO.

A new investment 'Tactics to minimise frost damage on the Eyre Peninsula' commenced in 2022 in partnership with AIR EP following growers' observations of the interaction between soil amelioration and frost damage. The researchers involved in this investment are monitoring crop phenology, canopy temperature and soil moisture on ameliorated and non-ameliorated soils to better understand their effects on frost damage, and whether any improvements are related to plant tolerance or frost avoidance. While frost was not a major issue in 2022, useful data was collected.

GRDC's ongoing investment 'Development and extension to close the economic yield gap and maximise farming systems benefits from grain legume production in SA', led by the University of Adelaide and PIRSA, again had trials across the EP. This investment is delivering grain legume validation and demonstration trials in response to emerging issues raised by growers, primarily via the GRDC National Grower Networks.

On the crop protection front, important initiatives such as Weed Smart, the National Canola Pathology Program and the Australian Fungicide Resistance Extension Network continue to provide growers with up-to-date advice regarding the management of weeds and diseases, and how to prolong the life of cost-effective chemistries. For example, a GRDC ryegrass forum conducted at Cummins in the spring of 2022 was very well attended, and also provided valuable information for upcoming investments.

As always GRDC and its partners make research information easily accessible and locally relevant to growers, exemplified by the National Variety Trials (NVT) Harvest Reports. These provide the latest independent information on yield, quality, and disease ratings from the NVT program to inform variety selection. The NVT Harvest Reports for the southern region are due to be published online by April 2023 nvt.grdc.com.au/harvest-reports/south.

In July 2023, GRDC will start implementing its new Research, Development and Extension Plan (2023-2028). The five year plan is a result of extensive consultations with growers, advisers, researchers and industry and is built on four pillars:

- Harness existing potential - the right crop and cultivar, crop protection, soils and agronomy.
- Reach new frontiers - transforming water and soil productivity and crop potential.
- Grow markets and capture value - value adding, reducing post-farm costs.
- Thrive for future generations - sustainable production, environment and social license.

In the past GRDC's investments primarily targeted higher profits (i.e. economic sustainability), but the industry can not do that in the long term if it ignores the impact of the grains industry on the environment and our communities. About 25% of our current investment portfolio also targets improved environmental outcomes, especially in the areas of pesticide use and soil health. The Australian grains industry has a clean and green image, and we need to help growers validate those credentials in an effective and efficient way. Hence, we are planning increased investment in the 'Thrive for future generations' pillar.

If you want any additional information about any GRDC investment there is more information on the GRDC investment listing on our website (grdc.com.au/grdc-investments), or should you wish to raise and discuss ideas with GRDC staff, please contact the GRDC Southern Office via southern@grdc.com.au.

Stephen Loss

GRDC Senior Regional Manager

Contents

Minnipa Agricultural Centre update

Amanda Cook
SARDI

Welcome to the twenty fourth Eyre Peninsula Farming Systems Summary, providing detailed reports on the outcomes of R,D&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, Future Drought Fund) 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.

Staff

In 2022 we farewelled Sue Budarick, who has been an invaluable part of the MAC team since 2007. Kym Zeppel moved into the AgTech Extension role and Marina Mudge into the NVT Senior Agricultural Officer position. Cainton Standley-Grace and Adele Shepperd joined the MAC team late 2022 as casual field assistants. Elijah Luo recently joined the MAC team as the SAGIT funded AIR EP Intern as well as Farzad Aslani, a new research officer who will be focussing on soils research.

The new plot harvester with an inboard weighing system arrived just in time for the 2022 harvest.

New Projects

The GRDC funded ‘Epidemiology and management of Rhizoctonia in low and medium rainfall zones’ (DAW2206-006RTX) started in 2022 with monitoring of treatments in the Soils CRC-GRDC Calcareous Soils trials located on grey calcareous sands. Further research trials will be implemented in the 2023-24 seasons.

GRDC has recently invested in a national project (UOQ2204-010RTX) to quantify the dynamics of nitrogen (N) cycling and losses across a diverse range of soil and environmental conditions representative of the Australian grains industry. Minnipa Agricultural Centre will host one of the two core trials for South Australia, with the trial starting in 2023 and running for 3 seasons.

Visitors

Mid 2022 saw visitors returning to the Minnipa Agricultural Centre, with business starting to get back to normal since COVID. AIR EP Low Rainfall R,D&E Committee Meeting held their first meeting at the Minnipa Agricultural Centre on 30 June and visited research trials.

MAC successfully held numerous extension activities in 2022, including the SARDI Farmer Meetings and the annual MAC Field Day which 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 Nelshaby Ag Bureau visited MAC on 15 August for a MAC farm tour and visited pasture trials. A GRDC National Grower Network meeting was held at Minnipa on 1 August to discuss regional research issues and priorities. The City of Port Lincoln Leadership Team representatives and Craig Midgley, Wudinna Council Economic Development Officer, visited MAC in late September to understand the agricultural research generated from MAC and the impact of the research on Eyre Peninsula farming businesses.

During the year SARDI Minnipa Agricultural Centre researchers presented research projects and outcomes at the GRDC Update, Soils CRC Conference, the Australian Agronomy Conference and the Australasian Weeds Conference.

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

It was great to host the MAC Field Day event on 7 September 2022, with over 130 growers and industry representatives visiting field trials and learning 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 that supports 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 2023 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 2022

Amanda Cook	MAC Senior Research Scientist (Agronomy)
John Kelsh	MAC Farm Manager
Fiona Tomney	Research Officer (Pastures), Drought Hub Coordinator for the Minnipa Node
Jessica Gunn	Research Officer (Livestock)
Farzad Aslani	Research Officer (Soils)
Zhaohan (Elijah) Luo	EP Grains Applied Research Intern
Nicole Baty	Project Management Support Officer (Agronomy)
Kym Zeppel	AgTech Extension Officer
Wade Shepperd	Senior Agricultural Officer (MAC Farm)
Ian Richter	Senior Agricultural Officer (Agronomy)
Craig Standley	Senior Agricultural Officer (Agronomy)
Marina Mudge	Senior Agricultural Officer (NVT)
Zakirra Simpson	Agricultural Officer (MAC Farm)
Leala Hoffmann	Administration Officer
Dr Rhiannon Schilling	Program Leader of Agronomy
Dr Nigel Wilhelm	Leader (Farming Systems)
Brian Dzoma	Research Officer (Calcareous Soils)
Katrina Brands	Casual Field Assistant
Rebbecca Tomney	Casual Field Assistant
Kysen Shepperd	Casual Field Assistant
Cainton Standley-Grace	Casual Field Assistant
Adele Shepperd	Casual Field Assistant

Table 1. Research projects delivered by SARDI Minnipa Agricultural Centre in 2022.

Project name	Funder	Summary
SARDI Projects		
Predicting Nitrogen Cycling & Losses in Australian Cropping Systems - Augmenting Measurements to Enhance Modelling	GRDC (UOQ2204-010RTX)	The project will quantify the dynamics of nitrogen (N) cycling and losses across a diverse range of soil and environmental conditions representative of the Australian grains industry. End: December 2026
Epidemiology and management of Rhizoctonia in low and medium rainfall zones	GRDC (DAW2206-006RTX)	Investigate disease management strategies to minimise the impact of Rhizoctonia in the LRZ and MRZ of the Southern and Western regions and SW NSW. An integrated and cost-effective approach of cultural, chemical and biological management strategies need to be developed as genetic solutions do not exist for Rhizoctonia. Contribute to an extension, communication, and training plan to deliver extension messages nationally. End: June 2025
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 supports 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
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: June 2023
Drought Resilience Practices in Mixed Farming Systems - Cross Hub Project	Australian Government's Future Drought Fund Soils and Landscapes Grant	Demonstration sites to be established in low rainfall farming systems to: • Demonstrate practices to improve rotations to increase soil N and reduce grass weeds for wheat production. • Determine if there are other measurable benefits to the farming system e.g. biomass production (for livestock feed), weed control and yield from early sowing? Focus groups in medium and high rainfall regions to identify best practice in containment feeding, knowledge gaps and barriers to adoption.
National Variety Trials	GRDC	Yield performance of cereal & break crop varieties at various locations across upper EP.
Crop Improvement Trials	Various	Various trials including; University of Adelaide - Heat Tolerant Barley AGT - Cereal Trials Longreach - Cereal Trials
Project delivery for AIR EP		
Best practice for early sowing opportunities	SA Drought Hub	Demonstration sites to be established in low rainfall farming systems to: • Demonstrate practices to reduce fertiliser toxicity and increase plant establishment in early sowing situations. • Determine if we can increase the seeding opportunities and plant establishment using new long coleoptile wheat varieties or seed priming. • Determine if there are other measurable benefits to the farming system e.g. biomass production (for livestock feed), weed control and yield from early sowing

Project delivery for AIR EP		
Strip and disc systems compared with knife points regenerative agriculture	SA Drought Hub	Demonstration sites to be established in low rainfall farming systems to determine: • Can we measure increased stored soil water in strip/disc vs conventional no-till knife point systems? • Are there other measurable benefits to the farming system such as soil cover, nutrition, weeds, disease, yield, soil health measures? • Are there impacts on pre-sowing herbicide efficacy in a strip/disc system compared with a conventional system?
Building drought resilience by scaling out farming practices that will enhance the productive capacity of sandy soil landscapes	Australian Government's Future Drought Fund Soils and Landscapes Grant	This project will enhance the drought resilience of farmers who manage 3 million hectares of sandy soils in the low-medium rainfall landscape of southeast Australia. This will be achieved through the adoption of practices that enhance the productive capacity of sandy soils by overcoming constraints including water repellence and compacted layers that prevent root growth and access to moisture and nutrients. Practices proven to work in small-scale trials will be scaled-out at 16 demonstration sites to build farmers' confidence across an extensive landscape of the Eyre Peninsula, Upper Yorke Peninsula, Mallee & Southeast regions. Case studies will be used to document outcomes from sites, with this information extended directly to 400 farmers through 17 events implemented by a consortium of grower groups. The project will also disseminate case studies using a digital extension hub & established social media networks to ensure maximum impact with farmers managing sandy soils across Australia.
Building resilience to drought with landscape scale remediation of saline land	Australian Government's Future Drought Fund	This project will demonstrate farmer ready management practices that break the cycle of saline land degradation exacerbated by very dry or drought conditions. Two key drivers of soil salinity will be addressed - dry saline land and Mallee seeps that cause lost production in low rainfall broad acre mixed farming landscapes. This project will establish 48 demonstration sites over two years working with farmers directly across 10+ million hectares of the low rainfall EP, Upper Yorke Peninsula, SA Mallee and Murray Plains, VIC and the NSW Mallee region.
Developing robust ground cover to enable resilience in low rainfall mixed farms - Seed priming	Australian Government's Future Drought Fund	Delivery of a component of the project 'Developing robust ground cover to enable resilience in low rainfall mixed farms', which aims to demonstrate, evaluate, and communicate innovative farming practices to low rainfall farmers in the tri-state Mallee and Eyre Peninsula regions to enable them to implement farming systems that maintain ground cover resilient to the pressures imposed by climate variability and management actions. The focus of this project is to deliver new and innovative technologies and practices to the region's farmers that support the maintenance of ground cover across the spectrum of seasons and sequences of enterprises. The outputs will be a synthesis of research knowledge of locally validated practices that will: reduce the disturbance and degradation of stubbles during seeding, harvest, and grazing; adopt stubble friendly amelioration practices; and result in drought proofed crop establishment.
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.
Complete project delivery		
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

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 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
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

Table 2. Minnipa Agricultural Centre events in 2022.

Event	Topic	Attendance
2022 EP SARDI Harvest Report Farmer meetings Minnipa, Piednippie, Ceduna, Port Kenny, Lock, Rudall, Cowell, Kimba 28 February-4 March	Presenters (in person/pre-recorded): Low Rainfall Barley Grass trial, Barley Grass Resistance - Amanda Cook Calcareous soils - Brian Dzoma SAGIT Herbicide Resistant Barley Grass, SAGIT Dry sowing and Long Coleoptile wheat - Amanda Cook Mixed annual legume pasture species - Fiona Tomney DLPS Grazing Trial and DLPS Demo sites - Ross Ballard AgTech - John Kelsh Sandy soils and NPKS - Dr Nigel Wilhelm Drought Hub - Fiona Tomney Pulses and Intercropping - Sarah Day	130 growers and industry representatives attended
Eyre Peninsula Farming Systems Summary	Compiling and printing 1000 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
AIR EP Low Rainfall R,D&E Committee Meeting Minnipa Agricultural Centre 30 June Wudinna 26 October	AIR EP Low Rainfall R,D&E Committee representatives held the June meeting at MAC and visited the research trials.	Low Rainfall R,D&E Committee and SARDI Staff
SAGIT Update Adelaide 27 July	MAC staff attended SAGIT research update.	Amanda Cook, Nicole Baty, Briam Dzoma and Nigel Wilhelm
Nelshaby Ag Bureau 15 August	Wade Shepperd took the group on a tour of the MAC Farm and Fiona Tomney presented trial information on the Annual Legume Pastures for Upper Eyre Peninsula project.	Nelshaby Ag Bureau, SARDI MAC staff
GRDC Minnipa NGN meeting 1 August	GRDC and local growers discussed regional research issues and priorities.	Local growers, GRDC and SARDI MAC staff
Soils CRC Conference Adelaide 23-25 August	Nigel Wilhelm presented Calcareous Soils research results and SARDI staff attended research planning meetings.	SARDI staff
MAC Field Day Minnipa Agricultural Centre 7 September	MAC Farm Update - John Kelsh Trends in temperature and rainfall on Eyre Peninsula - Dr Peter Hayman Deep P placement and current project round up - Dr Nigel Wilhelm Drought Hub Rotational Trial - Dr Chris Preston and Amanda Cook SAGIT Herbicide Resistant Barley Grass, SAGIT Dry sowing and Seed Priming - Amanda Cook NVT Variety Trials - Brianna Guidera and plant breeders SA Drought Hub - Fiona Tomney AgTech - Kym Zeppel Virtual Fencing - Megan Willis Foot and Mouth disease - Dr Cornelius Matereke Sandy Soils - Brett Masters Low rainfall pulses and broadleaf weed management in pulses - Sarah Day Mixed Annual Legume Pastures - Fiona Tomney Glyphosate Alternatives - Dr Chris Preston Calcareous Soils - Dr Nigel Wilhelm and Brian Dzoma Nitrogen, microbial activity and rhizoctonia in calcareous soils - Dr Gupta Vadakattu	130 growers, plant breeders and industry representatives

SAGIT Board Tour 7-8 September	The SAGIT Board visited project trial sites at Mount Cooper, MAC Field Day and Poochera Calcareous Soils site. 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, Nigel Wilhelm and visiting researchers.	3 SAGIT Board members and Drought Hub Intern and SARDI staff
Calcareous Soils site visit Poochera 8 September	SAGIT board representatives, agronomists and local growers visited the Calcareous soils site at MAC. Trial information was presented by Nigel Wilhelm and Amanda Cook (GRDC Rhizoctonia management).	SAGIT Board, SARDI MAC staff and growers
City of Port Lincoln Leadership Team Minnipa Agricultural Centre 30 September	City of Port Lincoln Leadership Team representatives and Craig Midgley Wudinna Council Economic Development Officer visited MAC and research trials. Presentations by Amanda Cook, John Kelsh and Fiona Tomney.	City of Port Lincoln Leadership Team, Wudinna Council and SARDI Staff
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
Australia Agronomy Conference Toowoomba 18-22 September	Brian Dzoma presented Calcareous soils research paper 'Low levels of group B herbicide residues affect subsequent crop performance on alkaline sandy soils in low rainfall farming systems'.	Brian Dzoma and Fiona Tomney
Australasian Weeds Conference Adelaide 25-29 September	Amanda Cook presented GRDC 'Demonstrating integrated weed management strategies to control barley grass in low rainfall zone farming systems' research paper.	Amanda Cook and Nicole Baty
Resilient EP RIG Meeting 10-11 March Port Lincoln 31 October Lock	Presentation by SARDI Amanda Cook on the 2021 soil characterisation information. John Kelsh and Amanda Cook attended RIG Meetings. Amanda Cook and Nicole Baty joined monthly on-line research meetings.	AIR EP, Regional Innovators Group (RIG), SARDI, EPAG, CSIRO
Future Drought Fund - Sandy Soils, Saline Soils and Robust Ground Cover 13-14 December	Amanda Cook and Brett Masters attended Drought Hub Sandy Soils, Saline Soils and Robust Ground Cover project meetings and presented Eyre Peninsula research results.	Amanda Cook and Brett Masters

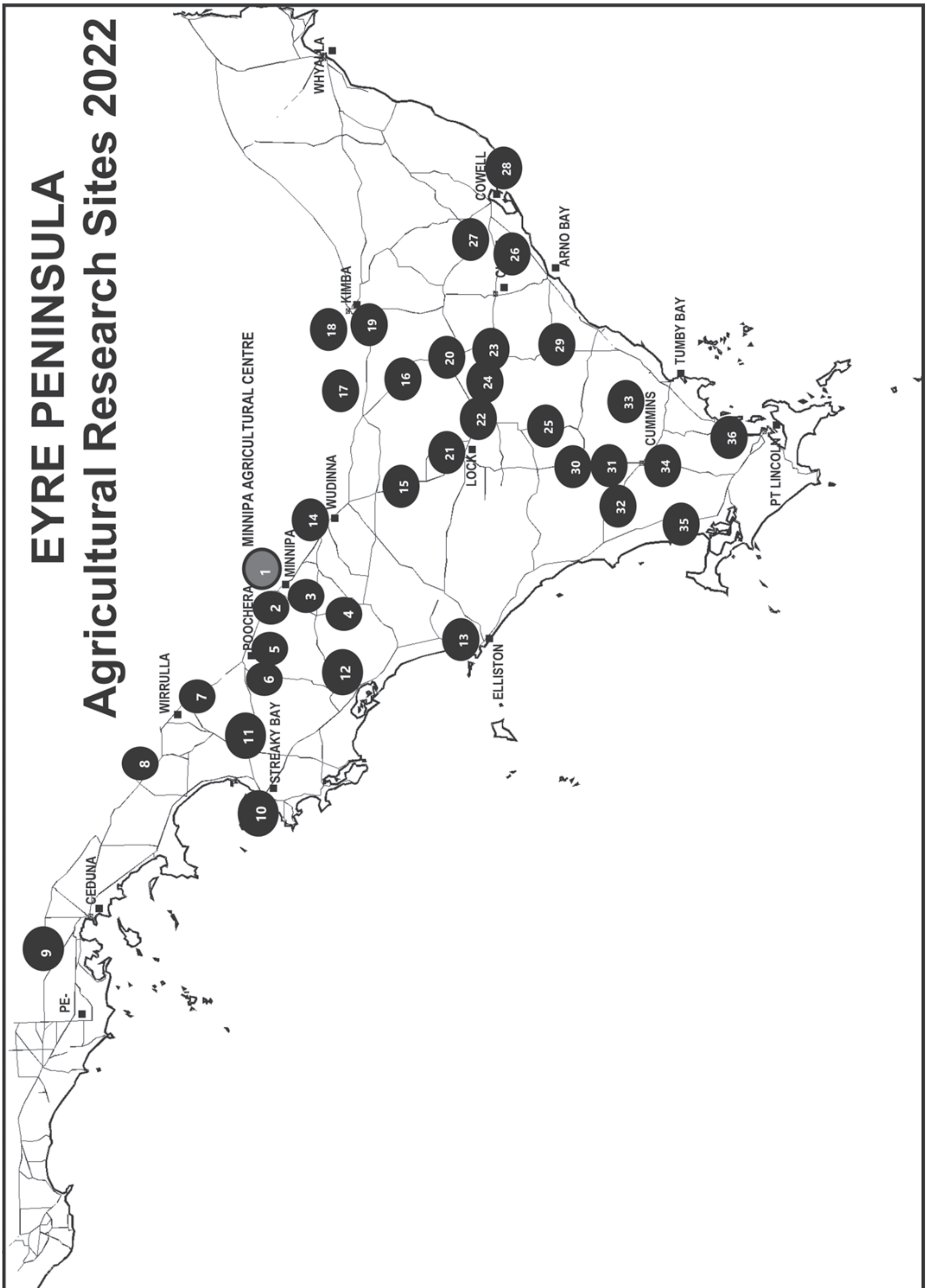
DATES TO REMEMBER

MAC Annual Field Day: Wednesday 13 September 2023

Thank you to Rabobank for contributing to the Minnipa Agricultural Centre Field Day and SARDI Farmer Meetings.

Government of South Australia
Department of Primary Industries and Regions

SARDI
SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE


EYRE PENINSULA
Agricultural Research Sites 2022
MINNIPA AGRICULTURAL CENTRE
COWELL
ARNO BAY
KIMBA
TUMBY BAY
WUDINNA
MINNIPA
POOCHERA
WIRRULLA
STREAKY BAY
LOCK
CUMMINS
ELLISTON
CEDUNA
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36

Eyre Peninsula agricultural research sites 2021 map references.

Map reference	Location	Trials	Host farm / business
1	Minnipa	NVT wheat and early wheat and barley. NVT Field pea & Canola - TT, IMI. Blackspot peas. Vetch breeding. Intergrain wheat and barley. AGT wheat. Annual Legume Pastures for the Upper EP. Barley grass management strategies. Soil Characterisation. Heat tolerant barley. Saline tolerant varieties. GM Canola. Herbicide resistance in barley grass. AGT seeding depth and herbicide. AGT CoAxium Barley. Calcareous soils. AgTech demonstrations. Saline soils. LongReach Early seeding and barley grass management. University of Adelaide heat tolerant barley. Glyphosate alternatives. Mixed cover crops.	SARDI Minnipa Agricultural Centre
2	Minnipa	Strip and Disc	Clint Oswald
2	Minnipa	Saline Soils, Soil Characterisation	Matthew Cook
2	Minnipa	Sandy Soils	Wes Daniell
2	Minnipa	Seed Priming, Soil Characteriations	Gareth Scholz
3	Minnipa	Soil Characterisation	Bruce Heddle
3	Minnipa	Soil Characterisation	Jerel Fromm
4	Mount Damper	Sandy soils	Nigel Oswald
4	Mt Damper	Soil Characterisation	AJ (Ashley) Michael
5	Poochera	Calcareous soils, Rhizoctonia Management	Shard Gosling
6	Chandada	Soil Characterisation	Shaun Carey
7	Cungena	Soil Characterisation	Myles and Kylie Tomney
8	Nunjikompita	NVT wheat and oats	Craig Rule
9	Penong	NVT wheat, SARDI wheat and barley trial, Early Sowing	Cade Drummond
10	Streaky Bay	Sandy Soils	Dion Williams
10	Streaky Bay	Soil Characterisation	Phil, Jan and Rochelle Wheaton
11	Piednippie	NVT wheat & Barley	Ian and John Montgomery
12	Port Kenny	Calcareous soils, Rhizoctonia Management	Simon Guerin
12	Port Kenny	Soil Characterisation	Nathan and Kylie Little
12	Calca	Soil Characterisation, barley grass	Craig Kelsh
13	Elliston	NVT barley. Cereal pathology.	Nigel and Debbie May
13	Elliston	Soil Characterisation	Tom Henderson
14	Wudinna West/ Pygery	Soil Characterisation	Greg Scholz
15	Warramboo	NVT wheat	Murphy Family
15	Warramboo	Soil Characterisation	Ben Pope
16	Cootra	Soil Characterisation	Todd Matthews
17	Pinkawillinie	Soil Characterisation	Paul Schaefer
18	Buckleboo	Soil Characterisation	Andrew Baldock
18	Buckleboo	Saline soils	Karinya Ag

18	Buckleboo	Strip and disc	Matt Vandeleur
19	Kimba	Pulse end-use in vetch & lentil. Lentil variety. Lentil Pre-emergent Herbicide Management	Tristan Baldock
19	Kimba	NVT Wheat	Trevor Cliff
19	Kimba	AIR EP soil borne pathogen	Tim Larwood
19	Solomon	Soil Characterisation	Shannon Mayfield
20	Darke Peak	NVT barley	Paul Dolling
20	Darke Peak	Soil Characterisation	Brad Wake
21	Lock	Soil Characterisation	Tim and Andrew Polkinghorne
21	Lock	Soil Characterisation	Gus and Mel Glover
21	Lock	NVT Canola - TT, IMI & RR	Leon and Karen Hurrell
22	Goldmine Hill	Soil Characterisation	Gus and Mel Glover
23	Rudall	Sandy Soils	Ben Ranford
23	Rudall	Soil Characterisation	Jason Burton
24	Murlong	Sandy soils	Mark Siviour
25	Hinks	Soil Characterisation	Justin Modra
26	Cleve	Soil Characterisation, Strip and disc	Paul Bammann
26	Yabmanna	Soil Characterisation	Justin and Kirralee Beinke
27	Mangalo	Soil Characterisation	Isaac Gill
28	Cowell	NVT wheat, Soil Characterisation, Early Sowing	Kaden Family
29	Wharminda	Sandy soils, Soil Characterisation	Hunt Family
29	Wharminda	Cereal pathology	Tim Ottens
30	Tooligie	Lentil Disease Management. Annual ryegrass management in Lentil. Grass and broadleaf weed management in Lentil. Lentil Pod Shatter. Ground Cover & Legacies of Pulses. Pulse Protein in Faba Bean & Field Pea.	Bill Long
31	Karkoo	Sandy soils	Modra
32	Yeelanna	Soil Characterisation	Jordan Wilksch
32	Brimpton Lake	Soil Characterisation	Luke Moroney
33	Cockaleechie	Soil Characterisation	Dan Adams
33	Ungarra	Soil Characterisation	Jamie Phillis
34	Cummins	Sandy soils	McCallum Family
35	Coulta	Herbicide Alternatives	Bruce Morgan
35	Mt Dutton	Soil Characterisation	Bruce Morgan
36	North Shields	Soil Characterisation	Mark Modra

Government of South Australia
Department of Primary Industries and Regions

SARDI
SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE

Agricultural Innovation & Research Eyre Peninsula update 2022

Bill Long 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 hosted, delivered and supported a range of activities across Eyre Peninsula in 2022. More than 30 RD&E projects were delivered on EP in 2022, ranging in value from $1500 to larger multi-year projects to the value of $3 million. Some of the AIR EP events delivered included:

- Young farmer network mapping meetings in January, February and March.
- AIR EP Lower EP Ag Expo featuring grain markets, nitrogen management, variable phosphorous rates, pulses in rotation and GM canola at Ungarra on 8 March.
- Mallee seeps technical workshop 9 March and 16 June.
- Mixed species workshop at Streaky Bay 18 March and Yallunda Flat 21 June.
- Regenerative Agriculture workshop in Port Lincoln 31 March.
- Pastures webinar with Ross Ballard, SARDI 6 April.
- GRDC ryegrass deep dive workshop with advisors at Cummins 28 June.
- Resilient EP nitrogen workshop at Cummins 6 July.
- Hosted a Department of Agriculture, Water and Environment visit on 25-26 July.
- Hosted the Resilient EP Innovation Tour of farms, bringing scientific expertise from across Australia to discuss opportunities for EP agriculture on 2-4 August.
- Sandy soils masterclasses at Murlong and Buckleboo on 30-31 August.
- Grain Legume Field Day/Frost field day and AIR EP AGM at Tooligie on 14 September.
- Various sticky beak days supported across EP in September and October.
- Salinity management workshop at Ungarra on 21 September.
- AIR EP Lower EP Crop Walk featuring pulses, canola, nitrogen, long coleoptiles, Resilient EP, lentil in sand and pastures on 29 September.

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 R,D&E investment in the region, reviewing projects and providing input into events for farmers.

Board Members: Bill Long (Chair), Andrew Polkinghorne, Ken Webber, Greg Scholz, Matthew Cook (LR R,D&E rep), Greg Arthur, Mark Stanley (special skills). In 2022 we farewelled Bryan Smith, the inaugural chair, and John Richardson and thank them very much for their service to agriculture with AIR EP and EPARF and LEADA prior to that.

Low Rainfall R,D&E Committee Members: Symon Allen (Chair), Andy Bates, Rhiannon Schilling, Amanda Cook, Greg Scholz (retired 2022), Daniel Bergmann, Matthew Cook, Rhys Tomney, Andrew Ware, Leigh Scholz, Kevin Dart, Chris Lymn (2023).

Medium Rainfall R,D&E Committee Members: John Richardson (Chair, retired 2022), Daniel Adams (current Chair), David Davenport, Dustin Parker, Billy Pedler, George Pedler, Jacob Giles, Denis Pedler, Lochie Siegert, Brett Masters, Daniel Puckridge, Nick Gale (2023).

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.

With thanks to our valued sponsors in 2022:

Gold Sponsors

Silver Sponsors

Bronze Sponsors

Eyre Peninsula seasonal summary 2022

Brett Masters
SARDI

Key messages

- **Intense storm activity in late January 2022 saw 80 to 250 mm of rain fall within 24 hours across the region. Runoff from this caused erosion and restricted paddock access and operations for some months.**
- **This and earlier rainfall resulted in high levels of stored soil moisture.**
- **Despite good subsoil moisture, dry conditions in March/April dried surface soils and delayed seeding in some districts, but good rain in late May resulted in good crop germination and early vigour.**
- **Further dry periods in June and July required crops to draw on stored soil moisture, but above average August and spring rainfall resulted in well above average crop yield potential.**
- **Lentils had very high yields throughout the region, except on areas on the lower EP which suffered extended waterlogging during the season.**
- **Exceptional yields combined with good prices made 2022 a profitable season for most.**

Summer 2021/22

Rainfall at harvest in 2021 prompted germination and rapid growth of summer weeds. Farmers began spraying these soon after harvest to conserve soil moisture for the 2022 crop, and most paddocks required multiple sprays to control successive germinations. Supply issues for some herbicides caused some farmers to cultivate to control Lincoln weed, blanket weed, and onion weed.

Cyclonic activity brought intense rainfall to central and eastern Eyre Peninsula (EP) on 21 January with reports of 80 to 250 mm of rain within a few hours causing flooding in Elliston, Wudinna, Kimba, Cleve, and Franklin Harbour LGA's. Intense storms also brought strong winds and around 80 mm of rainfall to the lower EP on 26 January. Runoff from this rain caused erosion in some eastern Eyre districts with gutters formed in parts of paddocks creating obstacles for normal paddock operations. Large areas of standing flood water remained for several months in many paddocks. To facilitate operations such as sowing and spraying, farmers started levelling affected areas as soon as they could get implements onto paddocks. Damaged roads in the Kimba, Cleve and Franklin Harbour districts caused issues for property access, the movement of agricultural equipment and supplies for some months and although paddocks contained large amounts of feed, many had fences damaged by flood waters and could not hold livestock.

Livestock remained in good condition over summer and, in addition to paddock feed, most farmers had adequate supplies of hay and grain on farm. Perennial pastures and mixed species summer fodder crops responded well to summer rains and provided some growers with additional feed options.

Soil moisture was very high at the end of March. This facilitated large scale deep ripping and delving operations on sandy soils in the western and central EP. Good soil moisture and favourable market conditions in early 2022 suggested that, except for small increases in canola and lentils to provide break options for weed control and manage frost risk, crop areas would be similar to normal.

Autumn

Grass weeds and medic pastures germinated rapidly with warm, moist soils. Good soil moisture and above average April rainfall on the upper Eyre Peninsula resulted in many western and central EP farmers starting seeding soon after Easter. Crops sown on flood affected areas in the Eastern EP germinated well and covered rapidly.

Dry surface soils resulting from dry conditions in late April and early May halted seeding, and caused uneven crop germination, particularly on non-wetting sands in the central and eastern EP. However, stored subsoil moisture maintained weed and volunteer crop growth, providing adequate surface cover for erosion protection on all but the most recently sown paddocks in most districts. Many landholders used seeding delays to continue soil modification and lime/gypsum spreading well into May, and although some lower EP paddocks were burnt to control ryegrass, most were minor burns along stubble rows.

Lower EP growers did not receive a "break of season" rainfall event and didn't start sowing crops until after Anzac day. Despite these delays most farmers sowed their whole cropping program with only small changes to crop areas.

Cool to cold temperatures, rain and very strong winds accompanied low pressure weather systems in late May. This slowed germination resulting in patchy crop establishment and variable growth, particularly on dry-sown paddocks. Isolated pockets of increased snail and mice activity were reported during autumn, but strategic baiting in vulnerable paddocks provided effective control.

Although annual medics and grasses in pastures germinated well, stubbles and summer weeds still provided good grazing and many growers left pastures ungrazed until they grew sufficient biomass following May rains. Livestock were in excellent condition at the end of autumn. There remained good supplies of hay in the region with producers only sowing a few hay paddocks to replenish on-farm supplies.

Winter

Despite delays seeding was mostly complete by the end of the first week in June. Scattered showers kept topsoils damp, assisting with crop germination and early vigour. Despite good pre-emergent herbicide efficacy, damp conditions and mild temperatures saw successive germination of weeds in crop.

Cooler temperatures in late June slowed crop and pasture growth. Whilst crops remained healthy the dry period set crop maturity about a fortnight behind with only small areas of dry sown cereals tillering by late June, and crops sown later in May only at the 2-4 leaf stage when cold conditions came. Multiple frost events were reported in inland districts in July. However, as crops were only at the early to late tillering stage they were unlikely to have impacted yield.

Dry conditions on the upper EP in early winter caused crops to draw on soil moisture and restricted crop and pasture biomass. This saw some growers supplementing paddock feed with hay and grain to allow pastures to recover. There were concerns that without early August rainfall crops would become moisture stressed. However, above average to well above average August rainfall (highest on record at Cummins) and warmer temperatures saw rapid growth of crops and pastures and crops remained healthy with good yield potential with livestock producers able to stop feed supplements.

With forecasts of good spring rainfall, additional nitrogen was applied to maintain crop yield potential, but supply chain issues made nitrogen fertiliser increasingly hard to source. Wet conditions saw increased pests and diseases with reports of Russian Wheat Aphid in cereals and a range of fungal diseases reported. Temporal waterlogging of many lower EP paddocks restricted trafficability for in-crop pesticide and nitrogen applications, resulting in a high demand for aerial contractors during the growing season. This early season waterlogging was somewhat mitigated by drier conditions in June and July, however, it was exacerbated by August rainfall and resulting in yellowing and poor growth of sensitive crops, particularly lentils. In most cases good crop growth in other parts of the paddock compensated for the affected areas, but there were many paddocks where crop mortality was substantial.

Spring

Mild conditions and average September rainfall maintained crop and pasture growth, allowing waterlogged soil profiles on the lower EP to dry out a little. On areas where waterlogging limited lentil growth, crops were sprayed off to control seed set of grassy weeds. Whilst several light frosts were reported in the central and eastern Eyre districts during September, they did not have large impacts on crop yields.

Good rainfall and mild temperatures in October provided ideal conditions for crop and pasture growth, which delayed crop and pasture senescence. These rains, along with good soil moisture and mild days helped to fill grain and, except in isolated areas where prolonged waterlogging limited growth of lentils or very dense crops collapsed, all districts had well above average yield potential at the end of October.

Damp, humid conditions resulted in increased fungal disease in pulses and cereals and growers applied fungicides to protect the high yield potential. Blackspot was high in peas throughout the upper and eastern EP, and heavy infestations of botrytis grey mould were reported in lentils. Powdery mildew and leaf rust were common in susceptible wheat varieties and caused severe damage in patches within paddocks. In affected crops, it was estimated that fungal diseases (powdery mildew and leaf rust) might have reduced yields by 10 to 15%, but fortunately, in most cases high yields from the rest of the paddocks compensated for yield losses due to powdery mildew.

With reports of high stripe rust loads in other regions, there were concerns that it might be an issue in wheat crops. While it was observed in crops across the region, fungicides applied to combat other leaf diseases effectively controlled it and limited the impact on crop yields. Continued damp conditions in spring increased snail activity across the region. Many farmers had to remove snails from harvested grain to meet delivery standards.

Pastures had high amounts of biomass at the end of spring, providing extended grazing until stubbles were available after harvest. Growers continued spray topping medic pastures to control grass weed seed set into late spring. Some hay was cut during September and October, mostly to replenish on farm supplies or for local sale, but rainfall and humid conditions hampered curing, with paddocks left unbaled due to quality decline. Regrowth on paddocks cut for hay increased surface cover and grazing opportunities.

Harvest 2022/23

Canola windrowing began in late October. Some barley crops were also windrowed to facilitate even ripening and minimise head loss. Severe winds on 18 November damaged ripe canola and barley crops, shaking grain from the heads. Yield losses were significant with reports of up to 50% damage in some central Eyre districts. Fortunately, due to the later season, most wheat crops were not yet ripe and did not sustain the same damage.

Whilst some canola, pulses and barley were harvested on the western and eastern EP in early November, good rainfall and mild temperatures slowed crop ripening, further delaying harvest with only about 10% of crops harvested by the middle of November. Farmers across the region took the opportunity to control emerging summer weeds while harvest was delayed and warmer weather in late November brought rapid senescence of crops and annual pastures.

Central EP pulse yields were exceptional with reports of 1.5 to 2.5 t/ha pea and lentil yields common on the grey calcareous soils, and up to 3.5 t/ha on the red loamy soils around Wudinna. Blackspot in peas was rife throughout the region which impacted yield and stained grain, resulting in quality downgrades. A late flight of native budworms was also reported in peas. These were generally controlled with routine insecticide applications and did not impact yield.

Canola yields in districts not affected by the wind event on 18 November, were well above average (in the order of 1.8 to 2.8 t/ha, with some reports of more than 3.0 t/ha on better soils around Mt Cooper). However, there were many reports of wind shaking canola seeds from the pods and reducing yields by 0.5 to 1.0 t/ha.

Cereals yielded well above average, however barley crops on the upper EP were particularly affected by wind damage. On paddocks with 4.0 to 5.0 t/ha potential estimates of yield loss generally ranged from 15 to 25% (with isolated reports of up to 50% yield loss). Whilst it was frustrating for growers to lose so much grain on the ground, particularly in a year with good grain prices, many of these paddocks still yielded above the long-term average.

As they ripened later, wheat crops generally had less yield loss to wind (in the order of 0.2 to 0.3 /ha). Reports of 3.4 to 4.0 t/ha wheat yields (over twice the long-term average) were common in western districts. Growers near Kimba and Koongawa reported yields of 3.4 to 4.2 t/ha with reports of 4.0 to 5.0 t/ha on better soil types around Wudinna.

Similar yields were reported in eastern Eyre districts, with cereal crops grown on a full soil moisture profile from January rainfall yielding more than 4.5 t/ha. On the heavier soils around Franklin Harbour cereal yields ranged from 2.5 to 3.5 t/ha with better soils at Darke Peak to Wharminda yielding 3.5 to 4.5 t/ha and some crops in more reliable areas near Cleve yielding 5.0 t/ha or more. Quality was generally good and whilst there was little hard wheat delivered due high yields, most crops achieved ASW or APW. Pulses yielded exceptionally well with reports of 2.5 to 3.0 t/ha of lentils, peas and beans and up to 4.0 t/ha of lupins. Canola also yielded well above average in excess of 2.3 t/ha.

On the lower EP, crops were much later and only canola and a small amount of barley were harvested by the end of November. Continued rainfall in eastern and lower Eyre districts kept most pulses and medic pastures still green at the end of November, which caused some issues with most growers having to desiccate pulses to harvest.

Damp, cool conditions at harvest meant growers found it difficult to get grain to dry below critical moisture levels for delivery. This delayed harvest considerably with most growers not finishing until mid-January. Cereal yields on the lower Eyre were above the long-term average, and reports of 5.0 to 6.0 t/ha were common in more reliable districts. Crops on heavier soil types north of Tumby Bay were reported to yield 3.8 to 4.5 t/ha.

Canola yields were exceptional and reports of 2.5 to 3.5 t/ha with oil content above 43% were common. Pulses generally yielded above the long-term average, except where disease, waterlogging, ryegrass competition or lodging were issues.

Rain at harvest caused some grain quality issues with black tip and shot grain resulting in quality downgrades at delivery. Fortunately, good yields and good prices still made 2022 a profitable season for most growers. Harvest rainfall also saw most growers applying their first summer herbicide spray before Christmas. There are concerns that increased snail activity will require more intensive management practices and that high amounts of weather-damaged grain on the ground might increase mice numbers in 2023.

Acknowledgements

The author wishes to acknowledge that much of the information contained within this summary has been compiled from PIRSA's 2022 Crop and Pasture reports and the Department for Environment and Water 'Erosion risk on SA's agricultural land' (Land Condition) monthly reports, 2023.

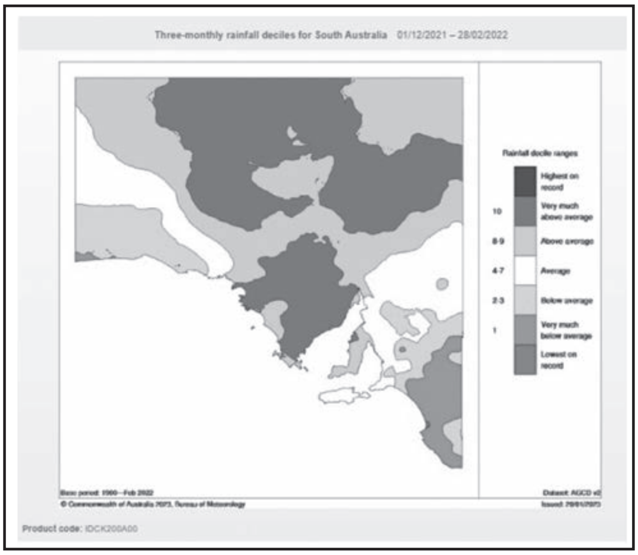


Figure 1.

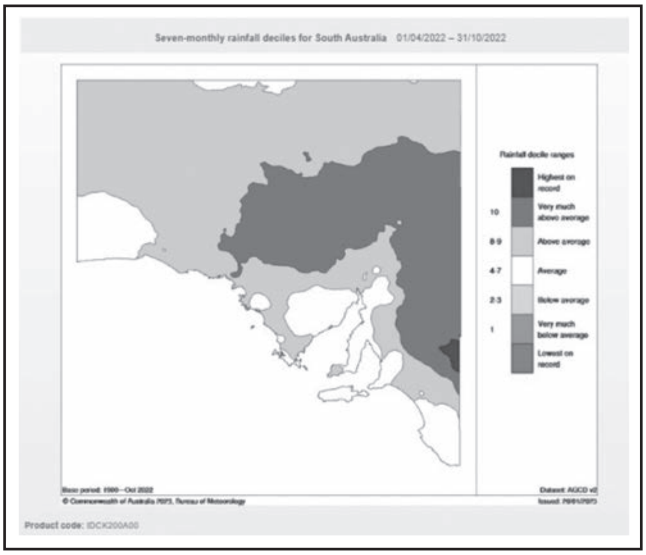


Figure 2.

Figures 1 and 2. Summer rainfall deciles 2021/2022 and April to October rainfall deciles, 2022 (Source:BOM).

Government of South Australia
Department for Environment and Water

Government of South Australia
Department of Primary Industries and Regions

MAC Farm Report 2022

John Kelsh
SARDI

Location
Minnipa Agricultural Centre
Rainfall
Av. Annual: 325 mm
Av. GSR: 241 mm
2022 Total: 529 mm
2022 GSR: 332 mm

Key outcomes

- **Exceptional yields across all crop types.**
- **Mild harvest conditions impacted quality.**

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?

Season

2022 was truly exceptional in many ways; favourable weather conditions and plenty of subsoil moisture from summer rains gave a good head start. The local rule of thumb that Anzac Day is the start of seeding, rang true this year with 13 mm being delivered on the day. Late May delivered good rainfall events, with June and July only receiving 25 mm. August, September and October delivered around 50 mm each and 75 mm in November. The mild, wet spring resulted in favourable grain filling conditions, showing what the upper EP is capable of when the conditions are favourable.

Cropping

The bulk of the MAC seeding program commenced a week later than intended, on 2 May due to COVID. Two paddocks of medic were sown (Seraph & Caliph), followed by Emu TF canola, then field peas, wheat, barley and triticale with sowing finishing on 8 June. A DAP-GranAM fertiliser blend was sown below the seed, with some paddocks being top-dressed and some having UAN applications (Table 1).

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

39% Wheat - 420 ha (Scepter, Hammer CL, Ballista, Calibre, Dual, Valiant CL, Razor CL, Anvil, Bitalli)

10% Barley - 113 ha (Commodus CL, Maximus CL, Beast)

8% Peas – 85 ha (PBA Butler)

7% Barrel medic (Caliph)

6% Strand medic (Seraph)

4% Canola – 46 ha (Emu TF)

1% Triticale – 10 ha (Razoo)

23% Self regenerated medic pasture - 246 ha

Yields were exceptional in some paddocks with most well above average (Table 1). MAC ended up harvesting more than 1,750 tonnes of grains and oilseeds. Wheat was mostly delivered at the APW grade, with some H2 and a few loads of ASW.

Livestock

Another successful year for the MAC Merino flock with nearly 400 ewes joined and 485 lambs marked. Although the scanning results were impressive, it seems that there were many late-term abortions resulting in a marking percentage slightly above average (Table 2).

Shearing remains on a 6 monthly schedule with the ewe flock consistently producing more than 4.5 kg/hd GFW per shearing event (9 kg/hd/yr). Current flock numbers are 399 flock ewes, 272 ewe lambs and 11 rams.

Acknowledgements

MAC farm staff: Wade Shepperd and Zakirra Simpson

MAC admin staff: Leala Hoffmann

Table 1. Cropping results summary table for the 2022 season, Minnipa Agricultural Centre.

Paddock	Rotation 18-19-20-21-22	Crop	Variety	Sown	Seed Rate (kg/ha)	Fert Rate (kg/ha)	UAN Rate (l/ha)	Harvest Date	Yield (t/ha)	Test Weight (g)	Protein (%)	Screenings (%)	Moisture (%)
AP Highway	W-B-P-W-W	Wheat	Hammer CL	26-May	70	50	-	17-Dec	2.6	79.3	8.9	-	-
AP MAC	W-L-W-B-P	Field Peas	PBA Butler	6-May	110	30	-	17-Nov	2.5	-	-	-	-
AP Town	B-C-W-W-P	Field Peas	PBA Butler	5-May	110	30	-	14-Dec	2.4	-	-	-	12.7
Barn	W-O-M-M-T	Triticale	Razoo	8-Jun	75	50	-	24-Dec	3.4	77.8	11.0	1.0	10.5
Minnipa Hill	M-W-W-M-W	Wheat	Scepter	18-May	70	50	-	16-Dec	2.4	80.4	10.6	0.6	10.9
North 2	M-W-B-M-W	Wheat	Scepter	18-May	70	50	-	16-Dec	3.2	79.0	10.9		
North 3	W-B-W-P-W	Wheat	Valiant CL	16-May	70	50	-	24-Dec	3.4				
			Anvil CL	24-May	50	50	-	23-Dec	2.8				
			Razor CL	24-May	65	50	-	23-Dec	3.0			0.7	12.9
			Hammer CL	25-May	70	50	-	22-Dec	2.4	78.0	11.9	0.5	10.7
North 4	M-W-B-M-W	Wheat	Scepter	19-May	70	50	60	27-Nov	3.6	81.7	11.5	0.4	9.9
North 5 N	W/B-M-W-M-W	Wheat	Calibre	27-May	60	50	60	25-Nov	5.0	79.2	10.7	-	-
North 6	W-O/V/C-B-W-M	Medic	Caliph	3-May	9	-	-	-	-	-	-	-	-
North 8	W-W-M-W-B	Barley	Commodus CL	7-Jun	65	30	-	29-Nov	2.7	-	-	-	-
North 10	B-V-W-B-B	Barley	Beast	2-Jun	65	30	-	3-Dec	2.0	-	-	1.5	12.1
North 12	C-W-B-P-W	Wheat	Ballista	1-Jun	70	50	-	19-Dec	3.6	78.8	11.6	-	-
South 3	W-B-C-W-B	Barley	Commodus CL	3-Jun	65	30	-	3-Dec	2.6	-	-	-	-
			Maximus CL	3-Jun	75			3-Dec	2.8	-	-	-	-
			Spartacus CL	3-Jun	65			3-Dec	3.1	-	-	-	-
			Spartacus CL	3-Jun	75			3-Dec	3.2	-	-	-	-
			Spartacus CL	3-Jun	85			3-Dec	3.1	-	-	1.2	10.6
			Spartacus CL	3-Jun	75			1-Nov	3.7	Cut for hay		2.8	9.6
			Commodus CL	3-Jun	65							0.8	9.6
South 4	V-W-B-O-W	Wheat	Scepter	17-May	70	50	-	10-Dec	3.8	79.6	10.3	-	-
		Wheat	Dual	16-May				19-Dec	3.7	79.5	10.9	0.5	11.8
		Durum	Bitalli	16-May		115	60	19-Dec	5.1	79.5	10.1	0.4	11.9
South 5	M-W-B-C-P	Field Peas	PBA Butler	7-May	110	30	-	4-Nov	3.1	-	-	0.8	5.7
South 6	B-C-W-M-W	Wheat	Scepter	22-May	70	50	60	13-Dec	4.6	80.5	10.6	-	-
South 7	M-W-B-M-W	Wheat	Scepter	20-May	70	50	60	14-Dec	4.6	80.1	10.5		
South 8	M-M-W-M-C	Canola	Emu TF	4-May	5	115	60	18-Nov	2.2	66.8	22.5		
South 9	B-M-W-B-M	Medic	Seraph	2-May	9	-	-	-	-	-	-		

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

Table 2. 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 %
2012	337	540	558	439	160	130	103	81
2013	350	534	531	448	153	128	99	84
2014	349	442	443	386	127	111	100	87
2015	424	555	534	437	131	103	96	79
2016	422	532	632	502	126	119	119	94
2017	366	428	458	361	117	99	107	84
2018	335	434	382	294	130	88	88	68
2019	342	486	485	434	142	127	100	89
2020	367	543	551	464	148	126	101	85
2021	398	625	512	485	157	122	82	78
2022	366	620	532	519	169	142	86	84
Av.	369	522	511	434	142	118	98	83

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

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 1

Soils

Section Editor:
Kaye Ferguson & Rhiannon Schilling
SARDI

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

Brian Dzoma[1], Nigel Wilhelm[1,2], Amanda Cook[1,2], Ian Richter[1] and Craig Standley[1]
[1]SARDI; [2]University of Adelaide.

Location
Minnipa
Minnipa Agricultural Centre
Rainfall
Av. Annual: 325 mm
Av. GSR: 241 mm
2022 Total: 529 mm
2022 GSR: 332 mm
Paddock history
2020: Volunteer pasture
2021: Wheat
2022: Barley
Soil type
Calcareous red loam
Soil test
high pH and carbonate, poor P reserves, high N reserves
Plot size
30 m x 2 m x 4 reps
Trial design
RCBD with 4 replicates
Yield limiting factors
Nutrition, hostile subsoil, Boron toxicity, net form of net blotch and rust leaf

---

Location
Poochera - Gosling Family
Rainfall
Av. Annual: 326 mm
Av. GSR: 247 mm
2022 Total: 550 mm
2022 GSR: 300 mm
Paddock history
2020: Volunteer pasture
2021: Barley
2022: Wheat

Key messages

- **A mildly calcareous soil was less responsive than highly calcareous soils to strategies which aimed to improve crop vigour and crop productivity.**
- **Short-term topsoil strategies resulted in better gains in crop biomass and yield when compared to the more longer-term subsoil strategies.**
- **Increasing seeding rates and nutrition at sowing is effective at achieving high plant densities, crop biomass and grain yield.**
- **A carbon-coated mineral (bespoke biochar) in the topsoil improved crop vigour, biomass and grain yield as well as providing good benefits into the second crop.**
- **High soil strength is an issue in calcareous soils but positive responses to deep ripping are not common and are usually limited by the hostile subsoil.**

Why do the trial?

Highly calcareous soils challenge crop production with a range of constraints and this limits the effectiveness of improved agronomic practices used elsewhere. When this project commenced in 2020, a literature review was undertaken to identify and develop integrated solutions to reduce the impact of multiple constraints to cropping in highly calcareous soils. The findings from the literature review helped formulate practical topsoil and subsoil strategies that had potential to lift crop production on the upper Eyre Peninsula and on similar soil types in other cropping regions in south-eastern Australia.

Initial trials were set up in 2021 at Poochera, Port Kenny and Minnipa, however, this article summarises results of topsoil and subsoil strategies from the second crop seeded on these trials in 2022. For details of trial set up and past results, see the article in the 2021 EPFS Summary: More profitable crops on highly calcareous soils by improving early vigour and overcoming soil constraints, p. 44.

How was it done?

The six replicated field trials established in 2021 at Poochera, Port Kenny and Minnipa were re-seeded in May 2022 with Maximus barley and DAP, both @ 50 kg/ha. At the Minnipa subsoil trial prior to seeding, a roller was used to break up clods which were a result of deep ripping in 2021.

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
RCBD with 4 replicates
Yield limiting factors
Nutrition, hostile subsoil, rhizoctonia

Location
Port Kenny
Simon Guerin
Rainfall
Av. Annual: 349 mm
Av. GSR: 270 mm
2022 Total: 487 mm
2022 GSR: 346 mm
Paddock history
2020: Volunteer pasture
2021: Barley
2022: Wheat
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
RCBD with 4 replicates
Yield limiting factors
Nutrition, hostile subsoil, take-all, crown rot

This was to improve seed soil contact at sowing and hence crop emergence and establishment. In the topsoil trials, all treatments were implemented at sowing, apart from sweep cultivation which was done in April 2022. Treatments are summarised in the table 1 below, and for comprehensive details of rates and formulations, see EPFS Summary 2021 article: More profitable crops on highly calcareous soils by improving early vigour and overcoming soil constraints, p. 44.

Plant measurements included crop establishment, crop vigour, early (GS31) and late (flowering) biomass, rhizoctonia, root health, plant nutrient analysis at flowering, grain yield & quality. Statistical analysis of data was performed using standard ANOVA models in R.

What happened?

Crop establishment

In the subsoil trials, deep ripping with or without inclusion plates, organic matter or fertiliser did not change plant populations and they averaged 80 plants/m^2 at Poochera and Minnipa, and 94 plants/m^2 at Port Kenny. In the topsoil trials, a higher seed rate (High seedrate fungicide banded N phosacid TEs) improved plant populations by 126% at Poochera, 96% at Minnipa and 65% at Port Kenny. Plant populations were just below 90 plants/m^2 at all sites with standard seeding rates.

Early crop vigour

Subsoil strategies at Minnipa and Port Kenny did not affect early crop biomass, however, at Poochera, deep ripping with inclusion plates plus Neutrog improved crop biomass by 30% when compared with typical practice.

Fresh carbon-coated minerals @ 500 kg/ha improved plant vigour in topsoil trials at all three sites (Table 2).

Table 1. Summary of topsoil and subsoil treatments in 2022.

Topsoil treatments	Details
Carbon-coated minerals 100kg/ha	Carbon-coated minerals @ 100 kg/ha
Carbon-coated minerals 500kg/ha	Carbon-coated minerals @ 500 kg/ha
Broadcasted urea	Broadcasted urea pre-seeding
Continuous P	Fluid P + trace elements at seeding + 2 in-crop foliar P sprays
Fungicide banded N phosacid TEs	Uniform fungicide + banded urea + phos acid + TEs (Zn, Cu, Mn)
Fungicide GranNP TEs	Uniform fungicide + Granular N&P + TEs (Zn, Cu, Mn)
Granfert N&P carbon coated minerals match	Granular N&P + nutrients to match Carbon-coated minerals
High seedrate fungicide banded N phosacid TEs	High seedrate (75kg/ha) + uniform fungicide + urea + phos acid + TEs (Zn, Cu, Mn)
Phosacid TEs	Phos acid + TEs (Zn, Cu, Mn)
Residual carbon-coated minerals	Residual Carbon-coated minerals
SE14 Wetter	SE14 wetter
Seed coating	Seed coating of microbes
Sweep cultivation	Sweep cultivation (pre-seeding)
Typical practice	***Typical practice (control)***

Table 1. Summary of topsoil and subsoil treatments in 2022 (continued).

Subsoil treatments	Details
Deep rip	Deep rip
DR carbon-coated minerals	Deep rip + carbon-coated minerals @ 5 t/ha
DR granfert carbon-coated minerals match	Deep rip + granular fert to match nutrients in carbon-coated minerals
DR granfert NEUTROG match	Deep rip + granular fert to match nutrients in Neutrog
DR Inclusion plates	Deep rip + inclusion plates
DR Inclusion plates NEUTROG	Deep rip + inclusion plates + Neutrog @ 5 t/ha
DR Neutrog	Deep rip + Neutrof @ 5 t/ha
DR Phos acid	Deep rip + Phos acid
DR Phos acid TEs	Deep rip + Phos acid + trace elements (Zn, Cu, Mn)
Typical practice	Typical practice (No deep ripping)
SE14 Wetter	SE14 wetter
Seed coating	Seed coating of microbes
Sweep cultivation	Sweep cultivation (pre-seeding)
Typical practice	***Typical practice (control)***

Soils

Table 2. Crop vigour (g DM/plant) in topsoil trials at Poochera, Minnipa and Port Kenny, 2022.

Topsoil treatment	Poochera	Minnipa	Port Kenny
Carbon-coated minerals 100kg/ha	1.50 abc	1.43 a	1.19 bcd
Carbon-coated minerals 500kg/ha	1.71 a	1.44 a	1.36 ab
Broadcasted urea	1.35 abcde	1.07 bcd	0.87 efg
Continuous P	1.44 abcd	1.40 ab	1.20 abcd
Fungicide banded N phosacid TEs	1.45 abcd	1.20 abcd	1.45 a
Fungicide GranNP TEs	0.78 f	1.14 abcd	0.88 efg
Granfert N&P carbon-coated minerals match	1.48 abc	1.19 abcd	0.97 defg
High seedrate fungicide banded N phosacid TEs	1.01 ef	0.90 d	1.08 cdef
Phosacid TEs	1.01 ef	0.98 cd	1.24 abc
Residual carbon-coated minerals	1.63 ab	1.24 abc	1.11 bcde
SE14 Wetter	1.16 cdef	1.16 abcd	0.86 efg
Seed coating	1.00 ef	1.01 cd	0.83 fg
Sweep cultivation	1.05 def	1.18 abcd	0.74 g
Typical practice	***1.23 bcde***	***0.98 cd***	***1.07 cdef***
LSD (0.05)	*0.42*	*0.34*	*0.3*
P value	*0.001*	*0.03*	*<0.001*
Mean (g DM/plant)	**1.25**	**1.15**	**1.05**

Crop biomass at GS31 was not affected by any of the subsoil strategies at Minnipa and Port Kenny. However, at Poochera Neutrog and carbon-coated minerals improved early crop biomass by more than 70% when compared to typical practice.

In the topsoil trials, 'high seedrate fungicide banded N phosacid TEs' improved early crop biomass by 97% at Minnipa, 68% at Poochera and 106% at Port Kenny, compared to typical practice. Carbon-coated minerals also improved crop biomass at Poochera and Port Kenny, but not at Minnipa.

Late flowering biomass was affected by many but isolated rhizoctonia patches across the Poochera trial; by take-all and crown rot patches at Port Kenny; and by boron toxicity, net form of net blotch and leaf rust at the Minnipa site. Late flowering biomass was not affected by any of the subsoil strategies at Minnipa or Poochera. However, at Port Kenny, deep ripping with Neutrog (with or without inclusion plates) resulted in 30% more biomass than typical practice. Physical disturbance alone, by deep ripping with or without inclusion plates did not affect flowering biomass at any site.

In the topsoil trials, 'high seedrate fungicide banded N phosacid TEs' consistently produced higher flowering biomass than the typical practice at all three sites (Table 3).

Fresh and residual carbon-coated minerals @ 500 kg/ha yielded more biomass at Minnipa, when compared to typical practice. There was a 20% reduction in late flowering biomass at Poochera from the use of 'SE14 wetter' and from the 'seed coating' when compared to typical practice.

Rhizoctonia

Root health measurements in August assessed the impact of both topsoil and subsoil strategies on plant tillering, seminal root health and crown root infection by rhizoctonia. Scores were quite variable and there were few clear trends with topsoil treatments.

'Fungicide banded N phosacid TEs' resulted in more tillers per plant in all three topsoil trials.

Carbon-coated minerals also improved tiller numbers at Minnipa, while continuous P improved tiller numbers at Poochera. Overall root health at Poochera and Port Kenny was not affected by the treatments implemented. However, at Minnipa, all three 'carbon-coated minerals' treatments had healthier roots and better root health scores.

In the **subsoil** trials, tiller numbers were not affected by treatments at Poochera and Minnipa. However, at Port Kenny, 'carbon-coated minerals' improved tillers numbers by nearly one per plant, compared to typical practice (3 per plant). Seminal root health was not affected by any of the strategies at any site. Crown root infection was not affected at Port Kenny and Poochera. However, at Minnipa, typical practice had the highest crown root infection (52%), while 'DR carbon-coated minerals' (17%), 'DR Phos acid' (22%) and 'DR Phos acid TEs' (23%) had much lower levels.

Nutritional status

Table 4 summarises ANOVA outputs for responses of key plant nutrient concentrations in flowering DM to topsoil and subsoil treatments at the three sites.

In the subsoil trials, nitrate N, boron and copper concentrations in whole shoots were not affected by treatments at any site. However, at Minnipa the highest shoot P concentrations occurred in 'DR_ carbon-coated minerals' (0.11 %), and highest K concentrations in 'DR Inclusion plates' (2.7 %). Zinc shoot concentrations were higher in "DR Neutrog' at Poochera and Port Kenny only.

In the topsoil trials, nitrate N concentration (mg/kg) in shoot biomass was higher with 'Fungicide banded N phosacid TEs' at Minnipa (348 mg/kg) and at Poochera (197 mg/kg). Shoot P was higher with 'Continous P' at both Poochera (0.16%) and Port Kenny (0.08%). The highest shoot zinc concentrations (mg/kg) were in 'Fungicide GranNP TEs' at Poochera (20) and at Port Kenny (12). At Minnipa, 'High seedrate fungicide banded N phosacid TEs' had the highest zinc concentration (14 mg/kg).

Grain production

All sites had high grain yields in 2022 with the subsoil Minnipa trial having the highest site mean grain yield of 4.3 t/ha (Table 5). No subsoil treatments changed grain yields at Minnipa, when compared to typical practice.

Table 3. Topsoil - Late flowering biomass (t DM/ha) at Poochera, Minnipa and Port Kenny, 2022.

Treatment	**Port Kenny**	**Poochera**	**Minnipa**
Carbon-coated minerals 100kg/ha	9.60 abc	9.14 abcd	6.85 bc
Carbon-coated minerals 500kg/ha	10.30 a	9.29 abc	6.46 bc
Broadcasted urea	8.76 bcd	7.56 def	6.85 bc
Continuous P	8.96 abcd	8.06 cdef	6.94 bc
Fungicide banded N phosacid_TEs	10.40 a	9.76 ab	6.61 bc
Fungicide GranNP TEs	9.36 abcd	7.56 def	7.34 bc
Granfert N&P carbon-coated minerals match	9.36 abcd	8.57 bcde	6.82 bc
High seedrate fungicide banded N phosacid TEs	9.96 ab	10.23 a	9.10 a
Phosacid TEs	9.63 abc	7.27 ef	7.68 b
Residual Carbon-coated minerals	9.90 ab	9.23 abc	7.33 bc
SE14 Wetter	6.96 ef	6.78 f	6.14 c
Seed coating	7.12 ef	6.75 f	6.28 c
Sweep cultivation	6.19 f	7.50 ef	7.37 bc
Typical practice	***8.33 cde***	***8.42 bcde***	***6.83 bc***
P value	*<0.001*	*0.001*	*0.02*
CV	*11.85*	*13.69*	*13.49*
Site mean (t DM/ha)	**8.86**	**8.25**	**7.07**

Table 4. Average nutrient concentrations in flowering DM at Minnipa, Poochera and Port Kenny in 2022 and the impact of treatments.

Subsoil	Minnipa		Poochera		Port Kenny	
	P value	mean	P value	mean	P value	mean
Nitrate N (mg/kg)	ns	82	ns	45	ns	30
Phosphorus (%)	0.01	0.09	ns	0.14	ns	0.04
Potassium (%)	0.001	2.4	ns	1.5	ns	2.3
Boron (mg/kg)	ns	42	ns	22	ns	18
Copper (mg/kg)	ns	5.5	ns	4.3	ns	4.6
Zinc (mg/kg)	ns	13	0.001	17	0.009	8
Manganese (mg/kg)	0.03	39	ns	16	0.03	8
Topsoil	**Minnipa**		**Poochera**		**Port Kenny**	
	P value	**mean**	**P value**	**mean**	**P value**	**mean**
Nitrate N (mg/kg)	<0.001	104	<0.001	58	ns	35
Phosphorus (%)	ns	0.09	0.001	0.11	<0.001	0.05
Potassium (%)	0.001	2.5	ns	1.8	<0.001	2.7
Boron (mg/kg)	ns	49	ns	24	ns	18
Copper (mg/kg)	ns	5.8	0.001	3.8	0.05	5.0
Zinc (mg/kg)	<0.001	15	0.01	16	<0.001	9
Manganese (mg/kg)	<0.001	39	0.001	15	ns	7

ns = Not statistically significant

At Poochera, all amendments applied into the subsoil increased yields above typical practice, with 'carbon-coated minerals' (4.41 t/ha) and 'Neutrog' (4.28) being the highest yielding treatments (Table 5). At Port Kenny, only Neutrog incorporated by inclusion plates yielded higher than typical practice.

Port Kenny had the highest yielding topsoil trial with mean barley grain yield of 4.09 t/ha. 'High seedrate fungicide banded N phosacid TEs' produced the highest barley grain yields at Minnipa (4.37 t/ha) and Poochera (4.17 t/ha) (Table 6).

At Port Kenny, 'carbon-coated minerals 500 kg/ha' resulted in the highest barley grain yields (4.76 t/ha). Carbon-coated minerals 500 kg/ha consistently yielded better than typical practice across all three sites. A positive P response was evident at Minnipa and Port Kenny because 'Continous P' and 'Phosacid TEs' yielded better than typical practice at these two sites.

Microbial seed-coating was the only treatment in the topsoil trials that yielded lower than typical practice.

Table 5. Effects of subsoil amendments on barley grain yield (t/ha) at Poochera, Minnipa and Port Kenny in 2022.

Subsoil treatments	Minnipa	Poochera	Port Kenny
	t/ha	t/ha	t/ha
Deep rip	4.41	3.90 bc	3.81 cd
DR carbon-coated minerals	4.42	4.41 a	3.95 bcd
DR granfert carbon-coated minerals match	4.18	4.04 abc	3.82 cd
DR granfert NEUTROG match	4.18	4.13 ab	4.23 ab
DR Inclusion plates	4.13	3.71 cd	3.87 bcd
DR Inclusion plates NEUTROG	4.42	4.20 ab	4.42 a
DR Neutrog	4.47	4.28 ab	4.13 abc
DR Phos acid	4.29	4.02 bc	3.71 d
DR Phos acid TEs	4.33	3.99 bc	3.84 bcd
Typical practice	***4.14***	***3.40 d***	***3.93 bcd***
P value	*0.177*	*<0.001*	*0.02*
LSD (P=0.05)	*ns*	*0.38*	*0.38*
CV	*4.85*	*6.57*	*6.65*
Site mean	**4.29**	**4.01**	**3.98**

Soils

Grain protein in the **subsoil** trials was highest at Minnipa (site average of 12.1%) compared to Poochera (11.3%) and Port Kenny (10.4%). Grain protein with granular fertiliser to match nitrogen and phosphorus in Neutrog (DR granfert NEUTROG match), had the highest protein at Minnipa (12.4%) and Port Kenny (10.7%). Grain proteins were not changed by treatments at Poochera.

In the **topsoil** trials, grain protein was also highest at Minnipa (site average of 12.1 %) compared to Poochera (11.3%) and Port Kenny (10.3%). 'High seedrate fungicide banded N phosacid TEs' had higher protein at all three sites, and typical practice had the lowest protein.

In the **subsoil** trials, typical practice had the highest cumulative grain yield at Minnipa (Table 7). At Poochera, 'DR carbon-coated minerals' had the highest cumulative change in grain yield (1.58 t/ha) over and above typical practice. DR Inclusion plates NEUTROG produced cumulative changes in grain yield over 15% of typical practice at both Poochera and Port Kenny.

In the **topsoil** trials, 'High seedrate fungicide banded N phosacid TEs' had more accumulated yield benefit at all three sites. Cumulative change in grain yield relative to typical practice was 1.13 t/ha at Minnipa, 1.54 t/ha at Poochera and 1.34 t/ha at Port Kenny (Table 7). Carbon-coated minerals 500 kg/ha resulted in the highest change in grain yield (1.99 t/ha at Poochera) of all treatments.

Table 6. Effects of topsoil strategies on barley grain yield (t/ha) at Poochera, Minnipa and Port Kenny in 2022.

Topsoil treatments	Minnipa	Port Kenny	Poochera
	t/ha	t/ha	t/ha
Broadcasted urea	3.71 de	4.14 b	3.55 cde
Carbon-coated minerals 100kg/ha	3.73 cde	4.21 b	3.75 bcd
Carbon-coated minerals 500kg/ha	3.92 bc	4.76 a	3.98 ab
Continuous P	4.00 b	4.19 b	3.70 bcd
Fungicide banded N phosacid TEs	3.84 bcde	4.36 b	3.84 abc
Fungicide GranNP TEs	3.65 ef	4.10 b	3.24 ef
Granfert N&P carbon-coated minerals_match	3.74 cde	4.33 b	3.71 bcd
High seedrate fungicide banded N phosacid TEs	4.37 a	4.35 b	4.17 a
Phosacid TEs	4.03 b	4.30 b	3.55 cde
Residual carbon-coated minerals	3.88 bcd	4.37 b	3.99 ab
SE14 Wetter	3.64 ef	3.68 c	3.25 e
Seed coating	3.48 f	3.70 c	2.89 f
Sweep cultivation	3.73 cde	3.32 c	3.54 cde
Typical practice	**3.69 de**	**3.49 c**	**3.44 de**
P value	*<0.001*	*<0.001*	*<0.001*
LSD (P=0.05)	*0.21*	*0.38*	*0.36*
CV	*3.87*	*6.52*	*6.96*
Site mean	**3.82**	**4.09**	**3.61**

Table 7. Cumulative change in grain yields (t/ha) in the topsoil and subsoil trials, relative to typical practice at Poochera, Minnipa and Port Kenny from 2021 to 2022.

Subsoil	Minnipa	Poochera	Port Kenny
Deep rip	-0.31	0.31	-0.15
DR carbon-coated minerals	-0.18	1.58	0.39
DR granfert carbon-coated minerals match	-0.50	0.76	0.07
DR granfert NEUTROG match	-0.46	0.76	0.50
DR Inclusion plates	-0.95	0.06	0.08
DR Inclusion plates NEUTROG	-0.19	1.07	1.14
DR Neutrog	-0.05	1.35	0.60
DR Phos acid	-0.29	0.85	-0.01
DR Phos acid TEs	-0.45	0.82	0.08
Cumulative yield (t/ha) - Typical practice	**7.66**	**5.97**	**5.79**

Topsoil	Minnipa	Poochera	Port Kenny
Broadcasted urea	0.04	0.52	0.12
Carbon-coated minerals 500kg/ha	0.85	1.99	0.97
Continuous P	0.73	0.74	0.48
Fungicide banded N phosacid TEs	0.20	0.87	0.33
Fungicide GranNP TEs	-0.07	0.36	-0.43
Granfert N&P carbon-coated minerals match	0.26	1.02	0.42
High seedrate fungicide banded N phosacid TEs	1.13	1.54	1.34
Phosacid TEs	0.71	1.01	0.25
SE14 Wetter	0.09	-0.03	-0.34
Seed coating	-0.36	0.01	-0.81
Sweep cultivation	0.08	-0.24	0.06
Cumulative yield (t/ha) - Typical practice	**6.51**	**5.19**	**6.10**

What does this mean?

The focus of this project was to assess the impact of long-term (subsoil) and year on year short-term topsoil strategies on early crop vigour, their ability to overcome constraints and on grain production on challenging highly calcareous soils.

After two years of conducting these trials, crop responses to the more costly subsoil strategies are smaller and less likely in highly calcareous soils with underlying physical, biological and chemical constraints. Ameliorating high soil strength by deep ripping has proven to be less effective on these types of soils than on other sands. In highly calcareous soils, the incorporation of organic amendments (neutrog and carbon-coated minerals) into subsoils has shown potential to improve crop production but is still economically dubious. However, this response needs to be validated over more situations to determine their general impact on longer-term crop productivity and profitability.

Several short-term and cheaper topsoil strategies have good potential to increase crop vigour and productivity. Plant populations, crop biomass and grain yields can be improved through the use of higher sowing rates, providing that the denser plant populations are supported by improved nutrition (N and P and trace elements). Carbon-coated minerals have also boosted crop vigour and biomass production when placed just below the seed. We believe that at least part of the benefits from this carbon-coated mineral is to deliver P to the crop in a more effective way than current mineral fertilisers. The availability of P in these challenging soils is always low and several other treatments with higher P also improved crop production. Carbon-coated minerals at a lower rate (100 kg/ha) did not perform as well as the initial higher rate of 500 kg/ha but the residual benefits of carbon-coated minerals were very good. Further investigation is needed to determine how best to apply carbon-coated minerals and how low they can be applied to improve crop growth and productivity.

In the meantime, farmers can improve crop production on highly calcareous soils by increasing seed and fertiliser rates above those typically used.

Acknowledgements

This project, "More profitable crops on highly calcareous soils by improving early vigour and overcoming soil constraints" is supported by the Cooperative Research Centre for High Performance Soils whose activities are funded by the Australian Government's Cooperative Research Centre Program and GRDC. The authors would also like to thank the landholders and families involved in this project: Shard Gosling, Simon Guerin and the Minnipa Agricultural Centre.

In-crop nitrogen supply capacity in wheat crops on highly calcareous soils

VVSR Gupta[1], T McBeath [1], SK Kroker [1], M Hicks [1,2], C Johnston [2], B Dzoma [3], N Wilhelm [3,4] and C Johnstone[2]

[1]CSIRO Ag & Food; [2]CSIRO Environment; [3]SARDI; [4]University of Adelaide

Key messages

- **In-situ estimation of nitrogen supply capacity using ion exchange resins provided a reliable measure of N supply in the field.**
- **Nitrate N supply capacity was generally lower in the highly calcareous soils at Poochera and Port Kenny compared to Lake Hawdon in the South-East South Australia.**
- **Very low concentrations of ammonium N levels in general suggests that multiple microbial groups may be responsible for nitrification process in highly calcareous soils.**

Why do the research?

Calcarosols occupy about 60% of the cropping soils in south-eastern Australia. There are several key constraints to crop growth on highly calcareous soils that interact to limit crop and pasture productivity. In the surface, high levels of alkalinity and carbonate inhibit the cycling and supply of nutrients such as phosphorus (P), nitrogen (N), sulfur (S), magnesium (Mg), iron (Fe), manganese (Mn), copper (Cu) and zinc (Zn). Soil microbial activity and biological processes can be influenced by several chemical (pH, carbonate associated toxicity, EC, organic C) and soil physical (aggregation, pore structure, matric potential and water holding capacity) properties.

In highly calcareous soils, edaphic factors such as high pH and salt/carbonate toxicity will influence the diversity and function of microorganisms involved in C cycling and microbial activities, thereby inhibiting the cycling and supply of nutrients (e.g. nitrogen and phosphorus). Available carbon (C) is a key driver of soil biological activity especially in low soil organic matter Australian agricultural soils (Gupta *et al*. 2019). It has been suggested that some calcareous soils occlude soluble organic C, therefore although the total organic C content of the highly calcareous soils may test high for a semi-arid environment, it is likely that much of that C may not readily available (Rowley *et al*. 2018; Tavakkoli et al. 2015). Seasonally changing soil moisture and biological available C levels can influence microbial activity and nutrient cycling processes.

The amount of plant available N in any soil is a balance between the mineralisation and immobilisation functions which are mediated by a variety of microbial processes. Within a growing crop, the plant rhizosphere effect on soil microbial activity has the potential to increase nutrient (e.g. N) mineralisation. Nitrogen mineralisation estimates are generally conducted using laboratory assays using disturbed soils. The in-crop N mineralisation / supply capacity in calcareous soils is not well understood. Measurement of nutrients accumulated on resins incubated in the field is considered a more realistic estimate of nutrient capacity as ion exchange resins can simulate nutrient flux to plant roots (Schoenau and Huang 1991). In this study, we used an ion exchange resin method (Plant Root Simulator, PRS® probes) to estimate N supply rates in field plots within the growing wheat crop during the 2021 & 2022 crop seasons.

How was it done?

In collaboration with the CRC project, PRS® probes were inserted vertically into the top 10 cm soil layer in selected treatments in field experiments at Poochera, Port Kenny and Lake Hawdon. In each plot, six anion resin probes were incubated to account for in-plot spatial variation. At Poochera and Lake Hawdon, cation probes were also incubated. The PRS probes were incubated inside a root-exclusion cylinders (open ended PVC tubes of 8 cm diameter) to avoid interference from growing plant roots and minimise nutrient uptake by plants. Also, effort was made to achieve proper contact between the resin and the surrounding soil. PRS probes were generally incubated in the field for 7-12 days to allow sufficient time for nutrient accumulation.

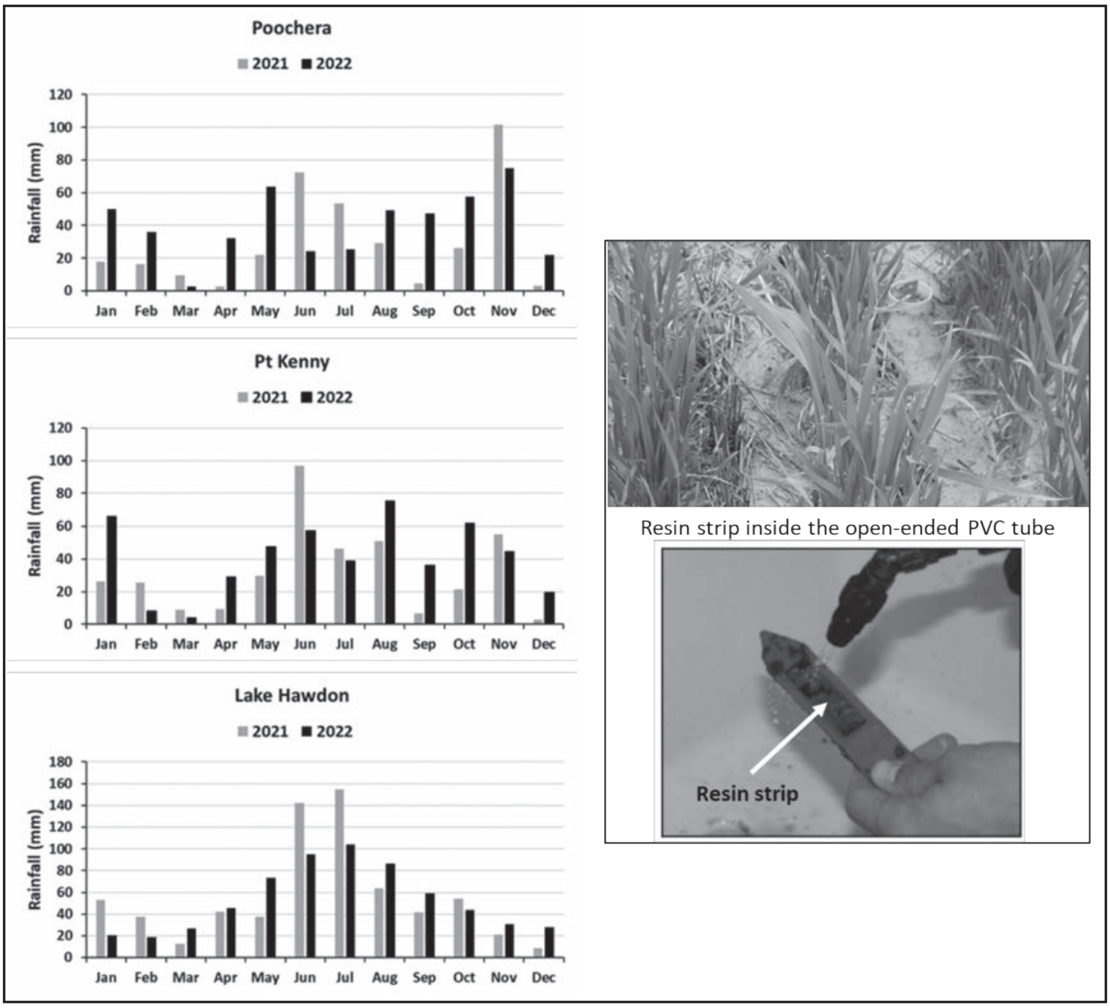


Figure 1. Monthly rainfall (mm) at the experimental sites at Poochera, Port Kenny and Lake Hawdon in 2021 (light grey) and 2022 (dark grey). Insert - images showing the resin strip and placement in a PVC tube within paddock.

These in-season assessments were conducted at the first two weeks after sowing (2021 and 2022, T0), 4-6 weeks after germination-early tillering (2021 & 2022, T1) and anthesis (2022, T2). During 2021, in the Poochera and Port Kenny experiments, measurements were made in Control (Treat 1) and Cultivation (Treatment 15) treatments whereas at the Lake Hawdon site measurements were made in Treatment 1 and Treatment 2 (P+TE). During 2022, *in-situ* measurements were made in the Control and Combination (High seedrate + fungicide + banded + phosacid + TEs) treatments. Detailed information about treatments in field experiments are presented in EPFS Summary 2022, p. 29 “More profitable crops on highly calcareous soils by improving early vigour and overcoming soil constraints”. Concentrations of anions (e.g., nitrate) and cations (e.g., ammonium) accumulated by the incubated PRS probes was determined using colorimetric methods and the N supply rate was estimated based on the specific surface area of soil influenced by the probes.

What was found?

In general, results from this *in-situ* estimation of nutrient supply capacity gave consistent and reliable measures of in-field tracing of nitrogen supply.

Results in Figure 2 indicate considerable differences in the in-crop nitrate N supply capacity between the field sites, time points and the seasons. For example, nitrate N supply capacity was consistently higher in the Lake Hawdon soil in both seasons (0.61±0.09 and 0.83±0.13 kg N/day/ha in 2021 and 2022) compared to that in the Poochera and Port Kenny experiments (average 0.35±0.07 kg N/day/ha). For example, at T1 and T2 samplings, N supply capacity at Poochera were significantly lower at 0.1-0.2 kg N/ha/day). During 2021, the nitrate N supply capacity at sowing in the Pt Kenny soil was significantly higher (0.77 to 0.82 kg N/ha/day) than that observed at T1 sampling (0.10-0.11 kg N/ha/day). This could be attributed to the high rainfall (96 mm) received during the sowing period (June; Figure 1). A similar trend was observed with sowing time measurement in the Poochera experiment during the 2022 season (72 mm rainfall). Water availability and management effects were found to have a substantial impact on soil microbial activity and biological function including N mineralisation in the laboratory-based incubation experiment using intact soil cores from the experimental sites.

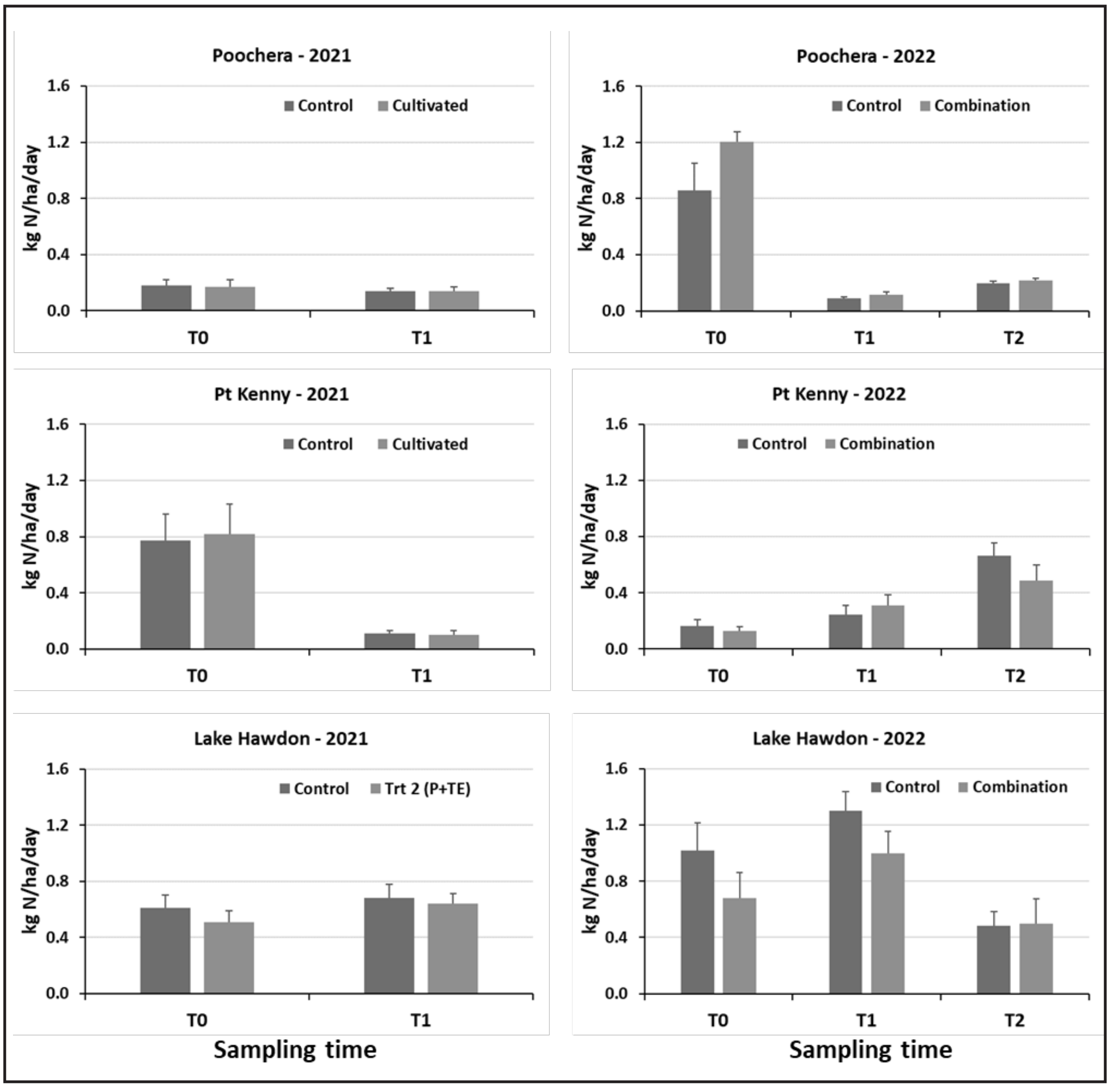


Figure 2. Nitrate N supply capacity estimates (kg N/ha/day) measured using PRS anion probes in field experimental plots during 2021 and 2022 across Poochera, Port Kenny and Lake Hawdon.

During 2021, there was limited variation in the N supply capacity between the two time points at Poochera and Lake Hawdon. At Port Kenny, N supply capacity at T2 was significantly higher compared to that at T0 and T1 sampling periods.

There was no treatment-based variation during the 2021 season at all sites. However, during 2022 season at Lake Hawdon N supply capacity was significantly higher in the 'Control' treatment compared to the 'Combination' treatments at T0 and T1 sampling. Plant available nitrate N levels in soils reflect the balance between the microbial processes of mineralisation and immobilisation (tie-up) by microbial biomass. Seasonally changing soil moisture and biological available C levels can influence microbial activity and nutrient cycling processes. Thus, the variations in the N supply capacities observed at different times and sites reflect the differences in soil chemical and microbial communities. Results from the individual probes indicated that there was a significant level of spatial variation in N supply capacity (data not shown).

Results from the cation probes (data not shown) indicated that concentrations of ammonium-N were generally lower (<0.01 kg/ha/day) in all the field soils and both seasons suggesting that nitrification (conversion of N to the plant available form, nitrate) may not have been a constraint during the sampling period. Populations of bacterial nitrifying microorganisms, major group of microbes responsible for the nitrification process in agricultural soils, were significantly lower in the highly calcareous soils from Poochera and Port Kenny compared to other soils. Our initial results indicated the presence of measurable populations of archaeal nitrifiers in the highly calcareous soils (data not presented). Recent evidence for non-calcareous soils within Australia and overseas has indicated that the nitrification process in soils is not only mediated by the bacterial nitrifiers but can also be supported by other microbial groups such as archaea and Comammox bacteria. Current knowledge on the factors that regulate these processes in calcareous soils is limited.

References

Gupta VVSR, Roper M, Thompson J (2019) Harnessing the benefits of soil biology in conservation agriculture. In (Eds J Pratley and J Kirkegaard) "Australian Agriculture in 2020: From Conservation to Automation" p. 237-253 (Agronomy Australia and Charles Sturt University: Wagga Wagga)

Schoenau JJ, Huang WZ (1991) Assessing P, N, S and K availability in soil using anion and cation exchange membranes. Pages 131–136 in Proceedings of the Western Phosphate and Sulfur Workgroup. Colorado State University, Fort Collins, CO.

Tavakkoli E, Rengasamy P, Smith E, McDonald GK (2015) The effect of cation–anion interactions on soil pH and solubility of organic carbon. European Journal of Soil Science 66, 1054-1062.

Rowley MC, Grand S, Verrecchia EP (2018) Calcium-mediated stabilization of soil organic carbon. Biogeochemistry 137, 27-49.

Acknowledgements

Funding for this research work is provided by the Grains RDC project CSP2009-003RTX (for CSIRO researchers). Participation by Nigel Wilhelm and Brian Dzoma was supported by the Cooperative Research Centre for High Performance Soils project. The authors would also like to thank the landholders and families involved in this project: Shard Gosling, Simon Guerin and the staff at Minnipa Agricultural Centre. Authors also acknowledge Dr Eric Bremer at Western Ag Innovations, Canada for providing some technical information.

Soil microbial indicators - what do they mean and how can they be used? A case study using the 'overcoming constraints on calcareous soil' field experiment.

Mick Rose[1,4], Lukas Van Zwieten[1,4], Katherine Linsell[2,4], Danielle Giblot-Ducray[2,3,4] and Amanda Cook[2,3,4]

[1]NSW DPI, Wollongbar; [2]SARDI; [3]University of Adelaide; [4]Cooperative Research Centre for High Performance Soils, Callaghan

Location
Minnipa
Minnipa Agriculture Centre

Rainfall
Av. Annual: 325 mm
Av. GSR: 241 mm
2022 Total: 529 mm
2022 GSR: 332 mm

Paddock History
2020: Volunteer pasture
2021: Wheat
2022: Barley

Soil type
Calcareous red loam

Soil test
High pH and carbonate, poor P reserves, high N reserves

Plot size
30 m x 2 m x 4 reps

Trial design
RCBD with 4 replicates

Yield limiting factors
Nutrition, hostile subsoil, boron toxicity, net form of net blotch and leaf rust

Key messages

- **Biochemical microbial indicators (labile C, microbial biomass, microbial activity) were generally correlated to each other, but unaffected by management practices applied at the site.**
- **Some specific microbial groups (measured by qPCR) were affected by management practices and their levels (*Rhizoctonia solani AG8, Pythium clade f*) were inversely correlated with measures of root health and yield.**
- **Ongoing research seeks to identify a minimum set of indicators for routine monitoring that relate to agronomic functions and/or ecosystems services.**

Why do the trial?

Over the last decade or more there has been increasing interest in, and recognition of, the role of soil biology in crop/pasture production and ecosystem health. Scientific advances have resulted in new ways to measure the diversity, abundance and function of soil microbiota. Landholders wish to better understand how they can use this information to manage the soil biology for better 'soil health' - for example by minimising chemical inputs, changing cropping practices, or sequestering carbon. However, many of the proposed indicators are too general, too specific, change too quickly or don't change quickly enough. As a result, many of these indicators are difficult to interpret in the context of monitoring change or agronomic decision making.

This project seeks to investigate which, if any, microbial indicators are strongly linked to agronomic or environmental outcomes, such as crop yield, soil structure or nutrient availability (Figure 1). Samples are being taken across five different experimental cropping sites applying different treatments aimed to overcome site-specific constraints. One of these field sites at Minnipa Agricultural Centre (paddock North 7/8) is the 'More profitable crops on highly calcareous soils by improving early vigour and overcoming soil constraints', outlined on p 44. of the EPFS 2021 Summary and p. 29 of this EPFS 2022 Summary. This paper highlights some of the initial findings based on the 2022 season at Minnipa. Monitoring will continue for the 2023 season at Minnipa.

How was it done?

We measured soil microbial indicators in five of a total of 14 treatments, one of which was the control (Table 1). Soil samples were taken prior to sowing, during flowering and after harvest. The results reported here focus on the in-crop measurements taken at flowering, since complete analysis of harvest samples are not yet available.

Soil samples were taken to a depth of 10 cm and were analysed for a suite of microbial indicators. These include measures of carbon fractions, microbial biomass and diversity (using phospholipid fatty acid profiles) and microbial activity.

Table 1. Summary of topsoil treatments monitored in 2022.

Topsoil treatments	Details
Carbon-coated minerals 500kg/ha	Carbon-coated minerals @ 500 kg/ha
Fungicide banded N phosacid TEs	Uniform fungicide + banded urea + phos acid + TEs (Zn, Cu, Mn)
Granfert N&P carbon coated minerals match	Granular N&P + nutrients to match Carbon-coated minerals
Phosacid TEs	Phos acid + TEs (Zn, Cu, Mn)
Typical practice	**Typical practice (control)**

Table 2. Summary of microbial indicator methods.

Indicator category	Details
Food Source	Total organic C and N (Leco) C fractions (MIR spectroscopy) Permanganate oxidisable C Hot water extractable C Soil protein (autoclavable citrate-extractable N)
Microbial biomass and composition	Microbial biomass C (chloroform extraction) Fungal:bacterial ratio (Phospholipid fatty acid analysis) Microbial community composition ratios (PLFA) Pathogens (qPCR, PredictaB® - 24 target organisms) Nematode community (qPCR - 15 target organisms) Arbuscular mycorrhizal fungi (qPCR - 6 target groups)
Potential microbial activity	Soil respiration (4-day CO_2 burst) Soil enzyme activities (6 enzymes involved in organic C, N, P, S turnover) Mineralisable N

Table 3. Significant effects of treatments on different soil chemical and microbial indicators.

Topsoil treatment	Mineral N (mg/kg)	*R. solani* (log pgDNA/g)	*Pythium* (log pgDNA/g)	AMFa (log kDNA copies/g)	AMFb (log kDNA copies/g)
Carbon-coated minerals 500kg/ha	6.0 b	2.7 b	1.57 a	1.87 a	1.17 a
Fungicide banded N phosacid TEs	34.0 a	1.9 a	1.45 ab	1.14 b	0.53 b
Granfert N&P carbon-coated minerals match	5.8 b	2.6 b	1.56 a	1.84 a	1.23 a
Phosacid TEs	4.2 b	2.5 b	1.35 b	1.75 a	1.19 a
Typical practice	5.5 b	2.6 b	1.54 a	1.80 a	1.16 a
LSD (P=0.05)	*20.6*	*0.5*	*0.16*	*0.40*	*0.43*
P-value	*0.03*	*0.02*	*0.05*	*0.008*	*0.02*

A more complete description of the microbial indicator measurements is provided in Table 2. Specific pathogen, mycorrhizal and nematode phylogenetic groups were also measured by quantitative PCR using the PredictaB® service provided by SARDI.

Microbial indicator data were related to plant measurements including late (flowering) biomass, root health, plant nutrient analysis at flowering, and grain yield. Statistical analysis of data was performed using standard ANOVA models in R to determine if treatments affected microbial indicators. Correlation analysis between different indicators was also performed in R.

What happened?

Treatment effects on measures of soil microbial indicators

In the topsoil trials, the applied treatments had no significant effects on most of the microbial indicators. The exceptions were a significant increase in the mineral N in soil at flowering and a significant reduction in the inoculum density of Rhizoctonia and two groups of mycorrhizal fungi (AMFa and AMFb) in soil treated with fungicides plus banded N, trace elements and phosphoric acid (Table 3). There was no significant effect of trace elements and phosphoric acid alone on these measures, suggesting that these effects were due to the fungicide and/or the banded N. In addition, the inoculum density of *Pythium* in the soil was lower in the treatment with phosphoric acid and trace elements compared to typical practice.

Relationships between different microbial indicators

Generally speaking, many of the measures of organic matter, microbial biomass and enzyme activities were significantly correlated. For example, measures of easily available (labile) C were significantly correlated with microbial biomass (total PLFA) and the activity of enzymes involved in organic C, N and P turnover (Figure 1).

Within the microbial and nematode phylogenetic groups, there was a significant relationship between the level of *Rhizoctonia solani* and AMF group A (Figure 2A) in soil, but no other strong associations. There were also very few associations between biochemical microbial indicators and microbial/nematode densities. The exception was a significant correlation between *Pratylenchus thornei* numbers and labile C/ microbial biomass (e.g. Figure 2B, only labile C shown).

Relationships between microbial indicators and crop health

Correlation analyses were performed to identify associations between crop health parameters and microbial indicators measured at sowing or measured at flowering. There were only a few strong correlations. These included a negative correlation between *Pythium* inoculum density at sowing and root health at flowering (Pearson correlation = -0.62); and a negative correlation between soil protein and shoot biomass at flowering (Pearson correlation = -0.63). The strongest relationship with yield was an inverse relationship with the inoculum density of *Rhizoctonia* in soil at flowering (Pearson correlation = -0.47). Interestingly, root health scores and shoot biomass measured at flowering had no significant correlation with final yield.

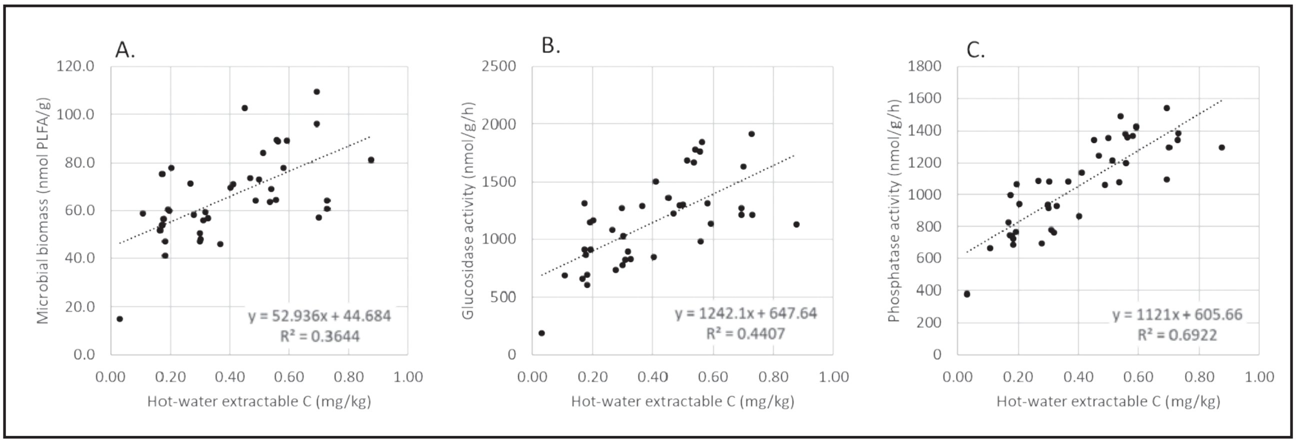


Figure 1. Correlations between different soil microbial indicators.

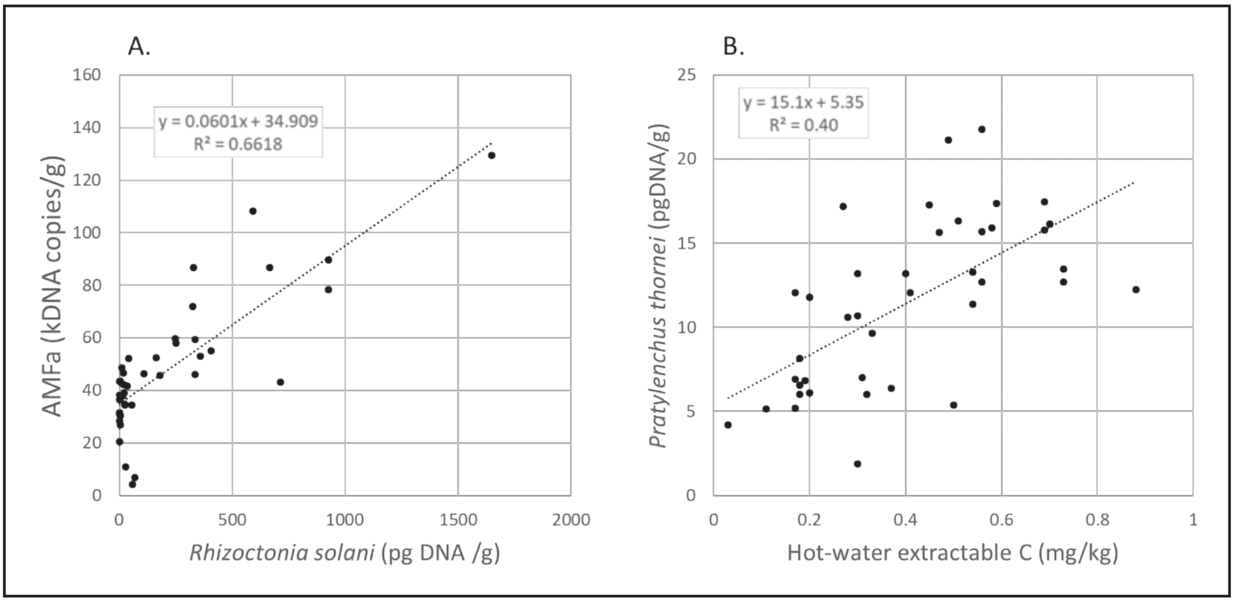


Figure 2. Correlations between qPCR microbial indicators.

What does this mean?

The focus of this ongoing project is to determine if, when and how microbial indicators respond to management strategies aimed to overcome constraints to cropping, and to determine whether any of these indicators are useful predictors of crop health.

In this case study, we found that many of the more 'general' soil health indicators measuring soil carbon fractions, microbial biomass or enzyme activities, did not change significantly in response to the treatments applied here. Moreover, these indicators did not have strong relationships with measures of crop health, biomass or yield. This suggests they may not be particularly useful for monitoring changes to soil health over the short-term, but their utility to detect changes over the longer term will continue to be explored in following seasons. Because many of these measures are highly correlated, that is, effectively giving similar information, measurement of a large suite of indicators in unlikely to be necessary for longer term on-farm monitoring. This is similar to current recommendations by the Soil Health Institute, who have proposed a minimum suite of three indicators for routine measurement - namely, soil organic C, soil C mineralisation potential (24-hr respiration) and aggregate stability (www.soilhealthinstitue.org).

In contrast to the more general indicators, the qPCR-based measures of specific microbial groups were able to pick up significant changes in response to some treatments. In particular, we were able to demonstrate that the treatment involving fungicide application brought about the desired effect of reducing the load of the soilborne pathogen Rhizoctonia. We also found that this treatment reduced the levels of two groups of mycorrhizal fungi. Although this would generally be considered as an undesirable side-effect because mycorrhizal fungi can assist in plant nutrient and water acquisition, there was no net negative effect on crop health since biomass, nutrient uptake and yield were not affected by this treatment in 2022 (see p. 29, Dzoma *et al* article) . Treatments containing phosphoric acid and trace elements also reduced the prevalence of *Pythium* in the soil at flowering.

Interestingly, *Pythium* and *Rhizoctonia* levels were found to have strong relationships with root health and crop yield, respectively. Together, these findings demonstrate that qPCR-based analysis of microbial phylogenetic and functional groups is a promising tool for better understanding how and why different management practices act on the soil biology to improve (or degrade) crop health. Ongoing project work will continue to monitor this and other sites around Australia to better understand the spatial and temporal dynamics of the different indicators, and their relationships to crop health and other soil functions. At the end of the project recommendations will be made on which, if any, microbial indicators should be included as routine monitoring tools for increased agricultural productivity and resilience to environmental stresses such as drought.

Acknowledgements

This project, "Soil microbial indicators: what do they mean and how can they be used?" (project ID 2.1.008) is supported by the Cooperative Research Centre for High Performance Soils whose activities are funded by the Australian Government's Cooperative Research Centre Program and GRDC. The authors would also like to thank Brian Dzoma and Nigel Wilhelm for data sharing, and Ian Richter, Brad Keen, Ken Leisha, Scott Petty, Kelvin Spann and Josh Rust for excellent technical support.

Soils

2022 was a good year for barley growing on an ameliorated deep repellent sand at Murlong

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

[1]SARDI; [2]Soil Function Consulting, Naracoorte, SA; [3]University of Adelaide.

Location
Murlong
Mark & Amy Siviour and family

Rainfall
Av. Annual: 332 mm
Av. GSR: 248 mm
2022 Total: 471 mm
2022 GSR: 295 mm

Yield
Potential: Wheat - 4.8 t/ha (French/Schultz)
Actual: 4.0 t/ha in best treatment

Paddock History
2021: Wheat
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
RCBD

Yield limiting factors
Late start, dry July

Key messages

- **Deep tillage boosted crop growth and yield five 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 had not provided additional yield after the first year, until 2022 when they increased wheat yields by at least 300 kg/ha when incorporated by spading.**
- **Only low cost soil amendments will be viable.**

Why do the trial?

Deep tillage can deliver large yield increases in compacted sandy soils. However, in 2018 when this trial was established, it was uncertain whether thorough mixing/dilution of the topsoil or adding amendments during this operation would be effective and profitable. It was also a time when inclusion plates were relatively new and their ability to increase mixing of surface applied amendments and/or topsoil, potentially with less risk of soil erosion compared to spading, was largely untested.

This trial aimed to:

- Determine if soil mixing and loosening improves yield in a sandy soil on the 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 fifth crop post amelioration and the accumulated grain yield benefit over five years. For details of past trial results, see the article in the 2021 EPFS Summary: Ameliorating a deep repellent sand at Murlong four years ago still improved wheat performance in 2021.

How was it done?

The trial is located on a broad sand dune at Murlong on the eastern Eyre Peninsula and comprises eleven 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. Spartacus CL barley was seeded in 2022 (Table 1).

Crop performance in an unmodified control has been 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 since except for a new treatment in 2022 which was ripping to 41 cm with inclusion plates.

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

Table 1. Trial establishment and cropping details for 2022 (trial was sown with Razor CL wheat in 2018, Scope CL barley in 2019, RM4 vetch in 2020, Hammer CL wheat in 2021 and Spartacus CL barley in 2022).

Date		
19 April 2018	Amendments applied	Organic Matter: Lucerne pellets at 5 t/ha. Nutrient Package: nutrients applied to match lucerne (N 167, P 14, K 105, S 12, Cu 0.03, Zn 17, Mn 0.18 kg/ha). NPKS 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.
31 May 2022	Sowing, adjacent to 2021 crop rows	60 kg/ha Maximus CL barley at 25.4 cm row spacing + DAP at 60 kg/ha and 63 kg SOA/ha banded below seed rows (all treatments). SE14 wetter sprayed into all seed rows at 4 L/ha.

What happened?

The season at Murlong in 2022 was the best we have experienced in the five years at the site, with barley yields between 2.5 and 4 t/ha (Figure 1). Spading and ripping continued to improve crop production even though they were originally applied in 2018 (Table 2). Barley yields increased by nearly 1 t/ha with either deep ripping or spading in 2022. Shallow ripping was less effective but still better than the unmodified control. Barley growing in plots deep ripped 5 years ago performed similarly to barley growing in plots deep ripped just prior to seeding in 2022 which shows that the benefits of physical intervention on these sands persist for a long time (noting that the trial has not been trafficked by heavy vehicles over those 5 years).

Barley established well in all treatments, averaging 80 plants per m^2 across the site. Numbers were slightly lower in shallow ripping treatments compared to spading, suggesting that the extra mixing with spading is still having a small and positive impact on water repellency. Deep ripping had plant populations in between shallow ripping and spading.

For the first time since 2018, amendments increased crop yields over and above the impact of soil loosening and mixing, but only where they had been incorporated by spading. Both types of amendments increased barley yields by more than 0.3 t/ha.

The accumulated benefits in grain yields over 5 crops at this site are now large (Table 2). The unmodified control produced a total of only 4.3 t/ha over the 5 crops but amelioration by either deep ripping or spading increased this total by an extra 3.5 t/ha or 4.3 t/ha, respectively. The increase in accumulated grain over the 5 crops was much smaller but still 2.1 t/ha with shallow ripping. Incorporating a package of mineral fertilisers or lucerne hay in the ripping or spading operations only produced substantial increases in accumulated grain production where they had been incorporated by spading. Mineral fertilisers and lucerne amendments resulted in 2 t/ha of more accumulated grain when incorporated by spading but these increases largely came in the first year with another useful increase only in the fifth year (Table 2).

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 3 t/ha of extra grain over the 5 years, deep ripping with inclusion plates was a competitive alternative to spading. Even shallow ripping resulted in more than 2 t/ha of extra grain over the 5 years. However, amendments only produced substantial increases in grain production when they were incorporated by spading which suggests that spading was a more effective tool than ripping if amendments are involved in the amelioration operation.

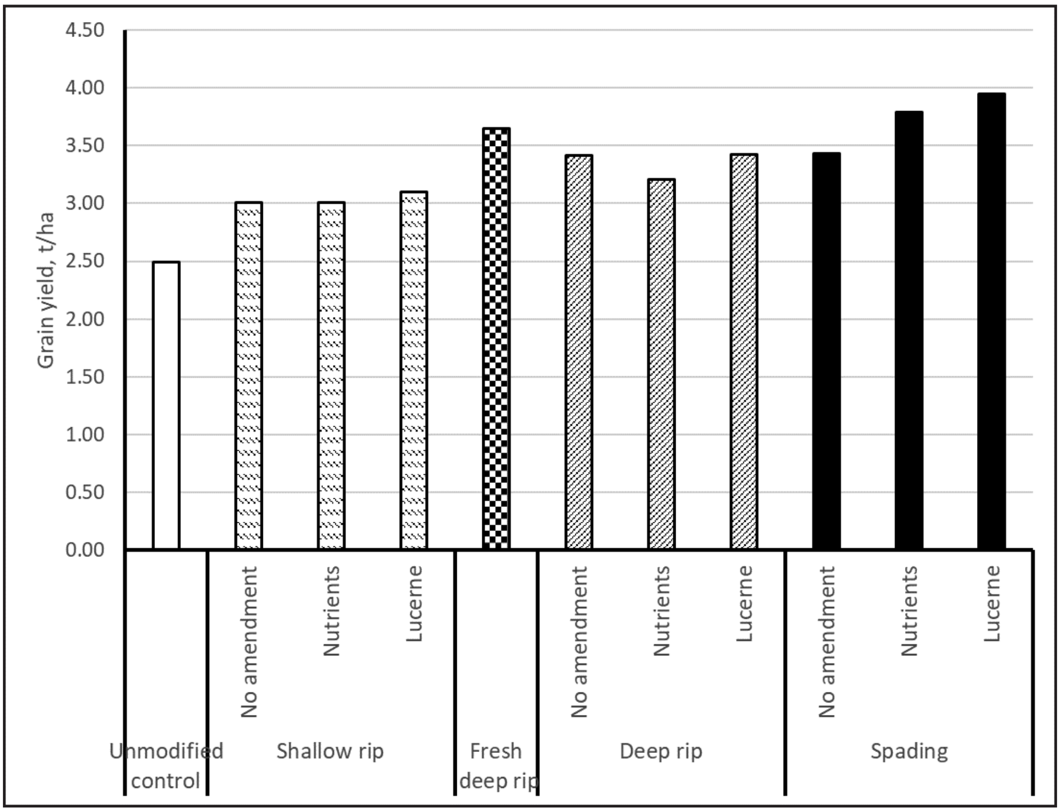


Figure 1. Effects of deep tillage and incorporated amendments on grain yield of barley at Murlong in 2022 (LSD, P = 0.05 is 0.25).

Table 2. Cumulative grain yield of crops (t/ha) with various amelioration strategies at Murlong from 2018 to 2022.

Physical intervention	**Amendment**	**Wheat in 2018**	**Barley in 2019**	**Vetch in 2020**	**Wheat in 2021**	**Barley in 2022**	**Cumulative grain yield**
None	None	0.48	0.72	0.19	0.45	2.49	4.33
Shallow Ripping	None	0.99	1.33	0.47	0.62	3.00	6.41
	Nutrients	1.2	1.37	0.52	0.57	3.00	6.66
	Lucerne	1.19	1.25	0.48	0.62	3.10	6.64
Deep ripping in 2022						3.65	
Deep Ripping	None	1.41	1.62	0.56	0.8	3.41	7.8
	Nutrients	1.9	1.52	0.49	0.72	3.20	7.83
	Lucerne	1.8	1.74	0.66	0.8	3.42	8.42
Spading	None	1.9	1.64	0.76	0.84	3.43	8.57
	Nutrients	3.22	1.83	0.72	0.98	3.79	10.54
	Lucerne	3.12	1.81	0.84	0.97	3.97	10.71
LSD (P=0.05)						*0.25*	*0.78*

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

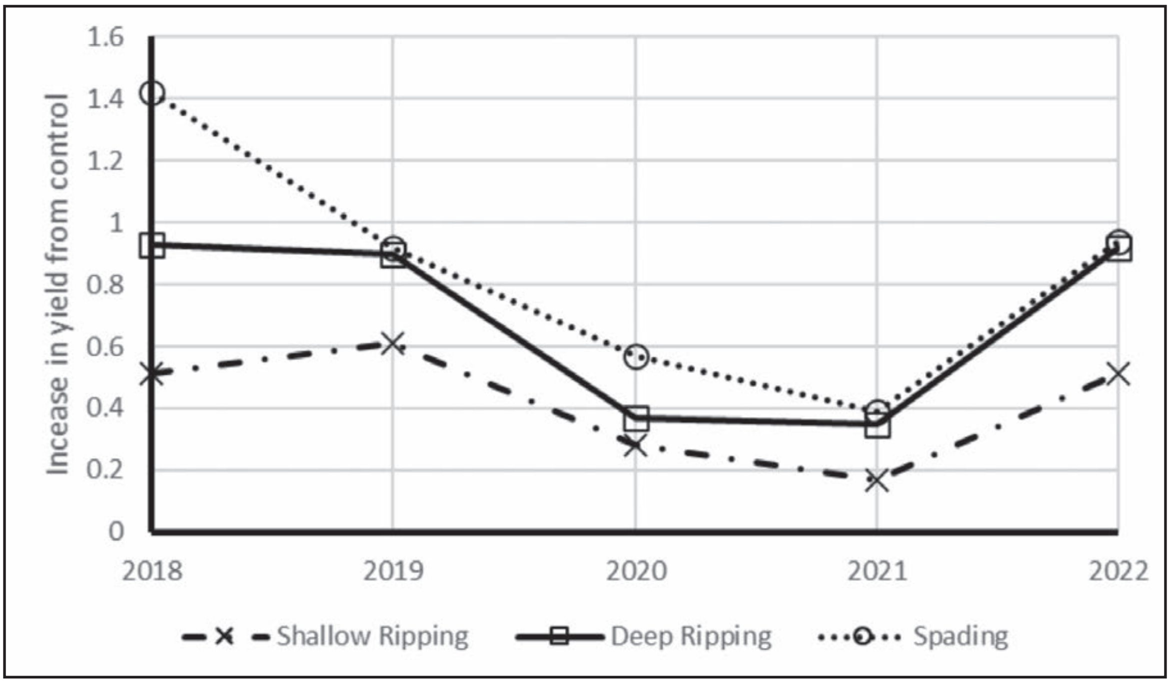


Figure 2. Benefits to grain yield of crops (increase in t/ha from unmodified controls) with 3 physical interventions at Murlong from 2018 to 2022 (amendments not included).

What does this mean?

Five 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 but a declining trend in yield benefits has now been reversed by the very good year in 2022. Benefits continuing beyond the fifth crop seems a likely prospect.

Spading has proven to be the most effective type of deep 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 but spading appears to be a better tool for incorporating amendments if that is part of the amelioration strategy. However, our experiences with incorporating high rates of fertiliser or organic matter (OM) are that the economic returns rarely justify the effort. Even with an extra 2 t/ha of grain over 5 years as was the case at Murlong, the cost:benefit outcome seems marginal.

An opportunity for further research in this space is to identify management strategies which will improve and prolong the benefits of physical loosening of compacted sands.

The Sandy soils project which has supported the work at Murlong finalises in 2023 so 2022 was the last season for this trial.

Acknowledgements

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

This work is funded under the GRDC project “Increasing production on Sandy Soils in low and medium rainfall areas of the Southern region” (CSP00203); a collaboration between the CSIRO, the University of South Australia, the SA Government Department of Primary Industries and Regions, Mallee Sustainable Farming Inc., Frontier Farming Systems and Trengove Consulting. The authors acknowledge the expert support of the SARDI Agronomy teams at Pt Lincoln and Minnipa for delivery of the trials.

References

Davies S, Armstrong R, Macdonald L, Condon J and Petersen E (2019). Soil Constraints: A role for strategic deep tillage. Chapter 8 in (Eds Pratley and Kirkegaard) “Australian Agriculture in 2020: From conservation to automation” p. 117-135 (Agronomy Australia and Charles Sturt University: Wagga Wagga).

GRDC GRAINS RESEARCH & DEVELOPMENT CORPORATION

Government of South Australia Department of Primary Industries and Regions

SARDI SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE

Using sowing strategies to mitigate water repellence at Wharminda

Brett Masters
SARDI

Location
Wharminda
Rainfall
Av. GSR: 252 mm
2022 GSR: 282 mm
Soil type
Shallow sand over sodic clay on carbonate.
Plot size
30 m x 15 m x 3 replicates
Yield limiting factors
Nil

Key messages

- **Crop establishment can be improved on water repellent sands by sowing a little deeper into stored soil moisture.**
- **GPS tracking can help to ensure that seed placement is consistent, however this can have reduced effectiveness when sowing on-row with high stubble loads.**
- **Knowledge of soil characteristics is important for identifying key production constraints and determining an appropriate and effective management strategy.**

Why do the trial?

The Wharminda district of the Eyre Peninsula has large areas of water repellent surface soils that restrict crop germination and growth. This can often result in poor surface cover and increased erosion, particularly in seasons where opening rains for seeding are delayed. There has been some past work to address water repellence in the district with farmers adopting practices such as clay addition, press wheels, stubble retention and split boot sowing. However, these have not always provided an effective solution. There has also been strong interest in previous wetting agent trials at Wharminda and the mitigation treatments at the Sandy Soils research trial at Murlong since 2018. The Hunts trialled a range of treatments to mitigate surface water repellence in 2021 including application of soil wetters at seeding, on row seeding and different sowing system configurations. Results from this trial were inconclusive and the landholders wanted to trial on-row sowing again in 2022 as a potential option to mitigate the impacts of water repellence on crop establishment. Above average summer rainfall resulted in good subsurface moisture, and the Hunts were keen to test the benefits of deeper seeding to improve crop germination.

This trial aimed to identify crop establishment and production benefits from:

- sowing on the previous year's stubble row compared to sowing in the inter-row and,
- sowing deeper into a layer of moist soil.

This article summarises crop growth responses from treatments in the 2022 season. For details of past trial results, see the articles in the 2019, 2020 and 2021 EPFS Summaries (EPFS Summary 2019, p. 99; Validating research outcomes to treat production constraints on sandy soils of Eyre Peninsula and EPFS Summary 2020, p. 84; Treating production constraints on the sandy soils of upper and lower Eyre Peninsula - Year 2 and EPFS Summary 2021, p. 39; Treating production constraints on the sandy soils of upper and lower Eyre Peninsula - Year 3).

How was it done?

In collaboration with AIR EP a replicated trial was established in Wharminda in 2022 as part of the GRDC Sandy Soils project (CSP00203). The site consisted of a shallow sandy rise (120 m long by 60 m wide) in the centre of the trial paddock. Sampling to characterise the soil profile was undertaken on 14 April 2022. Results revealed a water repellent shallow sandy topsoil overlying a light clay B horizon from 20 cm below the soil surface. Carbonate increased with depth, with surface extrusions of hard carbonate (limestone reef) to the south of the trial site.

Treatments aimed to mitigate the impact of surface water repellence on crop establishment and growth, focusing on inter-row vs on-row sowing and the additional impact of two contrasting sowing depths (shallow 5-6 cm and deep 6-8 cm) (Table 1).

Table 1. Summary of replicated trial sites.

Treatment	Treatment Label	Target sowing depth (cm below soil surface)
T1	Off row shallow	5-6 cm
T2	Off row deep	6-8 cm
T3	On row shallow	5-6 cm
T4	On row deep	6-8 cm

What happened?

Treatments were implemented at sowing on 6 May 2022 with the landholder using his seeder (which has GPS guidance capable of sowing on the previous years sowing row) to sow Commodus barley at 70 kg/ha. Samples taken on the previous year's stubble row and in the inter-row at seeding had little difference in soil moisture. The surface layers (0-5 and 5-10 cm) ranged from 1 to 4% soil moisture whilst the subsurface layers (which sit atop shallow clay) ranged from 5 to 8% moisture. Where clay was encountered at 15-20 cm on the western end of the trial (Rep 1), gravimetric moisture at sowing was 13%, on both the previous year's crop row and in the inter-row.

GPS based guidance enabled the seeder to track well between rows on the inter-row sowing treatments. However, sowing on row was difficult to maintain and tynes wandered resulting in a mix of 'on-row' and 'side row' furrows.

Plant density

Plant density was evaluated on 14 June, five weeks after sowing. Despite good summer rainfall and high moisture levels in subsurface layers (below 5 cm), surface soils were generally dry at this time. Crop germination and early growth was generally good with the crop at 3-4 leaf stage at monitoring. Assessments of seeding depth were also undertaken at this time with results indicating that seeding depth was highly variable within treatments (ranging from five to eleven cm below the soil surface), and that the target sowing depth for the treatment was not consistently achieved. Whilst assessments indicated that there was no difference in seeding depth between treatments at the 95% confidence level, the off-row shallow treatment was shallower than where deeper sowing was targeted or where on-row shallower sowing was targeted (which had deeper sowing than the off row deep treatment) at $P<0.1$. (Figure 1).

All treatments had higher plant numbers at crop establishment than the shallow off-row sowing ($P=0.005$) (Figure 2).

NDVI/Spring Biomass

Assessments of Normalised Difference Vegetation Index (NDVI) to identify any differences in winter growth were undertaken on 3 August using a handheld Greenseeker. Several crop biomass cuts were taken to calibrate NDVI values against dry matter (t/ha) and the mean NDVI value from four measurements per plot were extrapolated to estimate winter biomass (t/ha of dry matter) (Figure 2). Whilst there was no difference in growth at the 95% confidence level, the deeper sowing on-row treatment increased growth compared to the shallow off-row treatment at $P<0.1$. There was no difference between the other treatments.

There were no visual differences in growth between treatments in mid-September, and it was decided to take harvest index cuts to assess total biomass rather than spring dry matter.

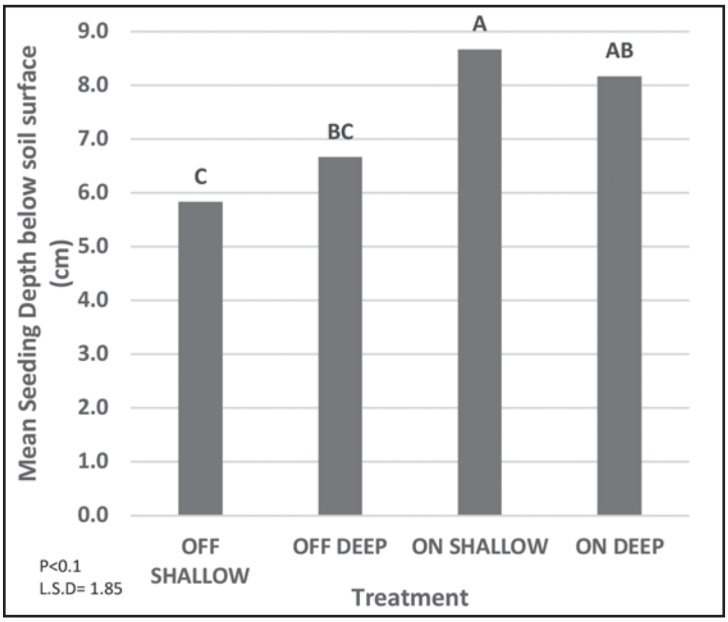


Figure 1. Average sowing depth (cm below the soil surface at Wharminda at crop establishment, 2022 (letters denote significant at P < 0.1).

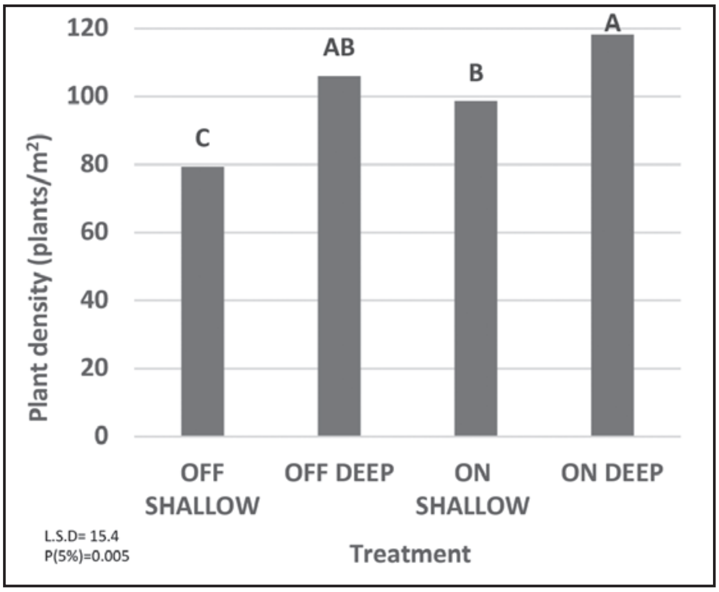


Figure 1. Plants per m² at Wharminda at crop establishment, 2022 (letters denote significant at P < 0.05).

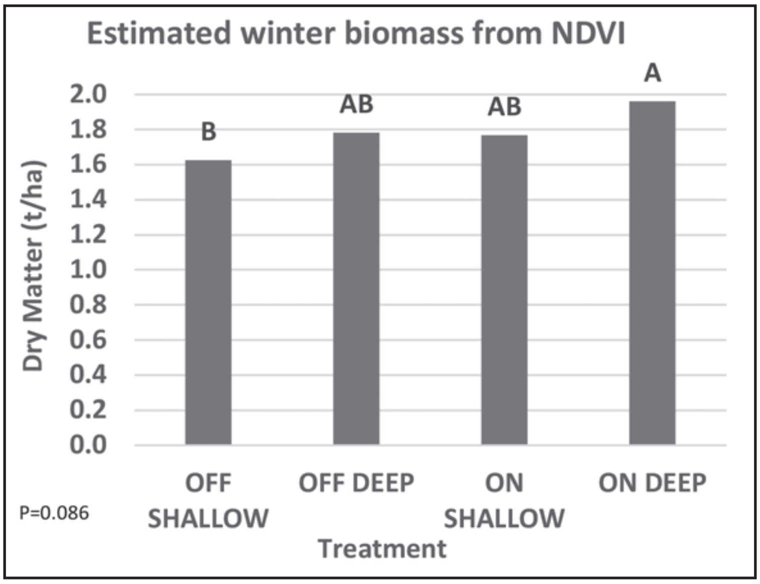


Figure 2. Estimated biomass (t/ha of dry matter) from winter NDVI measurements (letters denote significance at P < 0.1).

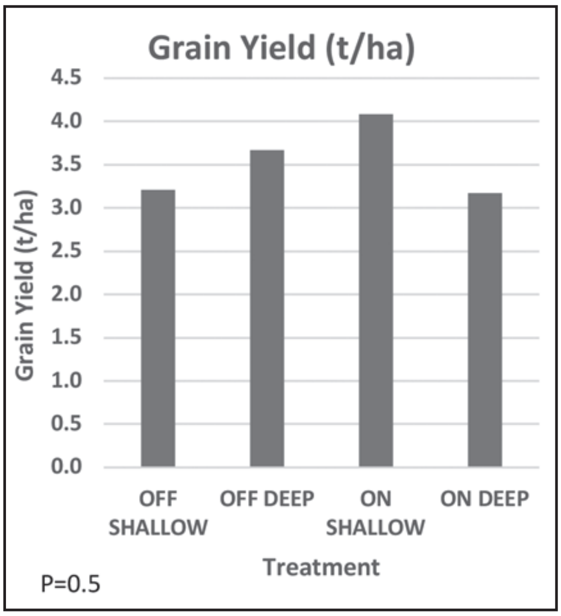


Figure 3. Barley grain yield at Wharminda, 27 October 2022.

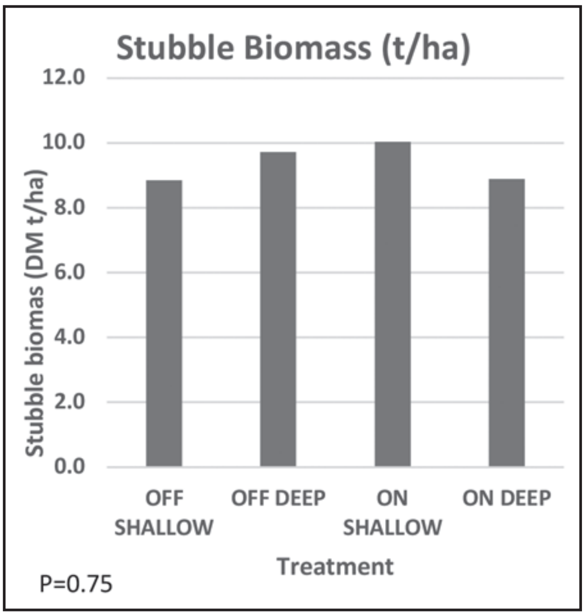


Figure 4. Barley stubble biomass at Wharminda, 27 October 2022.

Grain Yield

Harvest cuts were taken to assess grain yield and total biomass on 27 October 2022. Four cuts per plot were taken to ground level either side of 0.5 m measure. Stubble dry weights were extrapolated to dry matter (t/ha) (Figure 3). Heads were removed and threshed to obtain grain weights which were extrapolated to grain yield (t/ha) (Figure 4). Despite differences in crop establishment and some small crop growth benefits from deep seeding (at 90% confidence) there was no significant difference between treatments in the grain yield and stubble biomass.

What does this mean?

Good summer rainfall resulted in high subsurface moisture at seeding. This provided the ideal opportunity for the Hunts to trial deeper sowing as a strategy for managing soil water repellence. GPS seeder tracking was broadly effective in facilitating inter-row sowing, but the sandy nature of the soil and standing stubble reduce the accuracy of this when sowing on-row. This affected sowing depth, with only 1-2 cm difference between the sowing depth for the off-row shallow and off-row deep treatments.

Assessments of sowing depth also suggested that the average sowing depth on the on-row shallow treatment was deeper than where deeper sowing was targeted (but sowing depth on this treatment varied greatly from 5 to 11 cm and the mean sowing depth for the treatment might not accurately reflect the combined effect of shallow on-row sowing). All treatments had in increased plant numbers compared to the off-row shallow sown treatment.

Winter and spring rainfall provided good conditions for crop growth and the differences between treatments seen at crop establishment were not present later in the season. Despite no difference in biomass production and grain yield in 2022, trial results suggest that where surface soils are dry but subsurface layers contain moisture, sowing deeper can improve crop establishment on water repellent soils. Having high plant numbers at crop establishment has multiple benefits including improved surface cover for wind erosion protection and providing early vigour for improved crop resilience in poorer seasons. Whilst long coleoptile varieties will provide excellent options for deep sowing on these soils, results from this trial indicate that if surface soils are dry and subsurface layers contain moisture, sowing an extra 1-2 cm deeper can be helpful for early crop establishment even with commonly grown varieties.

Acknowledgements

The GRDC funded Sandy Soils project (CSP00203) is a collaboration between CSIRO, University of South Australia, Primary Industries and Regions SA, Mallee Sustainable Farming Inc, AgGrow Agronomy and Trengove Consulting. Thanks also goes to the landholder co-operators, Ed and Caroline, and Evan and Lauren Hunt as well as AIR EP for their support of this trial.

Deep ripping sandy soils on upper and eastern Eyre Peninsula

Brett Masters[1], Amanda Cook[1,2] and David Davenport[3]

[1]SARDI; [2]University of Adelaide; [3]Davenport Soil Consulting

Location
Streaky Bay, Mt Damper, Minnipa & Arno Bay
Dion and Tiffany Williams, Nigel and Lauren Oswald, Wes and Jacqui Daniell, Ben and Kathy Ranford

Rainfall
Av. GSR/2022 GSR
Streaky Bay: 303/384
Mt Damper: 218/263
Minnipa: 242/332
Arno Bay: 254/255

Soil type
Streaky Bay: Calcareous loamy sand with increasing carbonate at depth
Mt Damper, Minnipa and Arno Bay: white siliceous sand over poorly structured clay

Plot Size
Streaky Bay and Arno Bay: 30 m x 4 m x 3 reps
Minnipa: seeder width x 100 m, non-replicated demonstration
Mt Damper: 30 m x 10 m x 3 reps

Yield limiting factors
Dry conditions in June and July.
Hostile subsoil layers - carbonates and boron.
Layers of high soil strength on unripped plots.

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.**
- **Ripping at Arno Bay and Minnipa provided higher grain yield than the unripped controls, but not at Mt Damper or on a calcareous sand at Streaky Bay in 2022.**
- **Knowledge of soil constraints and the depth at which they are present in the soil profile is key for choosing the most appropriate soil modification strategy for each site.**

Why do the trial?

Sandy soils account for a significant proportion of Eyre Peninsula's agricultural soils (with approximately 20% consisting of either deep siliceous sands or sand over clays and another 30% as calcareous sands or loamy sands). Sandy soils have multiple constraints which can result in large differences between water limiting potential and actual crop yields. Recent trial work on the Eyre Peninsula conducted under the GRDC sands research and impacts programs has indicated that 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. For details of past trial results, see the articles in the 2019, 2020, 2021 EPFS Summaries (EPFS Summary 2019, p. 99-104; Validating research outcomes to treat production constraints on sandy soils of Eyre Peninsula and EPFS Summary 2020, p. 84-87; Treating production constraints on the sandy soils of upper and lower Eyre Peninsula - Year 2; EPFS Summary 2021 p. 39-43; Treating production constraints on the sandy soils of upper and lower Eyre Peninsula - Year 3).

In 2022 the impact of deep ripping and other treatments on crop growth and yield was assessed on several Eyre Peninsula demonstration sites established on sandy soils. Monitoring was conducted under an AIR EP project funded by the Australian Government's 'Future Drought Fund' (FDF). Given that deep tillage boosted crop growth and yield three years after implementation on three out of four GRDC sandy soil impacts amelioration sites on Eyre Peninsula (EPFS Summary 2021 p. 39-43), it was decided that deep ripping treatments should be the basis for the selection of monitoring sites.

These trials aimed to:

- Compare the production of deep ripped soil to unmodified controls on different sandy soils on upper and eastern Eyre Peninsula.
- Identify if the addition of manures or other organic material provided additional benefits.

This article summarises crop growth responses from treatments in 2022.

How was it done?

In collaboration with AIR EP, landholders, David Davenport (Davenport Soil Consulting) and PIRSA-SARDI researchers four demonstration sites were selected including:

- Mt Damper - monitoring of the spading and ripping site established in 2019 under the GRDC Sands Impacts project (EPFS Summary 2019, 2020 and 2021).
- Streaky Bay and Arno Bay - new replicated trials established under the EP Landscape's Board "Regenerative Agriculture Program" (EPLB RAP) funded by the National Landcare Program project with additional support from the Soils for Life 'Paddock Labs' project.
- Minnipa - a new deep ripping demonstration.

Table 1. Summary of trial sites monitored in 2022.

Site ID/ Location	Demo type	Soil type	Establishment year and project	Key soil constraints	In season measurements	Treatments
Dion Williams Streaky Bay	Replicated smaller plot - 30 x 4 m	Highly calcareous loamy sand	2022- EPLB RAP/Soils for Life 'Paddock labs'	Physical, nutrients	Baseline soil, plant emergence, dry matter, grain yield	**Control** - 55 kg/ha DAP **C based nutrition** Basal (25 kg/ha DAP)+ Manure (100 kg/ha Bounceback) Basal (25 kg/ha DAP)+ Manure (100 kg Bounceback)+ Phosacid (40 L/ha) **Companion planting** - basal (25 kg/ha DAP) + vetch **+/- Deep tillage** - deep ripping with inclusion plates (IP)
Nigel Oswald Mt Damper	Replicated large plot - 30 x 18 m	Siliceous sand over clay	2019- GRDC Sands Impacts project	Water repellence, physical, nutrients	Baseline soils 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 = 50 cm). **Soil amendments** - ripping+IP+nutrients
Wes Daniell Minnipa	Unreplicated - large plot 15 m x 100 m	Siliceous sand over clay	2022- FDF sands project	Water repellence, physical, nutrients	Baseline soils, plant emergence, grain yield	**Control** - unmodified Ripped - deep ripping
Ben Ranford Arno Bay	Replicated smaller plot- 30 x 4 m	Siliceous sand over clay	2022- EPLB RAP/Soils for Life 'Paddock labs'	Water repellence, physical, nutrients	Baseline soils plant emergence, dry matter, grain yield	**Control** - 65 kg/ha DAP/ SOA **C based nutrition** Basal (25 kg/ha DAP/ SOA)+Manure (100 kg Bounceback) Basal (25 kg/ha DAP/ SOA)+Manure (100 kg Bounceback)+ Phosacid (40 L/ha) **Companion planting** - basal (25 kg/ha DAP) + peas **+/- Deep tillage** - deep ripping + soil mixing of top 20 cm

Treatments were designed to address soil constraints at each site and involved a mixture of strategic deep tillage with and without soil amendments (Table 1). At the Mt Damper site (original treatments applied in 2019) additional nutrients were applied to meet the nutrient needs of potential production increases from addressing constraints over the previous 3-year period. For the other sites treatments were implemented prior to sowing in 2022. A major focus of the Paddock Labs project was to support landholders to enhance soil function and reduce reliance on expensive mineral fertilisers. Treatments at the Streaky Bay and Arno Bay sites compared mineral fertiliser with and without carbon (C) based fertiliser, or sowing legumes in crop.

Ripping at the Streaky Bay and Mt Damper sites was undertaken using a four tine Yeoman's plough with inclusion plates. At Arno Bay, ripping to 40 cm depth at a 0.5 m tyne spacing was conducted using a Bednar plough, whilst the landholder ripped a demonstration strip at Minnipa to bring clay to the surface.

Plant measurements included crop establishment, a measure of biomass production (NDVI and/ or biomass production) and grain yield assessments. Data from replicated sites was analysed using standard ANOVA models in Statistix 8.

What happened?

Intense storm activity in late January 2022 bringing up to 250 mm of rainfall in 24 hours resulted in most districts recording their highest rainfall totals ever for the summer period and full soil moisture profiles.

In 2022 all sites were sown by the landholders (Razor CL wheat at Streaky Bay, Vixen wheat at Arno Bay, Yallara oats at Minnipa and Butler peas at Mt Damper) and managed as per the rest of the paddock. Plant density was evaluated 4 to 6 weeks after sowing. Windy conditions and dry surface soils saw wind erosion on the Mt Damper and Arno Bay sites which resulted in high variation in crop establishment within plots. However, in most cases crop plant densities on these sites were around those expected for the crop type and rainfall zones. There was little difference in growing season rainfall compared to the long-term averages. However, January rainfall resulted in a full soil moisture profile at seeding which crops were able to draw on during dry periods in June and July. Cuts were taken in spring at all sites to assess the impact of treatments on biomass production. Good rainfall throughout the late winter and spring period provided ideal growing conditions for crops and pastures, whilst late spring rainfall slowed senescence on cereals, extending ripening and delaying harvest.

Streaky Bay

At Streaky Bay good early rainfall resulted in uniform wheat emergence with no significant difference ($P < 0.05$) on treated areas compared to the control (which had 106 plants/m^2). Assessments of winter and early spring growth; NDVI on 10 August and 19 September as well as dry matter cuts on 12 September, showed no differences (P values of 0.162, 0.414 and 0.175 respectively) in growth on the treated plots compared to the control (which had 6.3 t/ha of dry matter). Whilst the western side of the trial appeared visually greener, there was large spatial variation, and ryegrass was an issue across the site. Grain yields at Streaky Bay varied within treatments and across the site and there were no significant differences ($P = 0.89$) in yield between treatments (control averaged 3.0 t/ha of wheat).

Mount Damper

Despite having good subsoil moisture, drier periods in autumn and early winter at Mt Damper, Minnipa and Arno Bay resulted in dry topsoils and delayed seeding. Previous data from the Mt Damper site in 2019-2021 showed the biggest production increases on the spaded (+/- rip with inclusion plates) plots. In 2022 there was no difference in establishment ($P = 0.21$) or NDVI values on 5 August ($P = 0.33$) with controls averaging 58 plants/m^2 and NDVI of 0.37. When biomass was assessed on 6 October all treatments had higher NDVI values ($P = 0.008$) than the control which had a value of 0.41). However, as there was no difference ($P = 0.705$) in biomass between plots at this time (control averaged 4.4 t/ha of dry matter), this is likely due to earlier crop senescence on the control plots resulting in reduced NDVI reflection. There were also no significant grain yield increases ($P = 0.76$) at the Mount Damper site (with controls yielding 2.3 t/ha of peas).

Minnipa

At the Minnipa site winter NDVI assessments showed little difference in growth, but at biomass cuts in mid September the ripped treatment had 80% more dry matter than the control (which had 8.7 t/ha of dry matter), which resulted in 20% more oat grain yield on the ripped area compared to the control (which yielded 3.2 t/ha).

Arno Bay

At Arno Bay the landholder resowed the site at a 45-degree offset to the original sowing lines to try increase surface cover at emergence and reduce the erosion risk. As a result, plant densities were much higher than is normally recommended (120-140 plant/m^2) for this rainfall zone (Figure 1). Only the 55 kg/ha DAP with ripping and peas had higher plant numbers than the control which averaged 267 plants/m^2. Unfortunately, due to a mix up at sowing this treatment only had one replicate.

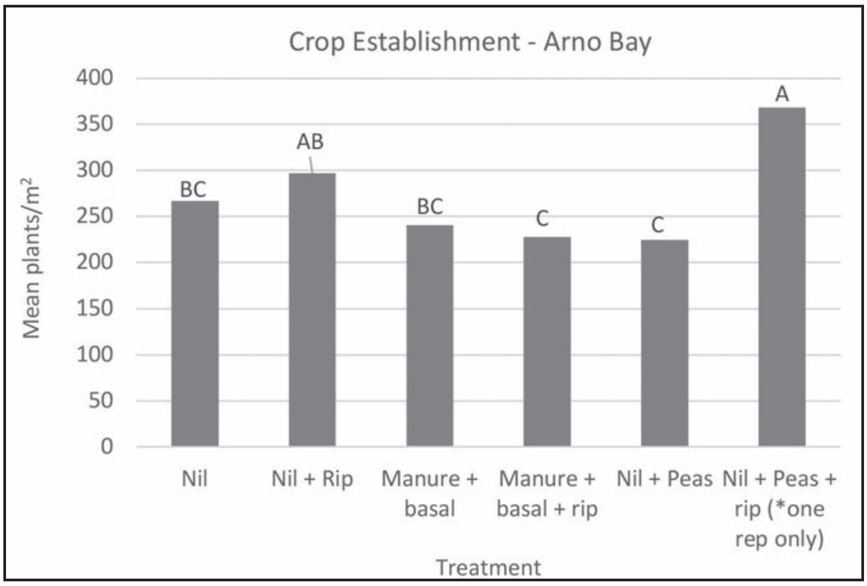


Figure 1. Plants/m^2 at Arno Bay at crop establishment. A different letter indicates a significant difference at $P < 0.05$.

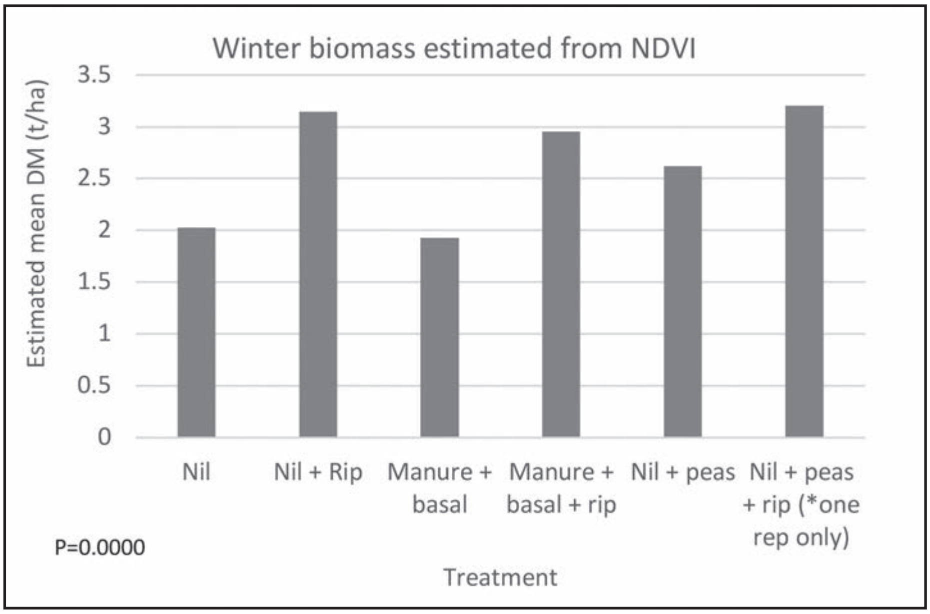


Figure 2. Estimated winter biomass from NDVI assessments on Arno Bay site taken in mid-August 2022.

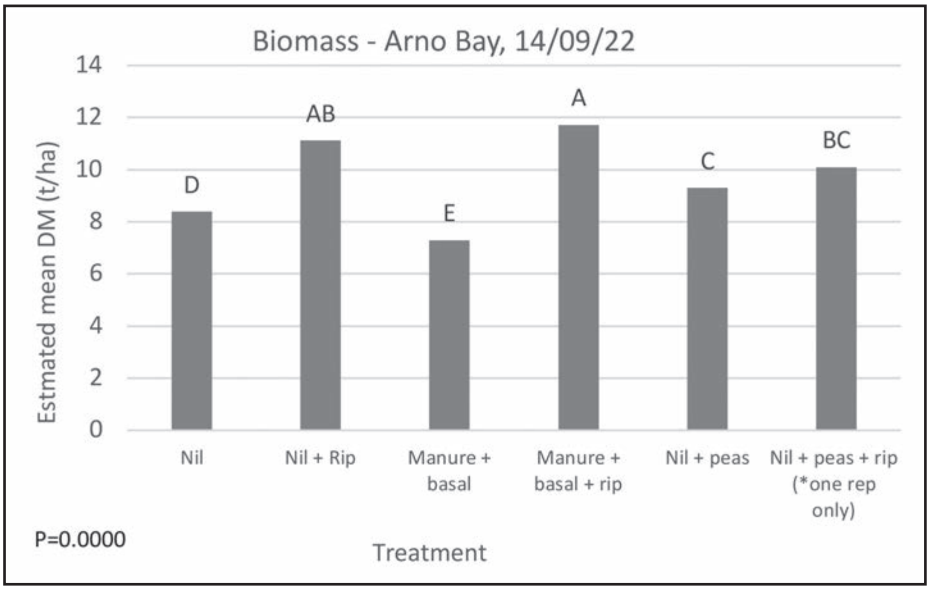


Figure 3. Spring biomass (t/ha dry matter) at Arno Bay. A different letter indicates a significant difference at P<0.05.

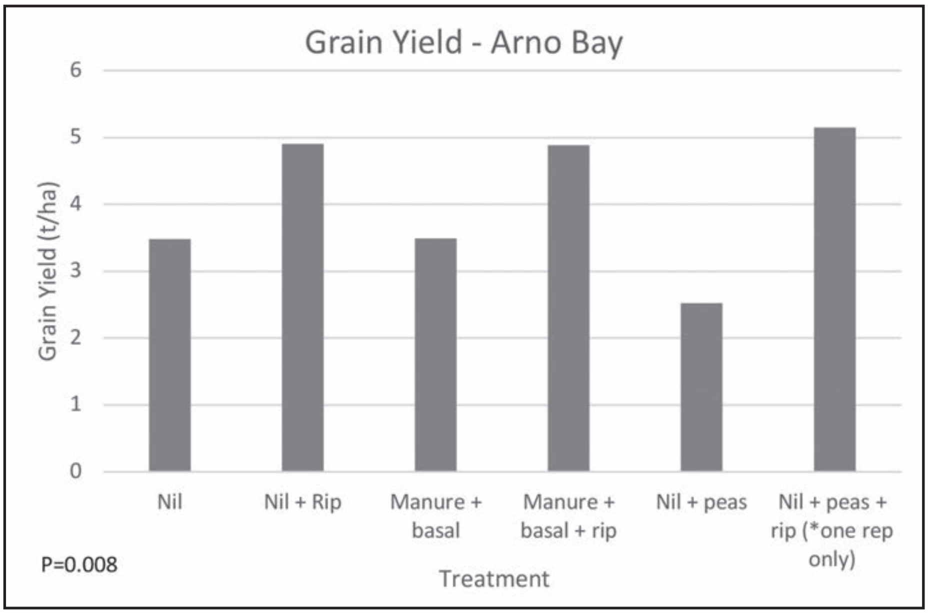


Figure 4. Wheat yields at Arno Bay, December 2022.

NDVI assessments were undertaken on 10 August. Calibration cuts were taken to convert NDVI values to estimated biomass (t/ha dry matter) (Figure 2). Data indicated that ripping improved crop growth (P=0.0059) compared to the corresponding unripped treatments Nil and Manure + basal treatments (Figure 2). Whilst Nil + Peas + rip was one of the treatments with the highest plant numbers at establishment (bearing in mind that this treatment had only one replicate), NDVI and biomass data suggested that there was not much difference in growth between the three ripping treatments (Figures 2 and 3).

Cuts were taken at anthesis to assess spring biomass (t/ha of dry matter). Results supported earlier crop establishment and NDVI data, with Nil + Rip and Manure + basal + rip having higher amounts of dry matter than their unripped comparison treatments (P = 0.0001) (Figure 3).

At this site there was little impact from amendments with all ripped treatments yielding more than the unripped treatments (Figure 4). Whilst severe powdery mildew was observed on the crop in early to late spring, visually it appeared that the severity of powdery mildew was much higher on the unripped treatments compared to the ripped treatments and was not associated with applied ameliorants.

What does this mean?

Due to favourable seasonal conditions grain yields were exceptional across the trial sites. As the soil constraints associated with these sites have a high impact on plant available water, the early rainfall makes interpretation of results problematic. However, some conclusions can be made including:

- Ripping on the Arno Bay site delivered substantial yield increases and even though there was higher biomass on these treatments there appeared to be less powdery mildew observed.
- At the Minnipa site there was a significant response to ripping suggesting treatment of a soil physical constraint by ripping.
- At the Arno Bay and Streaky Bay sites using a cheaper mineral/C based fertiliser mix with lower levels of nitrogen applied did not deliver a significant yield difference compared to mineral fertiliser alone.

In conclusion, these results 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 maintaining these production increases across different crop types and seasons requires further investigation.

Acknowledgements

These demonstration sites were made possible through funding from the Future Drought Fund's Drought Resilient Soils and Landscapes grants program and the Grains Research & Development Corporation and is supported by the SA Drought Resilience and Adoption Hub, for the project 'Building drought resilience by scaling out farming practices that will enhance the productive capacity of sandy soil landscapes', activity ID 4-H6P3CX5. The sites are also supported by the Australian Government's National Landcare Program, with support from EP Landscapes Board Regenerative Agriculture Program, Soils for Life (Paddock Labs Project), and AIR EP.

The authors would also like to thank the collaborating landholders involved in this project; Dion and Tiffany Williams, Nigel and Lauren Oswald, Wes and Jacqui Daniell and Ben and Kathy Ranford, without whom this project would not be possible.

Applying ameliorants improved crop establishment and growth on dry saline land patches on Eyre Peninsula in 2022

Brett Masters[1] and Amanda Cook[1,2]

[1]SARDI, [2]University of Adelaide

Location
Karcultaby, Minnipa, Buckleboo & Tumby Bay

Rainfall
Av GSR/2022 GSR
Karcultaby: 232/268
Minnipa: 241/332
Buckleboo: 196/194
Tumby Bay: 252/252

Soil type
Calcareous silty clay loam with increasing sodic subsoil layers and increasing clay and corbonate at depth.

Soil test
Saline and sodic subsoil layers often with high boron and carbonate at depth.

Plot size
Karcultaby and Minnipa:
30 m x 4 m x 3 replicates
Buckleboo:
15 m x 100 m, non-replicated
Tumby Bay: seeder width x 200 m, non-replicated

Yield limiting factors
Dry conditions in June and July at Buckleboo.

Key messages

- **The application of ameliorants, including sand and manures can provide improved plant establishment and growth on dry saline land.**
- **Understanding the nature of site soil constraints and of the applied ameliorants is key to maximising crop production benefits.**
- **The improved cover on treated areas, if maintained over summer, is expected to reduce evaporation and the capillary rise of salts to the surface, which could provide production benefits over multiple years.**

Why do the trials?

Patches of poor crop and pasture growth within paddocks, caused by the accumulation of salts in soil layers and not associated with saline water tables, are a common and persistent issue across the lower rainfall areas of Eyre Peninsula. Whilst these dry saline patches, historically referred to as ‘magnesia patches’, have been present for many years (Kennewell 1999), the results of a recent landholder survey (McDonough and Scholz, 2021) identifies landholder concerns that both the area of land impacted, and severity of production loss has increased in recent years.

In 2021 an AIR EP project, funded by the Australian Government’s National Landcare Program in conjunction with the Eyre Peninsula Landscape Board, investigated the differences in soil characteristics between areas of good crop growth and poor crop growth on sites at Karcultaby and Buckleboo. Results indicated that the soil profile in the better production zones had better drainage due to coarse carbonate fragments in the soil profile and less “wicking ability” limiting the capacity capillary rise of salts (Masters and Guidera, 2021).

Growers have tried several management approaches with varying levels of success, including the addition of soil ameliorants such as sand or organic matter to the topsoil. Under a project funded by the Australian Government’s Future Drought Fund and in collaboration with landholders, AIR EP and PIRSA-SARDI researchers, several demonstration sites were established in 2022 to assess a range of treatments, aimed at reducing the impact of these salts on crop and pasture production. This article summarises plant growth responses from treatments during the 2022 season.

How was it done?

Four demonstration sites (a mix of unreplicated ‘farmer scale’ and smaller replicated sites) were established in 2022 at Karcultaby, Minnipa, Buckleboo and Tumby Bay. Analysis of a composite soil sample in May 2022 showed that at Karcultaby and Minnipa salinity in the 0-10 cm layers was relatively low (<0.24 dS/m) but increased quickly in subsurface layers (0.77 dS/m in the 30-60 cm layer at Karcultaby and 0.54 dS/m at Minnipa). At Buckleboo salinity in the 0-10 cm layer was high (>1.0 dS/m and remained high throughout the profile). A composite sample across the site at Tumby Bay revealed slight salinity from 0-20 cm (0.23 dS/m) with increased salinity from 20-30 cm (0.68 dS/m).

Treatments were designed to investigate the production benefits of applying either a soil ameliorant (sand or manure) to the soil surface, or an alternative crop option on the dry saline affected area compared to the control crop (Table 1).

Table 1. Summary of dry saline land demonstration sites in 2022.

Co-operator Location	Demonstration type	Crop type and sowing date	Measurements	Treatments
Cook Karcultaby	Soil ameliorants (Replicated)	Barley (Scope CL)	Baseline soil salinity, plant emergence, NDVI, dry matter, grain yield	Control - untreated Soil ameliorants Surface manure @ 8 t/ha Surface sand @ 300 t/ha
Minnipa Ag Centre	Soil ameliorants (Replicated)	Wheat (Scepter)	Baseline soil salinity, plant emergence, NDVI, dry matter, grain yield	Control - untreated Soil ameliorants Surface manure @ 8 t/ha Surface sand @ 300 t/ha
Karinya Ag Buckleboo	Soil ameliorants (Unreplicated)	Oats (Yallara) and Vetch (Timok)	Baseline soil salinity, NDVI, dry matter, grain yield	Control - untreated Double sowing Soil ameliorants Low-rate sand @ 150-250 t/ha High-rate sand @ 250-500 t/ha
McCallum Tumby Bay	Plant options (Unreplicated)	Barley (Spartacus CL)	Baseline soil salinity, plant emergence, NDVI, dry matter	Control – Spartacus barley @75 kg/ha Plant options a. Moby barley @ 40 kg/ha b. Moby barley (40 kg/ha) + vetch (25 kg/ha) c. Moby barley (@ 40 kg/ha) + vetch (@ 25 kg/ha) + tillage radish (@ 2 kg/ha)

At Karcultaby and Minnipa the soil ameliorants were surface applied prior to seeding. At Buckleboo, the dry saline patch sown was sown with vetch/oats in early April try and get some cover on the site with the demonstration strips of sand being spread on top using a land-plane scraper in May. The sand demonstration strips were 15 m wide x 100 m long and crossed over two areas of better growth and two areas of salt scald. Plant measurements included crop establishment, a measure of biomass production (NDVI and/or biomass production). Grain yield was taken at Karcultaby and Minnipa. The Buckleboo site was sprayed out ("brown manured") at anthesis whilst the Tumby Bay site was cut for hay. Data from replicated sites was analysed using standard ANOVA models in Statistix 8.

What happened?

Intense storm activity in late January 2022 bringing up to 250 mm of rainfall in 24 hours resulted in most districts recording their highest rainfall totals ever for the summer period and full soil moisture profiles. In 2022 all sites were sown by the landholders and managed as per the rest of the paddock. The Karcultaby and Minnipa sites were sown to cereal crops (Scope barley at Karcultaby and Scepter wheat at Minnipa), whilst the Buckleboo and Tumby Bay sites were sown to mixed species cover crops (Yallara oats and Timok vetch at Buckleboo and mixtures of barley +/- vetch and tillage radish at Tumby Bay). At Buckleboo the western end of the demonstration site was double sown (with double seed and fertiliser) with the eastern end of the trial only sown once.

Crop establishment

Plant density was evaluated 4 to 6 weeks after sowing at Karcultaby, Minnipa and Tumby Bay. Two assessments of crop establishment were undertaken at Karcultaby due to staggered emergence, however the treated areas did not have higher plant numbers than the untreated control (which averaged 62 plants/m^2 on 7 June and 74 plants/m^2 on 24 June). At Minnipa there was no difference in crop establishment between the surface manure treatment and the control (which averaged 117 plants/m^2). However, the surface application of sand reduced plant establishment by 30% (Figure 1).

Results from soil analysis indicated that the salinity of the A horizon material used for the sand treatment at Minnipa was moderately saline (0.54 dS/m) which at a rate of approximately 300 t/ha might explain the poorer establishment on the sand spread plots. Both manure samples (sheep manure at Karcultaby and feedlot waste at Minnipa) had high salinity (1.0 ds/m at Karcultaby and 2.3 dS/m at Minnipa), but were applied at a lower rate (8.0 t/ha) than the sand so did not appear to affect crop establishment in the same way.

At Buckleboo NDVI readings were taken using a handheld 'Green seeker' on 5 August to assess differences in crop growth on the treated areas compared to untreated controls (Table 2). Assessments were undertaken on the two sand treatments (low rate of 150-250 t/ha and high rate of 350-500 t/ha) and three untreated control strips, including a 'control 0' located at the northern edge of the dry saline land patch which had generally better growth. NDVI assessments were taken at four points ('bays'), where crop growth was impacted by differing salinity levels or management practice.

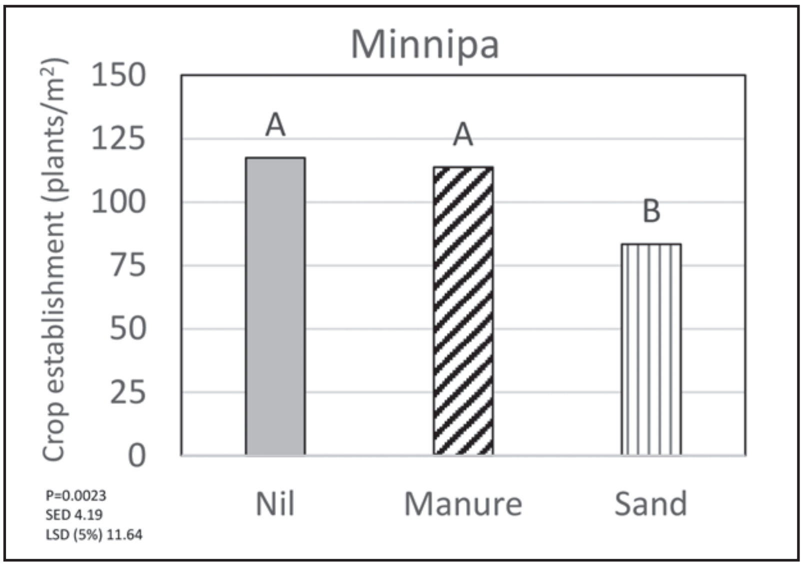


Figure 1. Plants/m² at Minnipa at crop establishment. A different letter indicates a significant difference at P<0.05.

Soils

Table 2. NDVI values on Buckleboo site, 5 August 2022.

	BAY 1: Lower salinity (Double sown)	BAY 2: Western scald (Double sown)	BAY 3: Lower salinity (Double sown)	BAY 4: Eastern scald (Single sown)
Control 0 (better production area)	0.73	0.75	0.73	0.53
Low rate sand (150 – 250 t/ha)	0.85	0.84	0.84	0.68
Control 1	0.79	0.37	0.82	0.54
High rate sand (350-500 t/ha)	0.89	0.63	0.87	0.78
Control 2	0.84	0.38	0.71	0.51

The matrix in Table 2 shows the high spatial variability of salt impact on crop growth within dry saline patches. NDVI values of 0.73 to 0.84 in the untreated areas with low salinity in controls 0 (an unaffected control strip at the northern edge of the dry saline patch), 1 and 2 were much higher than readings of 0.37 to 0.54 where high salinity resulted in bare scald. These values also showed much improved growth on the sand treated strips when compared to adjacent control scald areas at both the low and high rate of sand.

Crop establishment was assessed at Tumby Bay on 10 June (35 days after sowing) (Figure 5). Unfortunately, rabbits from a coastal reserve adjoining the paddock caused some damage to the southern edge of the demonstration with little crop establishment for approximately 40 m into the paddock. The affected area was excluded from the plant establishment assessments, with plant counts taken from a transect across each treatment beginning about 60 m in from the southern paddock boundary. Due to the high degree of spatial variability in salinity impacts on the site (due to microrelief within the flat paddock), four paired plant counts were taken for each treatment on adjacent 'good' and 'poor' patches and averaged for the treatment (Figure 2). Results showed 12-20% higher plant numbers on the mixed species treatments compared to the barley control (which had 80 plants/m²) on the unaffected (good) area (Figure 2). On the 'poor' area there were 30% higher plant numbers on the Moby barley+vetch treatment (73 plant/m²) compared to the barley control (which had 56 plants/m²), but establishment on the barley+vetch+tillage radish was not different to control in this area.

Biomass

A dry period in June and July followed by wet spring conditions brought average to slightly above average growing season rainfall across the region. Opportunistic growth assessments (NDVI and biomass cuts) were taken at each site. Winter biomass cuts at Karcultaby on 17 August showed improved crop growth (P = 0.026) on both the surface applied manure (4.3 t/ha) and sand (3.9 t/ha) treatments compared to the control (which yielded 2.2 t/ha of dry matter) (Figure 3). This improved growth was also supported by NDVI (P=0.032) assessments on that date. In early spring these differences were not significant at 95% confidence level but were at 90% (P=0.058).

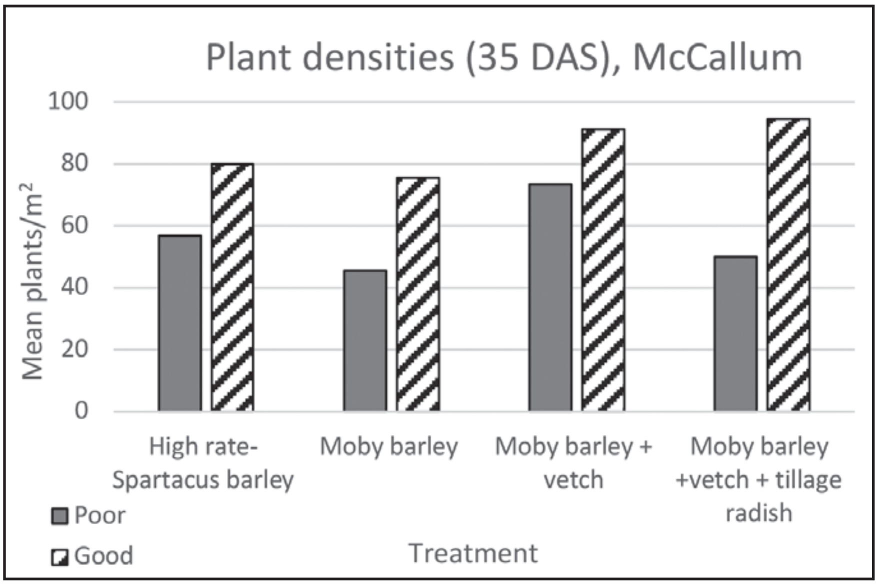


Figure 2. Plants/m² at Tumby Bay at crop establishment on 10 June 2022. Poor = areas of poor plant establishment; Good = areas of good plant establishment.

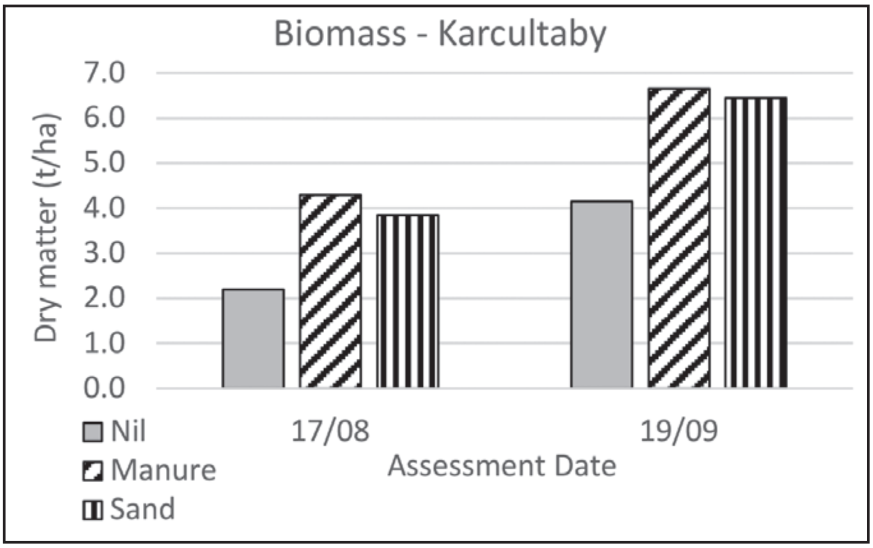


Figure 3. Dry matter (t/ha) at Karcultaby on 17 August and 19 September 2022.

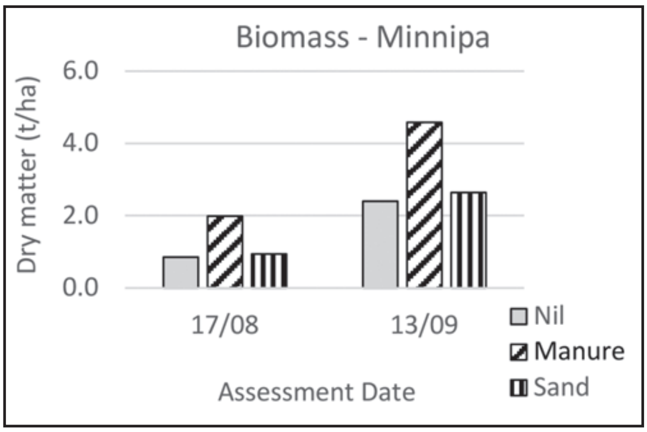


Figure 4. Dry matter (t/ha) at Minnipa on 17 August and 13 September 2022.

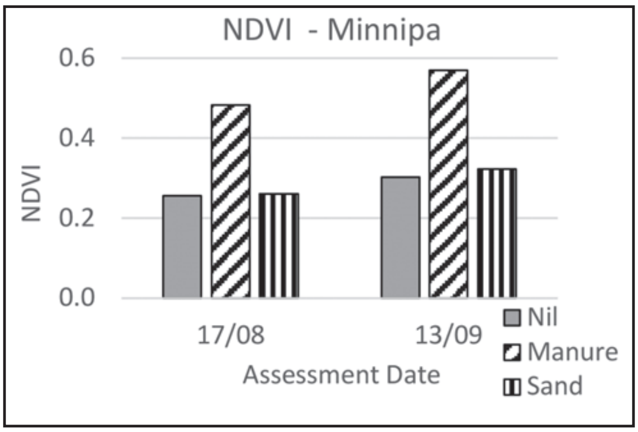


Figure 5. Minnipa NDVI on 17 August and 13 September 2022.

Despite poorer establishment on the sand treatment at Minnipa, by mid-August there was no difference in growth between the control (with 0.9 t/ha of dry matter) and the sand treatment, but the manure treatment showed improved growth (P = 0.021) with more than double the biomass of the control (2.0 t/ha) (Figure 4). This improved growth carried through into the spring biomass cut with no difference (P = 0.015) in dry matter on the sand treatment and 92% more dry matter on the manure treatment (5.0 t/ha) compared to the control (2.4 t/ha). NDVI values on these two assessment dates also reflected these improvements in crop growth on the manure treatments compared to the control (P = 0.0124 and P = 0.0005 respectively) (Figure 5).

The Buckleboo site was sprayed out ('brown manured') by the landholder on 10 September. Dry matter cuts were taken on 29 September to assess peak biomass. Results showed much higher biomass on the treated areas compared to the paired controls (Figure 6), with the scalded areas of the control strips averaging between 2.8 and 4.4 t/ha and the adjacent areas of the sand treatments averaging 7.0 to 10.3 t/ha of dry matter. The amount of dry matter on the double sown sand spread treatments (low and high rates) when the site was desiccated in spring was at least as good as the best areas of the untreated control (which had 9.1 t/ha dry matter).

Although unreplicated biomass cuts at Tumby Bay suggested higher biomass on the barley+vetch+tillage radish the landholder cut the demonstration site for hay before a measure of peak biomass could be taken.

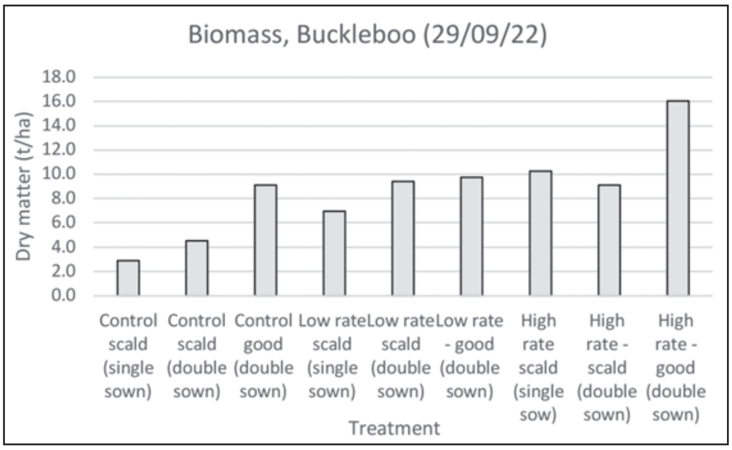


Figure 6. Peak dry matter (t/ha) at desiccation, Buckleboo, 29 September 2022.

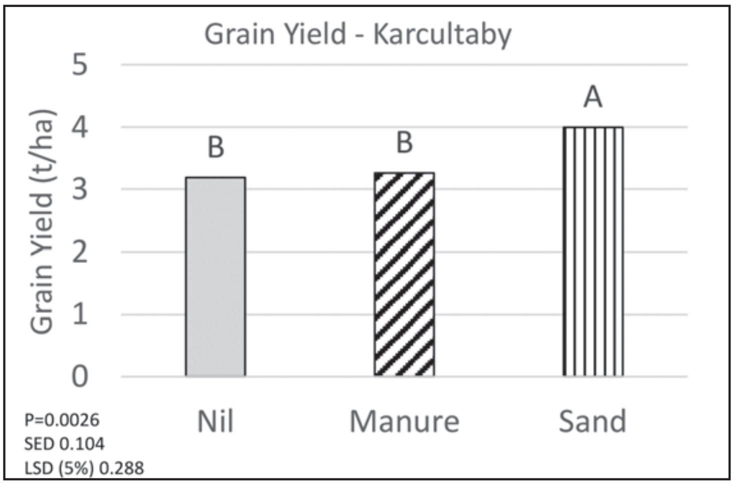


Figure 7. Barley grain yield (t/ha) at Karcultaby, December 2022. A different letter indicates a significant difference at P < 0.05.

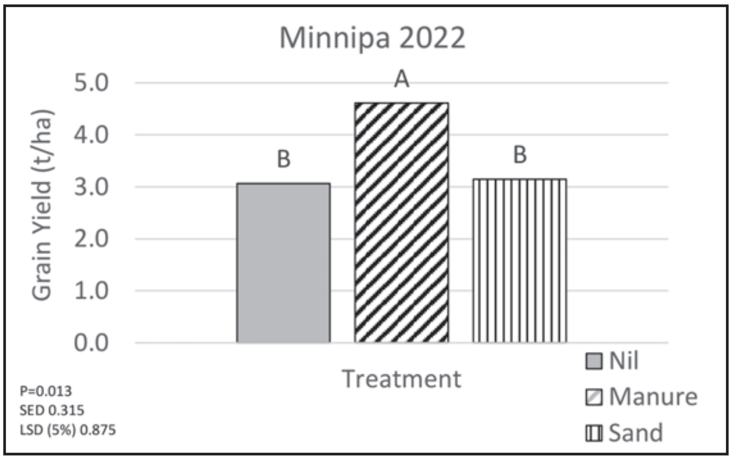


Figure 8. Wheat grain yield (t/ha) at Minnipa, December 2022. A different letter indicates a significant difference at P < 0.05.

Grain yields

The early growth improvements afforded by the manure treatment at Karcultaby compared to the nil control did not carry into improved grain yield, with the manure treatment yielding 3.3 t/ha and the control yielding 3.2 t/ha (Figure 7). However, the sand treatment continued to provide benefits and yielded 4.0 t/ha of grain.

The production trends observed in the crop establishment and biomass cuts at Minnipa carried through to grain yield with no difference in yield between the control (which yielded 3.1 t/ha) and sand treatment, whilst the manure treatment had a 50% yield improvement over the control (4.6 t/ha) (Figure 8).

What does this mean?

Despite little difference in growing season (April - November) rainfall compared to the long-term averages, January rainfall started the season with a full soil moisture profile which is likely to have washed salts deeper into the soil profile, facilitating better crop establishment compared to years which have a dry start. Field observations saw generally good crop establishment across the sites. Early observations indicate that the application of ameliorants, including sand and manures, have provided some benefit for improved plant establishment and growth in 2022. This is consistent with reports from landholders who have trialled the practices on their properties in recent years as well as results coming from demonstrations in other regions, including Yorke Peninsula and the Murray Mallee. Grain yields were exceptional at Karcultaby and Minnipa with even the controls yielding more than 3.0 t/ha. Both the manure and sand treatments at Karcultaby resulted in improved crop growth and yield. The manure treatment at Minnipa provided similar production benefits. Dry conditions in June and July checked growth on the scalded areas at Buckleboo, with well-established plants dying off, however this did not occur on the sand spread treatments.

The improved surface cover, if maintained by limiting grazing and soil disturbance, could reduce evaporation and the capillary rise of salts to the surface, which could provide production benefits over multiple years.

The poor performance of the sand spread treatment at Minnipa in 2022 is likely the result of the salt content of the spread material. This highlights the importance of understanding both the nature of the constrained soil profile as well as the ameliorant material to maximise the benefits from applied treatments. Organic amendments (e.g., feedlot manures, spoiled hay, or residues from chaff carts) can contain weed seeds and it is worth considering the risk of introducing new or potentially herbicide resistant weeds onto a site when considering using such amendments.

Whilst these results have shown some promise, there is still some unanswered questions about the rate of sand required to achieve economic yield benefits. At Buckleboo the double sown areas seemed to have improved surface cover and biomass compared to the single sown area, whilst at Tumby Bay the mixture of barley and vetch seemed to provide higher levels of ground cover. Both of these treatments warrant further investigation. Positive results from demonstrations using alternative species/varieties (i.e. safflower, Mulgara oats) to manage the dry saline patches in other regions could also provide management options for these soils on Eyre Peninsula. The sites which had ameliorants applied in 2022 will continue to be monitored, in conjunction with the establishment of new sites in 2023.

Acknowledgements

The project “Building resilience to drought with landscape scale remediation of saline land” has been funded through the Future Drought Fund’s Drought Resilient Soils and Landscapes grants program and is supported by the SA Drought Resilience and Adoption Hub. Mallee Sustainable Farming is the project lead, AIR EP is hosting the project on Eyre Peninsula, and on-ground activities and technical support are being delivered by the PIRSA/SARDI team. Activity ID: 4-H8FU6SC.

The authors would also like to thank the landholders involved in this project; Matthew and Amanda Cook, the staff at Minnipa Agricultural Centre, Tristan and Lisa Baldock and Mick McCallum as well as AIR EP for their support of these demonstrations.

P fertiliser banded at 20 cm no match for shallow P on a deep sand at Pinnaroo

Nigel Wilhelm[1,2] and Sean Mason[3]
[1]SARDI; [2]University of Adelaide; [3]Agronomy Solutions, Adelaide

Location
Pinnaroo, Upper SE of SA
Heath Nickolls & Family
Rainfall
Av. Annual: 339 mm
Av. GSR: 234 mm
2021 Total: 220 mm
2021 GSR: 146 mm
2022 Total: 519 mm
2022 GSR: 355 mm
Yield
Potential: Triticale - 6.9 t/ha (French/Schultz)
Actual: 4.0 t/ha in highest yielding treatment
Paddock history
2021: Barley
Pre 2021: out of production for and extended period
Soil type
Deep siliceous sand over clay
Soil test
Colwell P 3 mg/kg in top 10 cm
Colwell P <5 mg/kg below the top 10 cm
PBI, 6
pH 6.8 near the surface, approx 7 at depth
Plot size
25 m x 6 rows x 4 reps
Trial design
RCBD
Yield limiting factors
Very infertile soil

Key messages

- **Barley and triticale 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 2021.**
- **P applied in 2021 was poorly effective for triticale in 2022 regardless of application strategy.**

Why do the trial?

The aim of the trial reported here was to determine whether dual placement of shallow (10 cm) and deep (20 cm) banded P can improve crop yields of barley and triticale compared with shallow P placement alone. The benefits of P strategies in the year after application were also investigated.

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 (20-30 cm below the surface) with moisture present 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, so placing P deeper may be more effective than current strategies of in or around seed rows. 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 EPFS Summary 2020 and 2021 for a summary of a similar trial ("P fertiliser banded at 20 cm did not improve wheat performance compared to shallow P at Brinkworth in 2020") and for more details of the first year of this trial at Pinnaroo, respectively ("P fertiliser banded at 20 cm did not improve wheat performance compared to shallow P on a deep sand at Pinnaroo in 2021").

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 on 16 June 2021 with Spartacus CL barley and shallow P was applied during 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 press wheel 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, there was 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 dual P.

MAP was used as the source of shallow and deep P and N was adjusted in 2021 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/ha SOA 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.

In 2022, plots were re-seeded with Fusion triticale at 100 kg/ha on 17 May. No P was applied except in one treatment (had been a nil P in 2021) which received 256 kg MAP/ha (60 kg P/ha) banded under seed rows. All other plots received 56 kg/ha of banded urea to match the N applied with MAP in the fresh P treatment. Seeding passes placed seed adjacent to crop rows from 2021 and all plots received 4 L/ha of SE14 wetter in the seed rows.

Two weeks after seeding, 100 kg/ha of urea and 106 kg/ha of potassium sulphate were broadcast onto all plots. A further 80 kg/ha of urea was broadcast onto all plots eleven weeks after seeding.

Establishment, growth, grain yield and quality (still being processed) were assessed.

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

What happened?

Grain yields in 2021 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 improvement. Shallow P produced similar yields at much lower rates than deep P (Figure 1). Dual 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.

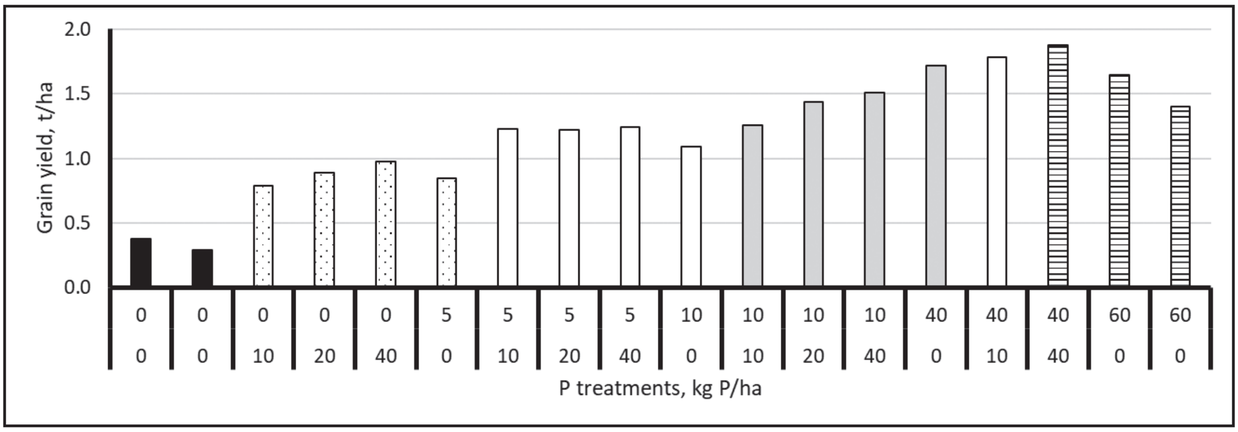


Figure 1. Effect of P rate and placement on grain yield of Spartacus CL barley at Pinnaroo in 2021. Note: Top figures on X-axis labels are shallow P, bottom figures are deep P (LSD, P=0.05: 0.2). First treatment is nil P and ripped, second treatment is nil P without ripping. Last bar is not ripped either. Patterns in bars represent different clusters of P treatments.

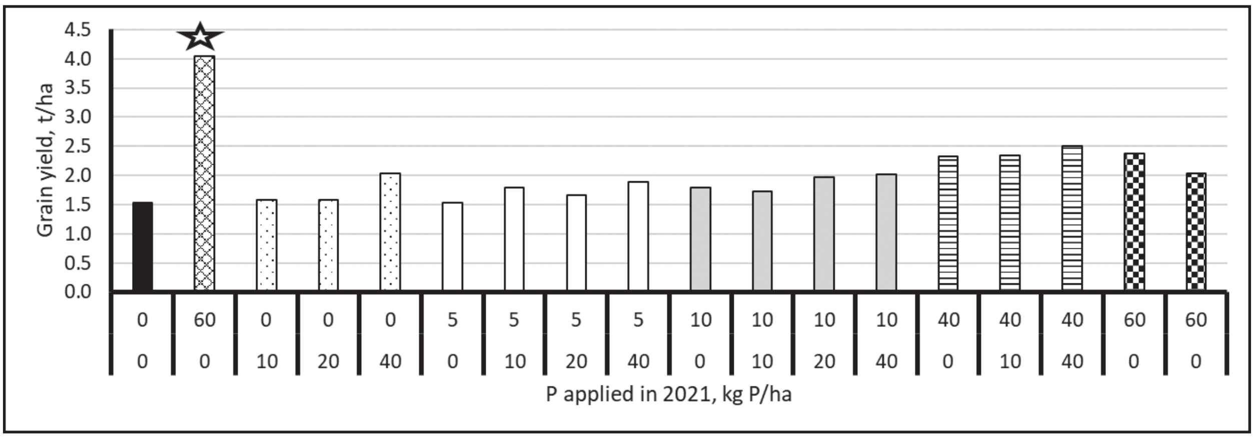


Figure 2. Effect of 2021 P rate and placement on grain yield of Fusion triticale at Pinnaroo in 2022. Note: Top figures on X-axis labels are shallow P, bottom figures are deep P (LSD, P=0.05: 0.2). The bar with the star is P applied in 2022 and the last bar was not ripped in 2021. Patterns in bars represent different clusters of P treatments.

Crop establishment in 2022 was unaffected by P rate or placement and averaged 190 plants/m^2 (data not shown).

Triticale responded very early to residual P on this very impoverished deep sand but the fresh application of P produced much superior growth to any other treatment. At flowering, fresh P (60 kg P/ha) resulted in 6.6 t/ha DM/ha while the next best treatment only produced 3.9 t/ha DM/ha (40/40 shallow/deep P). Without P, 2.1 t/ha DM/ha was produced by triticale. There was no evidence that deep P had superior residual benefits than shallow P.

All P strategies applied in 2021 were also poorly effective at producing triticale grain in 2022 (Figure 2). A high rate of shallow P resulted in 4 t/ha of grain yield in 2022, which was a much better growing season than 2021. With no P, yields were 1.5 t/ha while the best treatment of 2021 applied P only resulted in 2.5 t/ha of grain. Only the highest rates of P applied in 2021 caused any measurable increases on grain production of triticale in 2022. P placement had little impact on residual benefits to crop production.

At Brinkworth, it has not been possible to investigate the effectiveness of P strategies in the last two years because no responses in crop growth to P occurred in the lentils grown in 2021 or in the canola in 2022 (data not shown).

What does this mean?

The trends in crop performance so far across the whole project are that shallow P is more effective than, or equal to, dual P in the southern zone. Rarely has dual P been more effective than shallow P and it needs to be more effective given that it is more expensive and difficult to apply. The Pinnaroo site was chosen because dual P is more likely to be beneficial when topsoils are frequently dry and subsoils are wet. Modelling showed that a sandy soil in a medium rainfall area was a scenario where these two criteria could be met more often. Although the 2021 season was quite dry at Pinnaroo, and the 2022 season started reasonably dry, in both years dual P struggled to match the performance of shallow P. In 2021, better yields were attained with shallow P at the same rates as dual P so dual P caused a loss in revenue in that year.

The residual benefits of P applied in previous years to crop production has been very poor relative to freshly applied P regardless of application strategy in most trials and there has been very little evidence of deep P having superior residual benefits. What is clear from this trial is that any delay in P acquisition can cause a decrease in crop yields in a very P responsive situation.

The merits of continuing the existing trials into a further season will be discussed by the project team early in 2023.

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.

Soils

Closing the yield gap through better matching nitrogen supply to yield potential

Rebekah Fatchen, Jacob Giles and Andrew Ware

EPAG Research

Location
Cockaleechie
Rainfall
Av. Annual: 422 mm
Av. GSR: 341 mm
2022 Total: 596 mm
2022 GSR: 395 mm
Paddock History
2019: Wheat
2020: Canola
2019: Wheat

Location
Lock
Rainfall
Av. Annual: 387 mm
Av. GSR: 292 mm
2022 Total: 487 mm
2022 GSR: 292 mm
Paddock History
2019: Wheat
2020: Vetch
2019: Canola

Location
Minnipa
Rainfall
Av. Annual: 280 mm
Av. GSR: 223 mm
2022 Total: 487 mm
2022 GSR: 300 mm
Paddock History
2019: Lentils
2020: Wheat
2019: Canola

Key messages

- **The application of nitrogen (N) can play a critical role in attaining yield potential across all rainfall zones on the Eyre Peninsula, particularly in above average rainfall seasons. However, determining the quantity to add and where across a landscape with varying soil types can be difficult.**
- **Utilising pre-seeding soil tests, understanding the productive capacity of varying soil types and improved knowledge of N mineralization rates can result in nitrogen applications being better tailored to soil type and environment.**
- **Optimising N applications across variable soil types can increase yields and/or save inputs and increase margins.**
- **Starting N levels will heavily influence response to N. Knowledge of this should influence decision making.**

Why do the trial?

'Yield gap' is the difference between actual achieved crop yield and true potential yield (limited by rainfall and other environmental conditions). While many factors contribute to the yield gap, the largest contributor across all Australian rainfall zones is nitrogen deficiency (Hunt *et al*., 2021). Sub-optimal nitrogen use can contribute up to 60% lower yields than the true potential (Hochman *et al.*, 2018).

The well above average summer rainfall that fell between crop maturity 2021 and early 2022, coupled with effective summer weed control programs, saw many paddocks across the Eyre Peninsula commence the 2022 growing season with near full soil moisture profiles. Understanding how this stored water can translate into increased yield required understanding of soil characteristics, nitrogen levels and plant demand.

Getting the balance between application of nitrogen to capitalise on opportunity, but not over-spending when the result is far from assured, is incredibly difficult. The question then arose of how to increase confidence in nitrogen decisions, bring the yield gap closer, all the while taking economics into consideration? Trials were set up with the aim of reducing the gap between potential and realised yield through increased knowledge of soil water holding characteristics, starting nitrogen levels, and more informed knowledge of nitrogen mineralisation rates.

How was it done?

Three trial sites were chosen, each with duplicated trials in areas in the paddock that had historically performed better and poorer. Minnipa, Lock and Cockaleechie were chosen to represent the varying rainfall and production systems across the Eyre Peninsula. Better and poorer areas were chosen based on previous yield data and soil type, indicating consistency in high or low historical yields.

Trials were complete randomised block designs with four replicates. An additional two rows or eight plots were planted for deep soil N monitoring throughout the season, which were not harvested for yield due to the destructive manner of sampling.

Minnipa

The Minnipa site had a 1 t/ha canola stubble, on a sandy loam soil type. The good site was a consistently high performing area of the paddock, a well-draining soil which holds and responds to moisture and nitrogen well, resulting in high yields. The poor site also had high starting nitrogen and moisture down the soil profile, yet this was not accessible to the crop as boron levels became toxic around 60 cm, confirmed by soil characterisations at the start of the season.

Lock

The Lock trial was sown into a 1.5 t/ha canola stubble on a sandy loam. Areas of lower productivity usually correlated with shallow rock. The good trial site was a sandy loam over sandy clay loam, historically a highly productive part of the paddock. The poor site was a clay loam, in a rocky area, with a hard limestone layer at 40-50 cm. Highly calcareous shale/sand continued at depth.

Cockaleechie

The Cockaleechie good site soil type was clay loam over medium clay on a 6 t/ha wheat stubble. The trial in the high yielding zone at Cockaleechie was different to the Lock and Minnipa sites. This trial was a bigger trial, part of a BCG (Birchip Cropping Group) N Banking project. The ideas of targeting yield and inputs based on projected rainfall and deep N testing were the same between trials, with a slightly different layout. The Cockaleechie poor site was a sandy loam over clay.

Plots were all sown with Scepter wheat. Minnipa, Lock and Cockaleechie were sown on 10, 11 and 12 May respectively. Herbicide, fungicide and insecticide were applied as per district practice. All nitrogen was applied as top-dressed urea, hand spread. All plots received 14 kg/ha of nitrogen at sowing. The remaining nitrogen was applied on 17 June for Minnipa and Lock, then 27 June for Cockaleechie. The late application treatments were applied on 22 and 23 August. Biomass cuts of all treatments were taken at flowering as an indicator of N response.

Deep N samples were taken over the season to monitor nitrogen use and mineralisation. Pre-seeding, multiple in season and harvest cores were taken at all sites to monitor N. These plots only received 14 kg N at seeding.

Start of seeding plant available soil moisture levels were used in combination with historical rainfall to make approximate yield targets. From this target nitrogen requirements were calculated, using the rule of thumb of 40 kg/ha N per 1 tonne of wheat yield. Mineralisation estimates and starting soil nitrogen (0-60 cm) were taken from this number to quantify the remaining nitrogen requirement to reach the desired yield target.

Treatments

Each trial had eight N rate treatments. The goal of treatments was to match nitrogen application to a range of predicted yields, where historical rainfall deciles were used to create a range of yield potentials to be trialled.

Yield Target Example

Starting N = 40 kg/ha Average GSR rainfall = 300 mm

Stored moisture = 60 mm
Evaporation = 80 mm

Mineralisation = 50 kg/ha N
WUE = 20 kg/mm/ha

Yield = mm water evaporation*WUE (kg/mm/ha)

In this instance:

Yield = (stored moisture (60) + GSR rainfall (300)) - (evaporation (80))*WUE (20)

Yield = (360-80)*20

Yield = 5.6 t/ha

If the grower requires 40 kg available N in the soil per tonne of grain to be produced the N required is 5.6*40 = 224 kg/ha.

The quantity of N mineralised in the soil, through the breakdown of organic matter, can play a large role in-season supply of N. There are several rules of thumb to determine how much N may be mineralised. In this case we allowed for mineralisation of 50 kg/ha and starting soil N of 40 kg/ha.

This leaves an additional N required = 224 – (50+40) = 134 kg/ha.

When calculated this way, we will need an extra 134 kg N/ha added to the system to achieve the yield potential of this crop in an average season.

What happened?

Cockaleechie

Starting soil mineral N levels in the good site were almost double those in the poor site at Cockaleechie, with the poor site virtually exhausting all mineral N by the end of the season (Figure 1).

Figure 2 demonstrates the increase in net margin (calculated in Tables 1 and 2) on a responsive soil type in a water unlimited year at Cockaleechie. The poor site shows a small initial response to lower rates of N and profit, after which profit plateaus and gradually declines. The good site was highly responsive and profitable with added N.

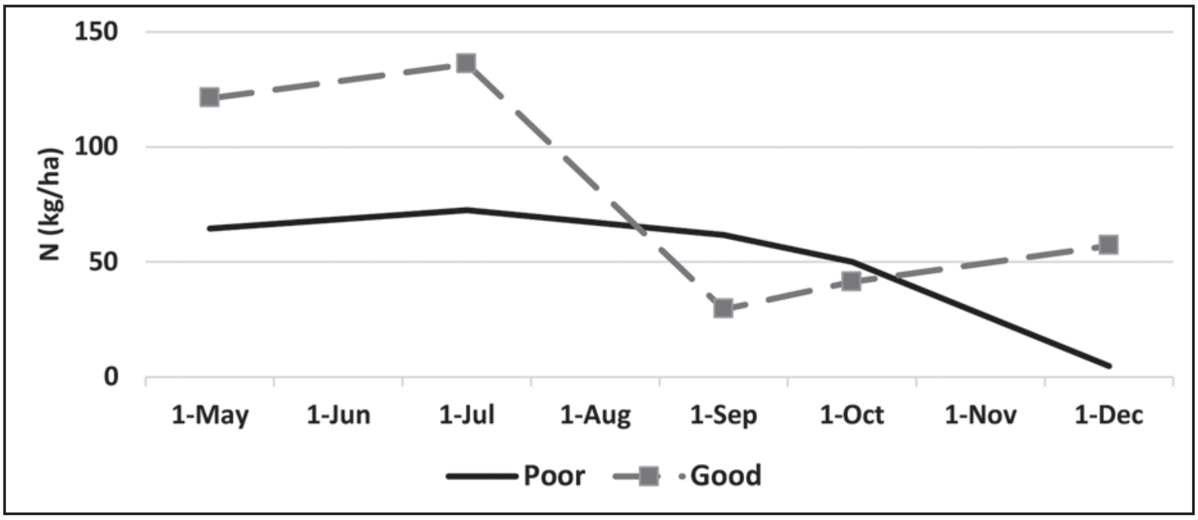


Figure 1. Soil mineral N levels (0-60 cm) at Cockaleechie over the 2022 growing season with no additional N after 14 kg/ha applied at seeding.

Table 1. Cockaleechie poor site biomass, grain yield, grain quality and partial net margins in 2022.

Treatment	N applied (kg/ha)	Biomass (t/ha)	Heads/m²	Yield (t/ha)	Protein (%)	Partial net margin ($/ha)
Late N	109	6.09	289	4.85	10.1	1414
50	23	6.73	356	4.04	9.5	1379
Decile 1	34	6.55	302	4.36	9.2	1463
100	46	7.38	380	4.66	9.3	1538
Decile 3	69	6.98	387	4.81	9.5	1515
200	92	8.29	365	4.97	9.5	1509
Decile 5	109	7.02	377	4.93	9.5	1437
Decile 7	163	8.81	433	5.23	9.7	1383
LSD (P=0.05)		*1.2*	*98*	*0.32*	*0.2*	

Table 2. Cockaleechie good site biomass, grain yield, grain quality and partial net margins in 2022.

Treatment	N applied (kg/ha)	Biomass (t/ha)	Heads/m²	Yield (t/ha)	Protein (%)	Partial net margin ($/ha)
Control	0	15.9	349	3.3	9.6	1199
Conservative	14	15.5	344	3.4	10.3	1210
Optimum profit	39	18.9	395	4.3	10.4	1538
Optimum yield	63	17.8	364	4.0	10.8	1596
Decile 1	70	17.0	361	4.6	10.6	1812
Decile 2-3	110	18.5	404	4.5	11.4	1786
District practice	136	18.2	380	5.1	11.4	2026
Decile 5	159	18.8	353	4.9	11.9	2076
YP BOM	215	17.6	382	5.2	11.8	2195
Decile 7-8	215	17.6	365	5.2	11.8	2190
LSD (P=0.05)				*0.78*	*0.6*	

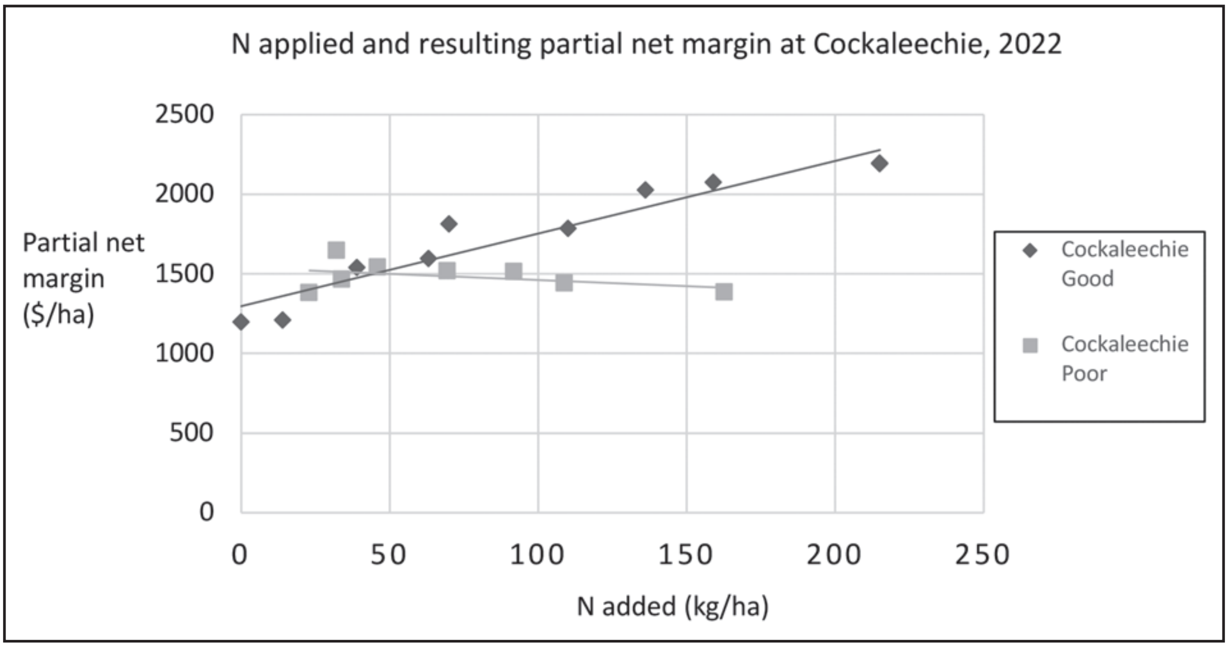


Figure 2. N applied and resulting partial net margin on good and poor areas at Cockaleechie in 2022. Net margins calculated as per Table 1 and Table 2.

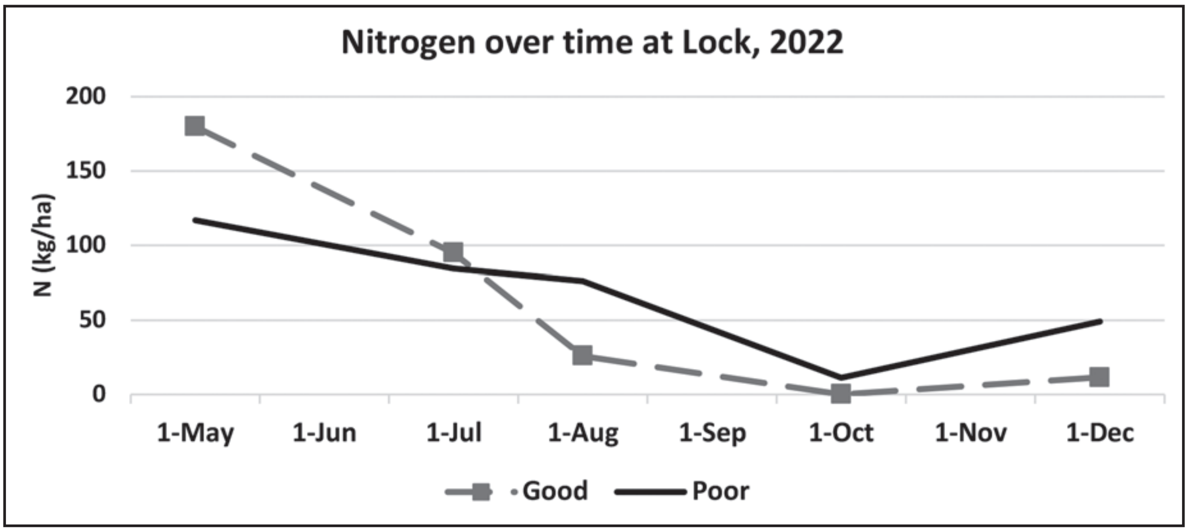


Figure 3. Soil mineral N levels (0-60 cm) at Lock over the 2022 growing season with no additional N after 14 kg/ha applied at seeding.

Lock

There were high starting N levels across both sites at Lock in 2022 (Figure 3). High N use by the crop shown by the large draw down on N during the growing season. While both sites are driven low throughout the growing season, mineralisation is demonstrated with an increase in soil mineral N immediately post crop maturation.

The Lock poor trial displayed an improvement in yield to the addition of N, however the 'good' trial did not (Tables 3 and 4). The primary reason for this is high starting N levels (Figure 3). The Lock good site yielded approximately 6.5 t/ha and the required N to achieve this at 40 kg/t is 260 kg/ha. Taking starting N of 180 kg/ha and 14 kg/ha added at seeding, plus modelled mineralisation of only 44 kg/ha leaves a deficit of 22 kg/ha. This should leave space for yield response and/or protein when additional N is applied. At 6.5 t/ha of yield, other yield constraints come into question such as crop density, other nutrition limitations and water stress. Further research would be required to confirm this.

The trial at Lock demonstrated the importance of understanding starting N levels. However, given the circumstances in 2022, that being high prices and a significant price jump between protein grades, it also demonstrated the value in acquiring marginally more yield or protein. This may not be the case in all seasons.

Table 3. Lock poor site biomass, grain yield, grain quality and partial net margins in 2022.

Treatment	N applied (kg/ha)	Biomass (t/ha)	Heads/m²	Yield (t/ha)	Protein (%)	Partial net margin ($/ha)
Late N	32	7.0	271	4.06	9.8	1361
Decile 1	0	7.5	275	3.82	9.6	1365
Decile 3	5	6.9	281	4.13	9.4	1463
50	23	7.6	323	4.05	9.7	1383
Decile 5	32	8.6	300	4.33	9.6	1458
100	46	7.4	309	4.20	9.3	1372
Decile 7	64	8.2	312	4.69	9.5	1488
200	92	10.1	351	4.74	10.1	1426
LSD (P=0.05)		*0.87*	*ns*	*0.17*	*ns*	

Table 4. Lock good site biomass, grain yield, grain quality and partial net margins in 2022.

Treatment	N applied (kg/ha)	Biomass (t/ha)	Heads/m²	Yield (t/ha)	Protein (%)	Partial net margin ($/ha)
Late N	26	17.0	360	6.45	10.3	2239
Decile 1	0	16.9	366	6.43	10.0	2305
Decile 3	5	16.6	375	6.54	10.0	2331
50	23	17.6	397	6.47	10.2	2254
Decile 5	26	16.9	420	6.44	10.0	2236
100	46	17.4	396	6.56	10.0	2222
Decile 7	77	17.2	425	6.63	10.4	2148
200	92	17.7	400	6.74	10.5	2416
LSD (P=0.05)		*ns*	*ns*	*ns*	*ns*	

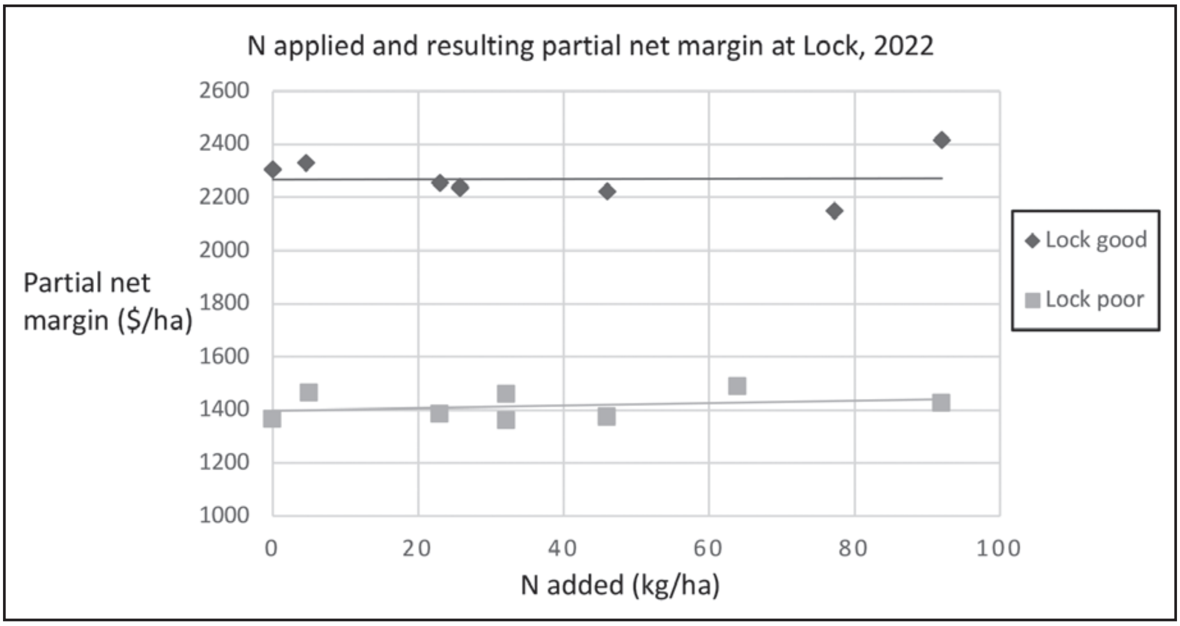


Figure 4. Nitrogen applied to good and poor sites and resulting partial net margins at Lock in 2022.

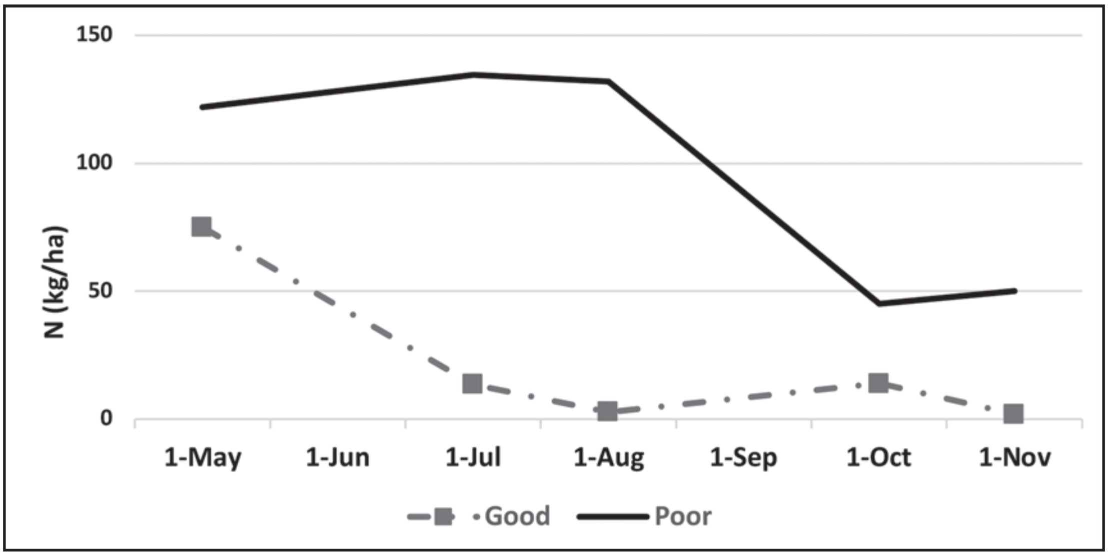


Figure 5. Soil mineral N levels (0-60 cm) at Minnipa over the 2022 growing season with no additional N after 14 kg/ha applied at seeding.

Table 5. Minnipa poor site biomass, grain yield, grain quality and partial net margins in 2022.

Treatment	N applied (kg/ha)	Biomass (t/ha)	Heads/m²	Yield (t/ha)	Protein (%)	Partial net margin ($/ha)
Late N	32	10.0	233	4.17	11.5	1692
Decile 1	0	10.7	169	4.26	11.2	1694
Decile 3	5	9.7	228	4.27	11.2	1684
50	23	12.1	242	4.26	11.1	1629
Decile 5	32	10.0	234	4.34	11.4	1635
100	46	10.1	229	4.35	11.2	1600
Decile 7	64	10.3	239	4.43	11.3	1571
200	92	9.5	234	4.41	11.4	1484
LSD (P=0.05)		*ns*	*ns*	*ns*	*ns*	

Table 6. Minnipa good site biomass, grain yield, grain quality and partial net margins in 2022.

Treatment	N applied (kg/ha)	Biomass (t/ha)	Heads/m²	Yield (t/ha)	Protein (%)	Partial net margin ($/ha)
Late N	76	12.5	273	4.37	11.9	1643
Decile 1	0	9.2	214	3.77	10.3	1347
50	23	11.2	229	4.25	10.0	1455
100	46	11.9	246	4.71	10.1	1556
Decile 3	49	12.7	298	4.67	10.2	1522
Decile 5	76	13.2	299	4.97	10.5	1553
200	92	12.0	296	4.70	10.7	1600
Decile 7	108	13.1	302	5.05	10.5	1685
LSD (P=0.05)		*1.12*	*68*	*0.43*	*0.4*	

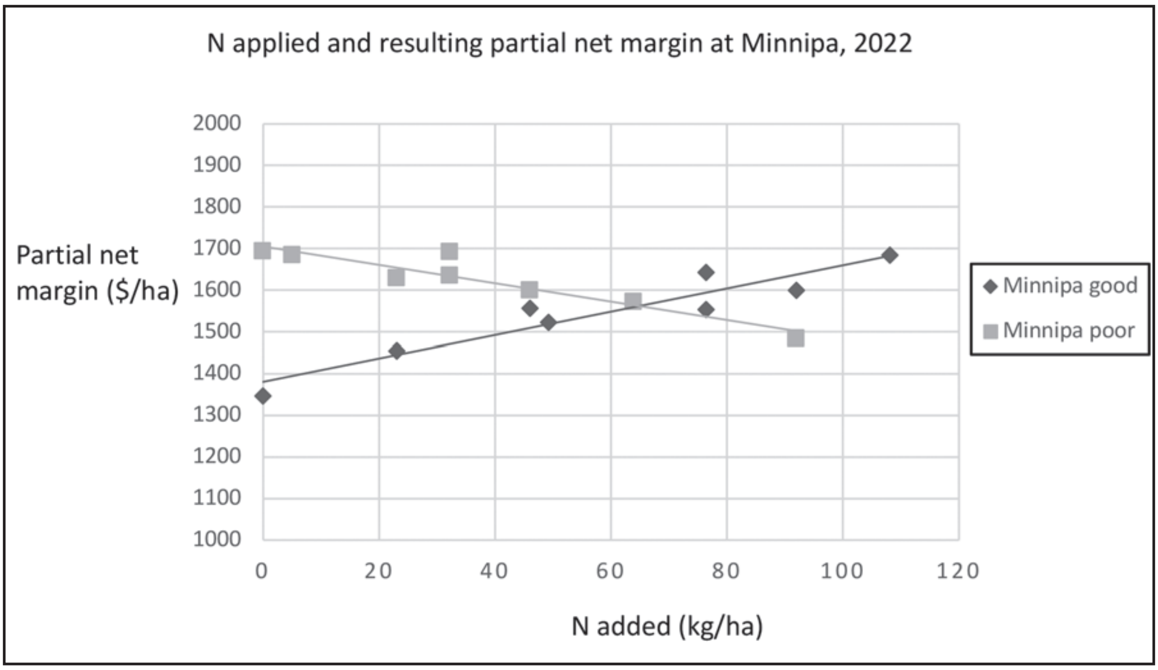


Figure 6. Nitrogen applied to good and poor sites and resulting partial net margins at Minnipa in 2022.

Minnipa

The Minnipa site responded in a similar fashion to Cockaleechie. The good site displayed an increase in partial net margin driven by significant yield and protein responses (Tables 5 and 6). The high starting N at the Minnipa poor site saw no significant response to yield and protein (Figure 5). In turn the money spent on inputs detracted from the partial net margin and resulted in a decline in partial net margins as inputs increased at the poor site (Figure 6).

What does this mean?

Pre-seeding soil testing and historical yield performance helped inform the estimated response to N application in 2022, rather than N application being a guaranteed return, across the board, in a season with high levels of stored soil moisture and above average growing season rainfall. By understanding how much N and plant available water was present in different production zones, forecast yields and N budgets were able to be generated and N responses better predicted.

References

Hunt, J., Kirkegaard, J., Maddern, K., Murray, J (2021), Strategies for long term management of N across farming systems, La Trobe University, National Landcare Program.

Hochman & Horan (2018), Causes of wheat yield gaps and opportunities to advance the water-limited yield frontier in Australia, Field Crops Research 228 (20-30).

Hunt, Kirkegaard, Maddern, Murray (2021) Strategies for long term management of N across farming systems, GRDC Update Papers.

Acknowledgements

Funding through the Australian Government's National Landcare Program Smart Farming Partnership. 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 growers and their families that 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. Also to the BCG (Birchip Cropping Group) N Banking project and the SAGIT funded EP grains research intern program.

EPAG RESEARCH

AIR EP Ag Innovation & Research Eyre Peninsula

Australian Government | National Landcare Programme

SAGIT

Resilient EP For a profitable farming future

Improving soil pH and crop production through the application of surface and subsurface applications of lime to treat acid soils at Brooker

Brett Masters, Andrew Harding and Brian Hughes
SARDI

Location
Brooker
Neil & Leah, Casey & Kathryn Carr
Rainfall
Av. Annual: 398 mm
Av. GSR: 314 mm
2022 Total: 552 mm
2022 GSR: 365 mm
Paddock History
2022: Scope CL barley
2021: Yitpi wheat
2020: Cobra wheat
2019: 44Y90 Canola
Soil type
Shallow loamy sand on clay
Plot size
24 m x 4 m 4 reps
Trial design
RCBD
Yield limiting factors
Very high ryegrass infestation
Moderate nitrogen deficiency throughout winter
Temporal waterlogging for extended periods throughout winter.

Key messages

- **In 2022, several lime treatments (3 t/ha and 6 t/ha surface and 6 t/ha incorporated lime) applied in 2020, improved barley grain yields by around 1 t/ha compared to untreated controls.**
- **With the high grain prices this is quite substantial across the whole farm.**
- **There was up to a 1.7 t/ha yield penalty from the sulphur treatment indicating the potential impact of further acidification on yield on Lower Eyre Peninsula soils if left untreated.**

Why do the trial?

There are around 186,000 ha (7%) of Eyre Peninsula's agricultural land which has surface soil acidity (0-10 cm depth). Although soil acidification is a natural process, acidification rates are accelerated by high rates of ammonium-based nitrogen fertilisers, and removal of agricultural products, particularly on low buffering (sandy) soils in high production systems in high rainfall environments. If not treated with lime a further 500,000 ha (19%) is at risk of becoming acidic over the next 10 to 50 years, leading to loss of production, reduced soil biological activity, reduced crop fertiliser use efficiency and increased soil acidification (Forward and Hughes, 2019).

Previous work has shown that the application of lime to acid soils in South Australia can result in improved crop and pasture production, particularly of acid-sensitive crop species such as lentils, chickpeas, and beans.

Recent trials on Eyre Peninsula have not always shown improvements in grain yield compared to the untreated control (EPFS Summary 2018, p. 141-145). A 5-year trial (funded by GRDC project DAW00252 'Innovative approaches to managing subsoil acidity in the Western Region' at Koppio showed that, whilst surface liming (at 5 t/ha) effectively increased topsoil pH compared to the control and combining this surface application with ripping and subsurface placement of lime also improved subsoil pH, grain yields were not consistently improved by the treatments (Guidera and Masters, 2022).

It is suggested that because this trial was sown with the same variety as that grown by the landholder on the remainder of the paddock, with many of the varieties which perform well on lower Eyre Peninsula having some acid tolerance, this acidity tolerance is masking some of the potential impact of soil acidification on crop production on the lower Eyre Peninsula. However, yield penalties observed on sulphur treated plots (applied at a rate to approximate surface acidification over a 10 year period), might warn of some of these potential impacts if left untreated. In addition, around 4% of EP agricultural land is considered to have acidic subsurface layers (Forward and Hughes 2019). If surface soil acidity is not treated by applying adequate amounts of lime, it will result in the progressive acidification of subsurface and subsoil layers (pH stratification), which is much more difficult and costly to treat.

This trial, funded under the GRDC's SA soil acidity program aims to improve soil pH and crop production through the application of surface and incorporated lime.

Table 1. pH of surface and subsurface layers on control plot.

Soil Depth (cm)	pH (Water)	pH ($CaCl_2$)
0-5	5.0	4.5
5-10	5.1	4.4
10-15	5.8	4.9
15-20	7.4	6.4
20-30	8.1	7.0

Table 2. List of treatments.

Treatment	Label
1. Untreated control	CONT1
2. Spare control	CONT2
3. Surface lime @ 3 t/ha	SURF_LIME3
4. Surface lime @ 6 t/ha	SURF_LIME6
5. Soil mixing to 15 cm	NIL MIX
6. Sulphur (10-year acidification equiv) mixed to 15 cm	SULF1 MIX
7. Lime @ 1 t/ha mixed to 15 cm	LIME1_MIX
8. Lime @ 3 t/ha mixed to 15 cm	LIME3_MIX
9. Lime @ 6 t/ha mixed to 15 cm	LIME6_MIX

How was it done?

The trial was established on a shallow acidic loamy sand over clay flat at Brooker on the lower Eyre Peninsula in May 2020. Heavy infestations of ryegrass have been an on-going issue for the landholder at the site.

Soil testing showed that the soil pH (0-10 cm) was well below the target level of 5.5 ($CaCl_2$) and the sub-surface layers (10-15 cm) were also acidic (Table 1). The soil from 15 cm is neutral to alkaline with increasing carbonate at depth.

A randomised complete block small plot trial (24 x 4 m) was designed consisting of 9 treatments including lime applications at 0, 3 and 6 t/ha with and without mixing to 15 cm, and a sulphur treatment (mixed) to simulate the effect of a further 10 years of soil acidification if not treated with lime (Table 2). Treatments were based on soil test results and were replicated four times.

Treatments were applied in 2020 at the commencement of the trial. Lime and sulphur treatments were spread by hand on 13 April 2020 with subsurface mixing undertaken the following day. Subsurface mixing was achieved using the landholder's cultivator with sweeps, which mixed the soil to ~15 cm, rather than deep ripping. This was done to avoid introducing anomalies such as highly sodic or calcareous subsoil material. The 3 t/ha lime rate aimed to increase pH at the surface (0-10 cm) above the critical value of 5.5 $CaCl_2$, with a double (6 t/ha) rate used to see if it provided a faster/larger pH and crop response or moved deeper into the soil. An additional 1 t/ha lime mixed treatment was also added as mixing would distribute the lime deeper in the profile also affecting change in the subsurface layer.

Crop establishment counts were taken on all plots 4-6 weeks after seeding and dry matter cuts were taken as a measure of peak biomass at flowering. These measurements were taken from either side of a 50 cm ruler at 4 locations per plot and extrapolated to plant density (plants/m^2) and dry matter (t/ha) respectively. The trial was harvested using the SARDI small plot harvester in all years (2020, 2021 and 2022) with plot yields extrapolated to t/ha. Data was analysed using standard ANOVA models in Statistix 8.

What happened?
2020 and 2021 results

In 2020, the trial was sown to Cobra wheat and managed by the landholder as per the rest of the paddock. There was little difference in production between treatments. It is unusual to see lime responses in the year of application. Given concerns that varietal tolerance to soil acidity in commonly grown wheat varieties, including Cobra, might be masking the potential yield impacts of current and future soil pH if acidification is allowed to continue, the site was sown with Yitpi wheat using the SARDI plot seeder in 2021. Yitpi wheat has some acid sensitivity and provided an opportunity to observe production response to liming treatments on acid sensitive varieties.

There were no differences in crop establishment between treatments (P = 0.76), and no differences between treatments in measurements of winter crop NDVI (P = 0.18) or spring biomass (P = 0.25) (Guidera and Masters, 2022). Significant ryegrass infestation on the site resulted in severe competition with crop throughout the season, which is likely to have reduced confidence in production data for this season. The trial was harvested using the SARDI small plot header. The sulphur treatment yielded less than the 6 t/ha rate of lime (either surface applied or mixed), however no treatments yielded significantly higher or lower than the control.

2022 Results

Intense storm activity in late January 2022 brought around 100 mm of rainfall to the district within 24 hours, resulting in high stored subsoil moisture levels. Given the issues with ryegrass in previous seasons it was decided to sow the site to Scope CL barley (providing an acid sensitive control and in-crop herbicide options). The site was sprayed with a knockdown including Clearfield chemistry and sown with the SARDI plot seeder on 24 May 2022. In June and July there was a dry period, however this was followed by above average rainfall in late winter and early spring that resulted in soils being saturated for an extended period. A post sowing pre-emergent spray was also applied to control emerging ryegrass in crop.

Crop establishment, early growth, and plant tissue analysis

Plant density was evaluated on 14 June when the crop was at 2-3 leaf stage. Emergence was uniform with no difference (P =0.75) in plant numbers between treatments and the controls (which averaged 108 plant/m^2). The crop showed symptoms of moderate to severe nitrogen deficiency in early July, however waterlogged soils made site trafficability difficult and additional nitrogen was not applied until after plant tissue samples were taken on 9 August.

Plant tissue concentrations of nitrogen at the time of sampling (i.e., prior to urea application) were low (<3.5%) across all treatments and although statistically significant (P=0.05), except for where 6 t/ha lime was mixed into the subsurface no treatments had higher N concentrations than the control (which had leaf tissue N of 2.4%).

The control plots had higher (P=0.007) leaf concentrations of phosphorus (P) than where sulphur had been applied. There was no difference in P between other treatments compared to the control (which had 0.26% P). Whilst all limed treatments had higher levels of potassium (K) than the sulphur treatment (P=0.04), LSDs were small (0.31%) and there was no difference between the control and sulphur plots, or control and other treatments.

As expected, concentrations of sulphur in the plant tissue were much higher (P=0.008) on the mixed sulphur treatment, but there was no difference in sulphur concentrations between the controls and other treatments.

Higher concentrations (P=0.002) of aluminium (Al) were also recorded where sulphur was applied (17%) compared to the control (13.6%). This is expected as Al is found in forms which are more easily taken up by sensitive plants as pH decreases. Apart from a reduction in Al on the 3 t/ha lime mixed treatments there was no difference between the concentration of aluminium in the control compared to other treatments. Although having lower Al than the control, the concentration of Al in the 3 t/ha lime mixed treatment was not different to the other treatments. Again, this highlights the solubility of aluminium under very low pH and the need to maintain pH above the critical value of 5.0 ($CaCl_2$).

Leaf tissue concentrations of copper (CU) and zinc (Zn) did not differ between treatments. Iron levels were higher (P=0.007) in treatments where lime was applied at 3 t/ha or more than in sulphur treatment (Figure 1). The 6 t/ha lime mixed rate also had higher leaf iron (Fe) than the control.

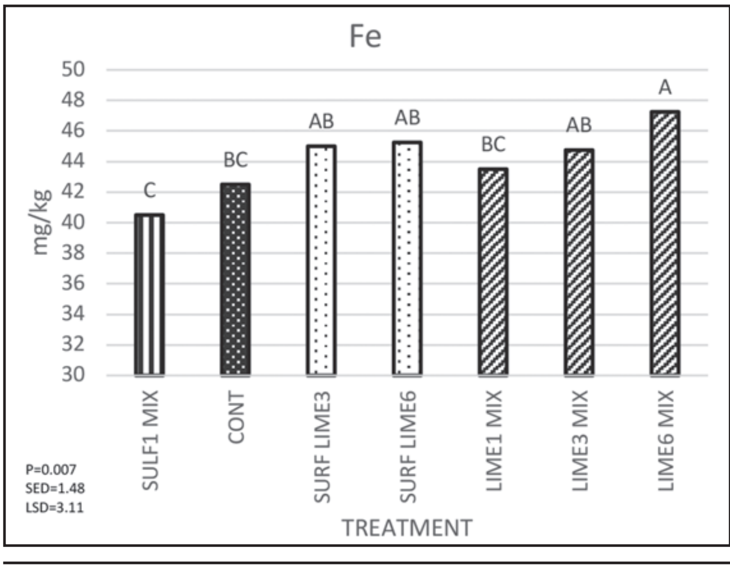


Figure 1. Leaf tissue iron (Fe) at mid to late tillering on barley at Brooker. A different letter indicates a significant difference at P<0.05.

Soils

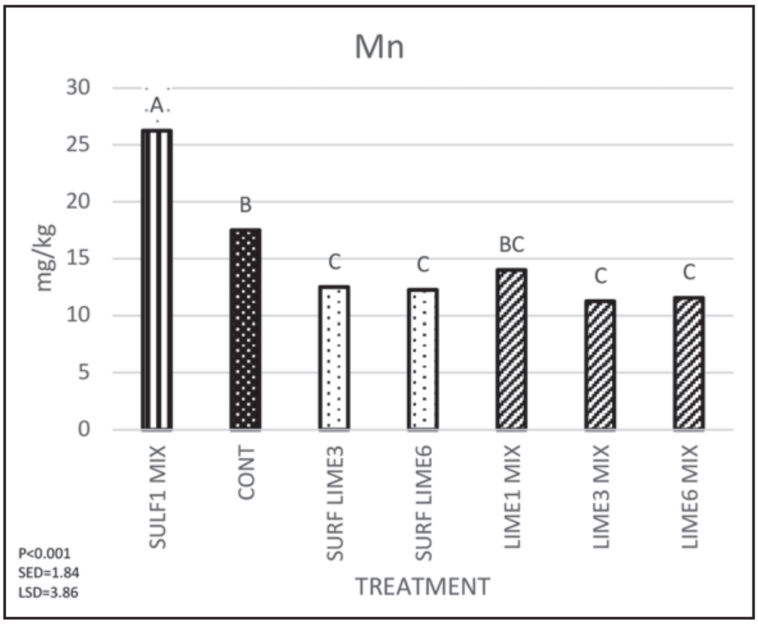


Figure 2. Leaf tissue manganese (Mn) at mid to late tillering on barley at Brooker. A different letter indicates a significant difference at P<0.05.

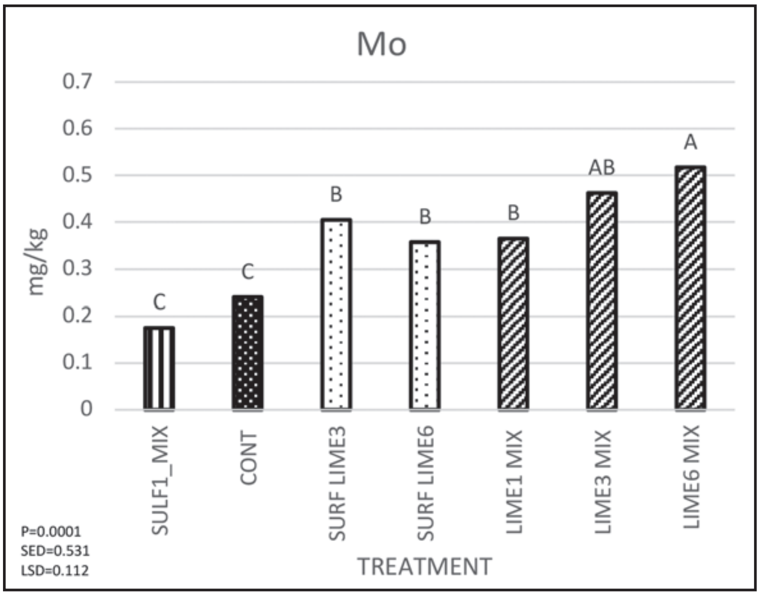


Figure 3. Leaf tissue molybdenum (Mo) at mid to late tillering on barley at Brooker. A different letter indicates a significant difference at P<0.05.

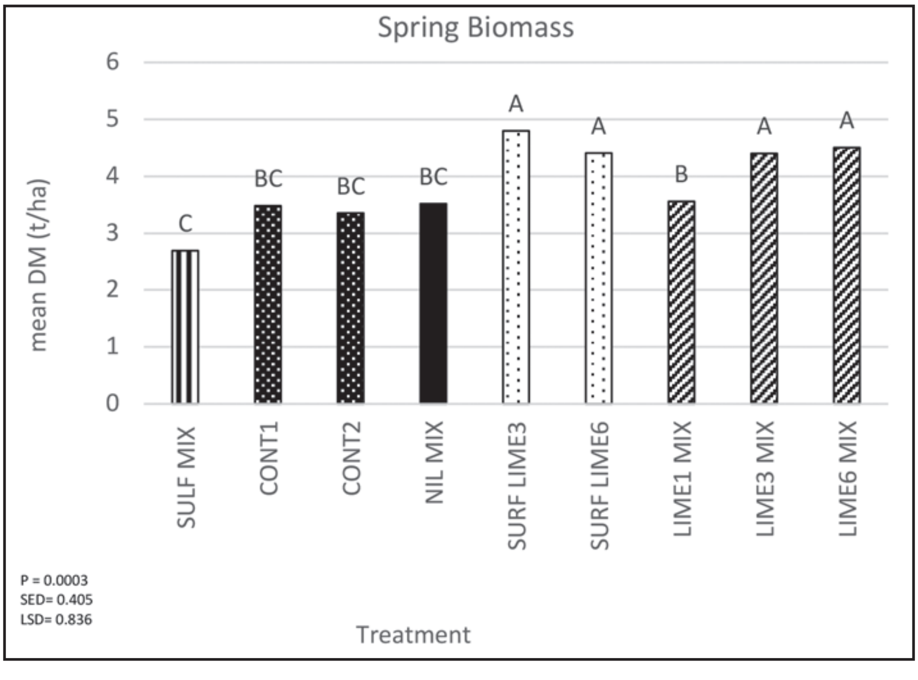


Figure 4. Barley dry matter (t/ha) at Brooker, September 2022. A different letter indicates a significant difference at P<0.05.

Manganese (Mn) was lower (p≤0.001) on treatments where higher lime rates were applied compared to control plots (which had mean leaf tissue concentrations of 17.5 mg/kg) or plots where a very low rate of lime or sulphur was mixed into the subsurface (Figure 1). This is expected and serves as a caution that where high rates of lime are applied, and soil manganese is low, fertiliser Mn applications might be required to compensate.

Plots where lime was applied had higher (P < 0.001) tissue concentrations of Molybdenum (Mo) (ranging from 0.36 to 0.52 mg/kg) than controls or sulphur treatments (at 0.24 and 0.18 mg/kg respectively) (Figure 3). The 6 t/ha lime mixed treatment had higher leaf Mo than surface lime plots or those where 1 t/ha lime was mixed into the subsurface.

Spring Biomass Production

NDVI assessments were scheduled for mid-August. However, high ryegrass numbers in plots would have impeded NDVI interpretation so biomass cuts at head emergence were taken as a measure of crop growth instead. Drier periods in early spring reduced the impact of waterlogging and the crop responded to the nitrogen application with improved colour and vigour. Dry matter cuts to assess spring biomass were taken on 20 September, with 4 cuts along either side of a 0.5 m ruler taken per plot. Given the high levels of ryegrass within plots, care was taken when cutting to remove and discard any ryegrass from the sample. Samples were oven dried and dry weights extrapolated to dry matter (t/ha) (Figure 4).

Spring biomass production in 2022 was higher (P=0.0003) on all treatments where lime was applied at rates of 3 and 6 t/ha (ranging from 4.4 to 4.8 t/ha) than on unlimed treatments (which had <3.6 t/ha of dry matter). This response was not dependent upon whether the lime was surface applied or mixed to 15 cm. Biomass was higher than the sulphur treatment where a light rate (1 t/h) lime was mixed. However, this treatment and the mixing only treatment did not result in high biomass than the control (which averaged 3.6 t/ha of dry matter). This again reflects the potential long-term impacts of soil acidification if left untreated.

Grain Yields

The trial was harvested by SARDI using a small plot harvester on 16 December. Plots yields were extrapolated to grain yield (t/ha). Grain yield was increased (P<0.05) by surface liming (3 and 6 t/ha) or 6 t/ha lime mixed, compared to unlimed or sulphur treatments (Figure 5).

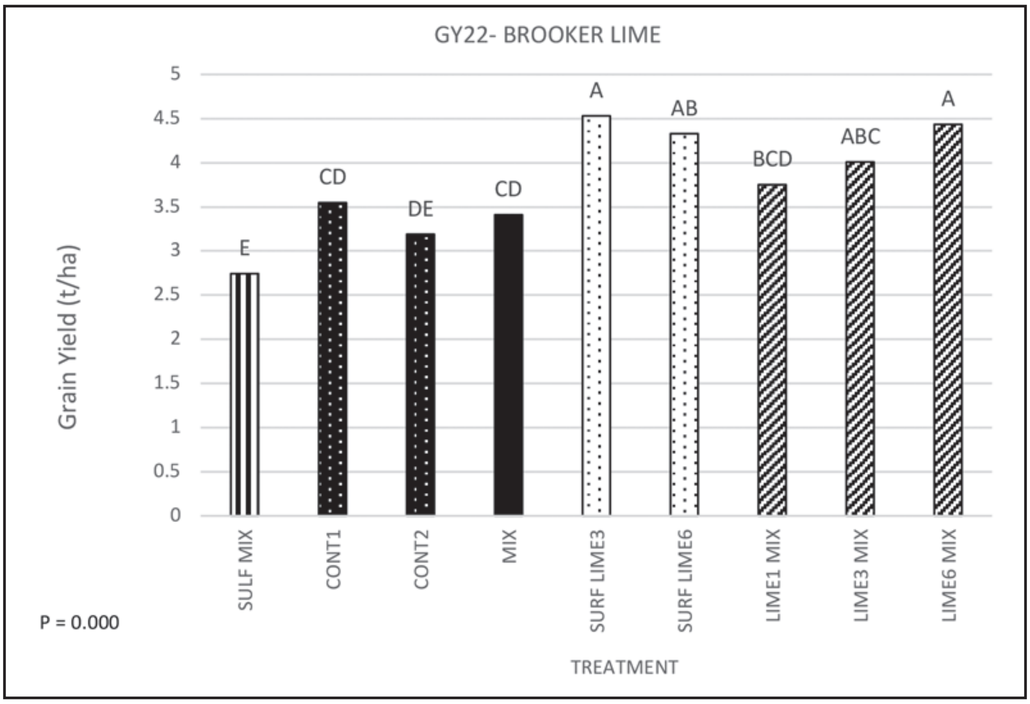


Figure 5. Barley grain yield at Brooker, December 2022. A different letter indicates a significant difference at P<0.05.

What does this mean?

Results in the first season following treatment (2020) did not show any response to treatments. This might be due to a combination of factors including a time delay between lime application and neutralisation of soil acidity and that a variety with some tolerance of soil acidity (Cobra) was grown in that year. It is unusual to observe lime responses in the year of application.

Three years after establishment this trial has shown improved crop growth and grain yields on sensitive cereal varieties to rates of lime applied at 3 t/ha or more. Plant tissue tests confirm that liming can reduce the availability of toxic aluminium uptake by plants. These tests also indicate that plant uptake of molybdenum was increased by liming, but that it might take a year or two for this to take effect. However, Mn concentrations in plant tissue tests indicated that lime applications can reduce the availability of manganese for plant uptake which should be considered when planning fertiliser strategies on limed soil.

In both 2021 and 2022 results, the sulfur treatment (which approximates acidification of low buffering soils if left untreated over a 10-year period) reduced crop productivity and yield. This is similar to the impact of the sulphur treatment observed at the long-term trial site at Koppio and highlights the potential impact of soil acidification on crop production in the region.

Although some trends have been observed in sensitive crop varieties in the last two seasons the trial should continue to be monitored to identify potential:

- further yield declines on the sulphur treatments, and
- yield increases when lime treatments become effective or with different crop tolerances.

The trial will continue to be monitored in 2023 to assess the impact of the treatments on crop yield. Soil sampling will assess the pH amelioration down the profile with and without mixing.

Acknowledgements

The research reported here is made possible by the significant contributions of the growers (Neil, Leah, Casey and Kathryn Carr) through both trial co-operation and the support of the GRDC. We'd like to thank them for their continued support. Thanks also goes to the Port Lincoln SARDI Agronomy team for the management.

References

Forward and Hughes, 2019 'Soil acidity status report 2019 - Eyre Peninsula NRM Region' DEW, September 2019.

Guidera and Masters, 2022 'GRDC Subsoil Acidity Project - Brooker Trial report 2021', PIRSA.

Project Partners

The GRDC Acid Soils SA project, formally titled 'New Knowledge and Practices to Address Topsoil and Subsurface Acidity Under Minimum Tillage Cropping Systems of South Australia', is a Grains Research and Development Corporation (GRDC) investment which brings together project partners from South Australia's Department of Primary Industries and Regions, the Department for Environment and Water, the University of Adelaide, Trengove Consulting, Penrice and AgCommunicators.

Section 2

Section Editor:
Nigel Wilhelm
SARDI

Farming Systems

Best practice for early sowing opportunities

Fiona Tomney[1,2], Amanda Cook[1,3], Ian Richter[1], Craig Standley[1] and Marina Mudge[1]
[1]SARDI; [2]Flinders University; [3]University of Adelaide

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

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

Key messages

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

Why do the trial?

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

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

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

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

How was it done?

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

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

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

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

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

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

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

What happened?

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

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

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

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

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

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

Farming Systems

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

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

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

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

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

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

What does this mean?

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

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

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

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

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

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

Acknowledgements

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

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

Australian Government
Department of Agriculture, Fisheries and Forestry
Future Drought Fund
AIR EP Ag Innovation & Research Eyre Peninsula
THE UNIVERSITY of ADELAIDE
SARDI
Flinders University
SA DROUGHT HUB
Government of South Australia Department of Primary Industries and Regions
SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE

New agricultural technology at the Minnipa AgTech demonstration farm

Kym Zeppel
AgTech Extension Officer, PIRSA, Minnipa

Key messages

- **The AgTech Program is a PIRSA initiative which aims to improve on-farm productivity by raising awareness about new and readily available technologies for agricultural enterprises.**
- **The AgTech Program is assisting primary producers to understand AgTech solutions suitable to their enterprise and to make informed AgTech adoption decisions.**
- **The program also aims to accelerate the development and commercialisation of AgTech solutions to future proof South Australian farms.**
- **There are five AgTech Demonstration Farms located around the state including: Struan/Kybybolite, Loxton, Nuriootpa, Turretfield and Minnipa. The Minnipa AgTech Demonstration Farm is located at the Minnipa Agricultural Centre (MAC).**
- **All demonstration farms are open to primary producers to understand AgTech solutions being demonstrated and access assistance from AgTech Extension Officers.**

Background

There are a vast number of technologies available to primary producers, and PIRSA is assisting producers to make better and more informed decisions about which AgTech solutions are right for them. The PIRSA AgTech Demonstration Farms help by analysing the benefits of various technologies after using them on the Demonstration Farms. These evaluations are available in our Fact Sheets and Case studies for each technology.

When evaluating a remote monitoring technology, connectivity options can be a significant factor in deciding on which solution is best suited to your needs. Connectivity options for the devices we are using at MAC include:

- Mobile Phone Network using 3G/4G often via the lower powered and extended range options such as Cat-M1 and NB-IoT
- Satellite connection
- LoRaWAN (Long Range Wide Area Network) which is a low-powered long-range network you can setup on your own farm to reduce the ongoing connectivity costs of technology, by using your own network rather than each device having its own direct data connection.

Various AgTech suppliers have provided their products for use or demonstration at the Minnipa AgTech Demonstration Farm. Farmers and advisers can see these products in action here to help make an informed decision about what may suit their own enterprise. The products currently being demonstrated at MAC are:

Remote Water Monitoring Solutions

Remote water monitoring gives you insights into the state of your water infrastructure right to your mobile phone or other device. It provides alerts for problems such as leaks or blockages, ensuring that your livestock don't go without water. It can also reduce the number of times you need to drive out to check stock water, therefore reducing vehicle and labour costs.

The water monitoring solutions implemented on the Minnipa AgTech Demonstration Farm are:

- Remote Tank Level monitor by Farmbot. Solar powered and connecting via satellite or mobile network.
- Remote Tank Level monitor by Farm Tasker. Battery powered with 10+ year battery life, connecting via mobile network or LoRaWAN.
- Remote water pressure monitor by Farm Tasker. Battery powered with 10+ year battery life, connecting via mobile network or LoRaWAN.
- Remote meter reader by Farm Tasker. Battery powered with 10+ year battery life, connecting via mobile network or LoRaWAN.

Automated stock water supplementation - DIT AgTech uDose
DIT AgTech's uDOSE system proportionally doses ruminant animals' water supply with liquid mineral supplements. uDOSE may be used to address deficiencies that are limiting production. This system ensures that all stock receive an accurate dose of the supplement via their drinking water, regardless of their propensity to want the supplement, with one system able to dose the water supply across multiple paddocks and troughs. The remote monitoring feature enables you to track usage and detect higher than usual water flow which could identify a leak in your water supply.

Weather Station - D3Ag Arable Mark 2
Portable weather station with remote access and the ability to measure temperature, rainfall and plant health indicators to aid in efficient decision making.

Cordless Shearing Handpiece & Hoof Trimmer - Mobishear
Australian designed cordless battery-operated shearing handpiece and hoof trimmer for easy use out in the paddock.

Air Compressor - Bruder Australia
Trailer mounted farm air compressor and blow gun for cleaning and machinery blowdown. Specifically designed for agricultural applications with a top-exit exhaust to reduce fire risk and a combined air filter for both the compressor and the engine for ease of maintenance.

Spray System - HARDI GeoSelect
Spray system using drone imaging for selective, targeted weed spraying which minimises chemical use for summer spraying. This system is an option on most new HARDI sprayers and there is a detailed video of our demonstration of this unit available on our website at: https://www.pir.sa.gov.au/research/agtech/attend_demos/minnipa_demo_farm/spray_system_hardi_geoselect

Interrow Weeder - Techgrow International
Mechanical weeder using camera technology to weed between crop rows reducing the need for chemical spray.

Farm Visitor Management - Onside
Farm visitor software for biosecurity safety and compliance.

Farm Data Management Software:
You can compare the two different farm management software packages we are demonstrating at MAC which both provide a single point of data collection for planting, harvesting and general farm activities. These products are listed below along with a benefit we have experienced from each:

- Agworld - also enables easy data access and communications with your agronomist.
- eAgronom - also features a simple and effective integrated inventory system.

What does this mean?
Demonstration opportunities
If you would like a more in-depth look at any of the technologies at the Minnipa Demonstration Farm, please contact Kym Zeppel, AgTech Extension Officer. Kym is available to meet with you to discuss your particular technology needs. There are fact sheets and case studies available for more details about all technologies across all farms. You can also visit the Minnipa demo farm website at: https://www.pir.sa.gov.au/research/agtech/attend_demos/minnipa_demo_farm

Acknowledgements
Julie Wedderburn, Manager, Water and AgTech and Major Programs
Dr Robyn Terry, Senior AgTech Extension Officer, SARDI and Major Programs.

Developing robust groundcover to promote resilience in low rainfall mixed farms using seed priming

Jack Desbiolles[1], Amanda Cook[2,3], Farzad Aslani[2], Gareth Scholz[4], Ian Richter[2] and Craig Standley[2]
[1]University of South Australia; [2]SARDI; [3]University of Adelaide; [4]SANTFA

Location
Minnipa
G & R Scholz

Rainfall
Av. Annual: 325 mm
Av. GSR: 241 mm
2022 Total: 485 mm
2022 GSR: 235 mm

Paddock history
2022: CL Hammer wheat
2021: Self-regenerating medic pasture
2020: Longsword wheat

Soil type
Sand (non-wetting)

Plot size
10 m x 1.7 m x 3 replicates

Key messages

- **Deeper seeding was the most effective factor improving wheat crop establishment and early/late development. While no grain yield benefits were detected in 2022, deeper sowing increased both protein content and grain size.**
- **Seed priming showed some potential to improve wheat seed germination rate under laboratory conditions but did not express any clear benefits under field conditions.**
- **Soil wetter resulted in a small improvement in wheat crop establishment and early vigour.**
- **The year 1 results suggest seeding into deeper moisture with a long coleoptile variety can best maximise stubble groundcover in non-wetting sandy soil conditions. This work is continuing in 2023.**

Background

The project 'Developing robust groundcover to enable resilience in low rainfall mixed farms' led by Mallee Sustainable Farming aims to demonstrate, evaluate, and communicate innovative farming practices to low rainfall farmers in the tri-state Mallee and Eyre Peninsula regions to enable them to implement farming systems that increase and maintain groundcover resilient to the pressures imposed by climate variability and management practices.

The focus of this project is to demonstrate new and innovative technologies and practices that support the maintenance of functional groundcover across the spectrum of seasons and sequences of enterprises. The outputs will be a synthesis of research - proven innovative practices, that are validated locally at paddock-scale and that can assist with maximising surface residue retention and longevity. Example strategies include reducing the disturbance and degradation of stubbles during seeding, harvest, and grazing; optimising stubble-friendly soil amelioration practices; and drought proofing crop establishment via seed priming or seeding into stubble-row moisture.

Seed priming refers to the process of pre-soaking seeds in a solution to kickstart the process of germination and advance it sufficiently such that 'primed' seeds placed in soil will require less soil moisture to finish germination and more successfully establish as seedlings. This concept is well proven internationally with increasing adoption by smallholder farms and is most beneficial under marginal soil moisture conditions, which are becoming increasingly prevalent in rainfed farming systems. Primed seeds can be re-dried for storage or used straight away 'wet' in the crop sowing operation.

Why do the trials?

A collaboration activity between SARDI, UniSA, SANTFA and AIR EP is focussing on validating and demonstrating a strategy under the drought-proofed crop establishment component of the project, which is seed-priming. A feature of the demonstration activity will be the development of a scalable, proof-of-concept mechanised solution for implementing on-farm hydro-priming and tailoring of air-seeder technology to deliver 'wet' seeds.

Seed germination is a 3-phase process, which includes I: 'imbibition' (or rapid hydration), II: 'activation' where water uptake slows down and major metabolic changes take place in preparation for embryo development, and III: 'physical germination' following a renewed rate of water uptake to sustain the emergence of the first root (radicle) followed by the first shoot. Only phases I and II are reversible with no impact on seed viability. Seed priming thus initiates the early stage of seed germination (up to phase II above) and ultimately reduces the amount of soil moisture and time required to complete the germination, hastening seedling emergence.

'Hydro-priming' was used in this trial and refers to the soaking of seeds in water. Various solutions may be used instead of water to seek additional agronomic benefits in specific soil and crop contexts with techniques such as nutri-priming (to fortify seeds with trace elements such as zinc or molybdenum), 'osmo-priming' (to improve germination ability in saline-environment) and bio-priming (with beneficial micro-organisms).

How was it done?

In 2022 three experiments were implemented:

- To assess changes in wheat seed weight during 25 hours of soaking (imbibition).
- To investigate the impact of a short seed imbibition period on emergence in pots.
- To assess value of hydro-priming on a non-wetting sand in the field.

Experiment 1

A first pot experiment was undertaken in mid March, whereby eight replicates of 100 wheat seeds (variety Hammer CL) were each placed in 50 ml of distilled water in a sealed container and weighed hourly (after air drying on paper towel) over a 12 hour period, with a final seed weight taken at 25 hours. Soaking periods of 6-24 hours are often cited in seed priming literature.

Experiment 2

A second pot experiment was undertaken pre-sowing whereby four replicates of 100 wheat seeds (variety Hammer CL) were each placed in 50 ml of water in a sealed container for 3 hours, before planting in pots. The soil type was a non-wetting sand taken from the 2022 trial site. The seeds were planted at 3 cm deep in two rows 175 mm apart (7 inch row spacing) in containers 250 mm (wide) by 350 mm (length) by 200 mm (deep). Pots were placed in a glasshouse on 12 March and first emergence was recorded 48 hrs later on 14 March. Emergence was monitored daily over 6 days.

Experiment 3

A replicated small plot field trial was established in a non-wetting sand near Minnipa to evaluate the impact of two seed priming levels (6 vs 12 hours soaking), seeding depth (shallow, medium, deep) and a soil wetter. Using a knife point press-wheel plot seeder, twelve treatments (shown in Table 1) were applied to 6 rows (0.255 m) x 10 m long field plots which were arranged in a randomised complete block design with three replicates.

The trial was sown on 29 April with AGT Calibre (110-115 mm long coleoptile) at 70 kg/ha with 55 kg/ha MAP banded above the seeds. A soil wetter (SE14 at 3 L/ha) was delivered in furrow in 80 L/ha volume for appropriate treatments. The trial area was sprayed pre-sowing and in-crop by the grower. Extra urea (25 kg/ha) was broadcast after sowing and another 50 kg/ha was broadcast in-crop on 13 July.

Initial soil moisture samples were taken at 3 cm intervals directly before seeding (Table 2). Seeds were weighed into bags to the calibrated rate of 70 kg/ha and 12 samples were separately soaked for either 6 or 12 hours. The imbibed seeds were air dried on paper towel then placed into seeding envelopes for immediate sowing with a cone seeder. Crop establishment was assessed twelve times in the five weeks after sowing. Early dry matter cuts and NDVI were taken on 6 July (10 weeks after sowing), and late dry matter cuts on 13 October (late flowering for the deep sown treatment). The trial was harvested on 12 December for grain yield and quality assessment.

The 2022 season was an ideal growing season with stored soil moisture due to good February rains and an early seeding opportunity following a 14 mm break of the season on 26 April. Post seeding rainfall is shown for the 6 week period in Table 3a, highlighting only little rainfall post seeding until week 4 and 5 when 18 mm and 58 mm fell, respectively. Minnipa monthly rainfall for 2022 is listed in Table 3b. Minnipa recorded a decile 9 rainfall in 2022 complemented by stored subsoil moisture from summer rains in late 2021.

What happened?

Experiment 1

Soaking wheat seeds in water increased seed weight rapidly at first, and then more gradually, up to a maximum of 57% over the 25 hour period (Figure 1). It would appear that longer soaking would have increased seed weight further by imbibition, albeit at a decreasing rate which suggest the process had reached activation phase II of germination. Wheat germination starts once the weight gain during imbibition reaches around 35-45%. The significant weight change in primed seeds also implies that seeder calibration must be adjusted pro-rata to maintain the targeted plant population.

Table 1. Experimental treatments and targeted settings.

Treatments	Seeding depth (NB: seeds placed at the bottom of the furrow)	Soil wetter	Hydro-priming (hours)	Furrow tilling depth from surface (mm)
1			No	
2	Baseline: at the moisture front ("INTO")	No	6	up to 75
3			12	
4			No	
5	30mm deeper than baseline ("BELOW")	No	6	up to 105
6			12	
7		No	No	
8		Yes	No	
9	30mm shallower than baseline ("ABOVE")	No	6	up to 45
10		Yes	6	
11		No	12	
12		Yes	12	

Table 2. Soil moisture profile data with depth.

Depth (cm)	0-3	3- 6	6- 9	9-12	12-15	15-30	30-60	60-90	90-120
Average Gravimetric water content (% w/w)	1.3 c	1.3 bc	3.3 b	3.6 b	3.6 b	5.5 a	6.3 a	6.3 a	6.3 a

Note: Means with the same letter are not significantly different (P<0.05).

Table 3. 2022 post-seeding weekly rainfall and monthly growing season rainfall for Minnipa (mm).

a) weekly rainfall post seeding	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Total
	4.7	2.3	1.0	18.0	57.6	10.6	

b)	Jan-March	April	May	June	July	Aug	Sept	Oct	Nov-Dec	GS (mm)
2022 Season rainfall	100.6	36.2	75.5	27.8	28.4	50.8	54.0	59.6	96.4	332
Long Term Average	46.3	18.0	34.3	42.5	44.8	43.1	32.6	26.1	39.3	241

At 25 hour soaking time, it was observed that seeds had yet to start softening, which would make them vulnerable to damage by mechanical handling (e.g. grain augers). Seed priming thus needs to be carefully calibrated to remain within the 2nd phase of germination where the process may safely be reversed by slow drying (in case soil moisture conditions become too marginal) without loss in seed viability. Re-drying of primed seeds in the furrow implies a delayed opportunity to benefit early crop establishment, but such risks can be mitigated by sowing to greater depth where more soil moisture is typically available to finish the germination process and be better insulated against early evaporation.

Experiment 2

A three hour soaking in water caused a significant emergence improvement on the third day, whereby un-primed seeds had no emergence at all, while nearly 7% of primed seeds emerged in the first 72 hours. However, in both treatments, emergence became similar from day 3 onward (Figure 2). It is unclear why a relative slow-down was measured on day two with primed seeds. The initial burst is likely to be linked to a subset of seeds having more effectively imbibed initially and reached early phase 3 stage. A bigger benefit of seed priming may be expected following longer soaking duration which might result in a greater difference between the two curves of Figure 2. A more detailed pot trial will be conducted in 2023.

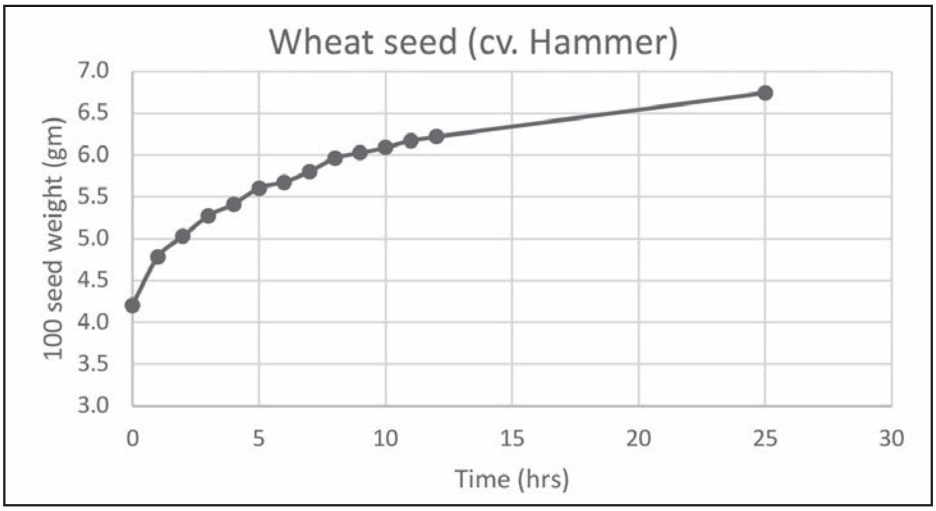


Figure 1. Change in wheat seed weight during soaking in water over a 25 hour period.

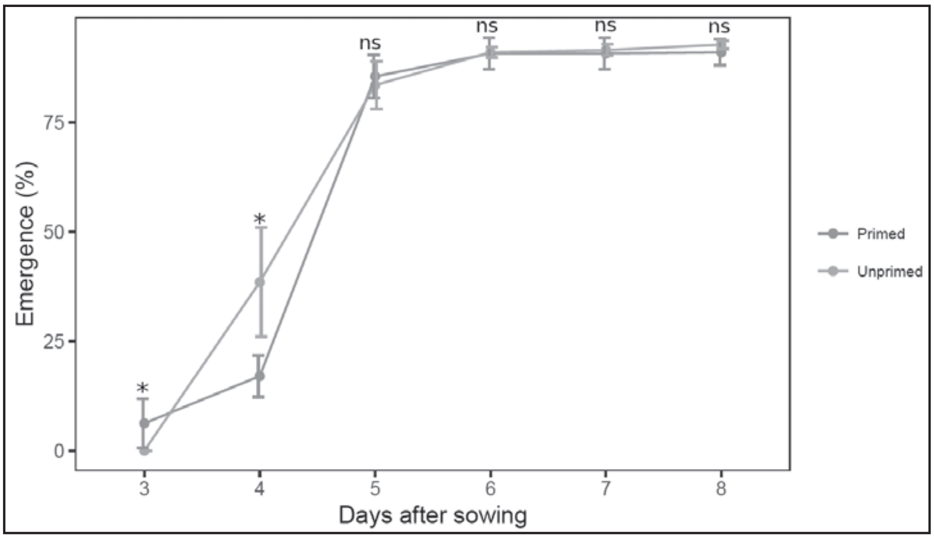


Figure 2. 3hr primed wheat seed (cv Hammer) emergence in pots.

Field Trial

Plant Establishment - Figure 3

Deep seeding resulted in remarkably higher early plant density, a difference which remained consistent over the sampling period until both shallow and baseline sowing finally reached similar plant density levels 46 days after sowing, following significant rain at 4 - 5 weeks.

Seed priming showed no benefit at any of the depths. Conversely, the addition of a soil wetter at the shallow depth provided a significant benefit (21-38 plants/ m^2) over the period specifically with unprimed seeds. Under the experimental conditions, deeper sowing into higher soil moisture was therefore the most reliable technique to enhance establishment with visual benefits also observed on initial growth of wheat.

Early NDVI and Dry Matter (t/ha) - Figure 4

Similar pattern to crop establishment data was observed for Early Dry Matter (EDM), measuring a 4.7-fold increase over the seeding depth range, whereby the highest EDM was obtained under the deep seeding treatments, followed by the baseline seeding depth and least under the shallow seeding depth (NB: similar trends were exhibited for NDVI, data not shown). In line with its effect on plant establishment, soil wetter significantly improved EDM, measuring a 1.8-fold increase. No consistent benefit of seed priming on EDM (data not shown) could be detected at any of the depths, while NDVI data suggested a slight negative impact (-12%) of seed priming.

Late Dry Matter (t/ha) – Figure 5

Treatment differences measured later in the season (late flowering to late booting) became less obvious, with a trend of slightly higher (+27%, borderline significance) crop dry matter under deeper seeding. No benefits of soil wetter or seed priming were detected.

Grain yield and quality (t/ha) – Figure 6

No differences in wheat grain yield were measured, with the trial averaging 3.6 t/ha. In contrast, grain quality was affected by seeding position (Figure 6), whereby deep seeding slightly increased protein content and more particularly grain size (1000-grain weight).

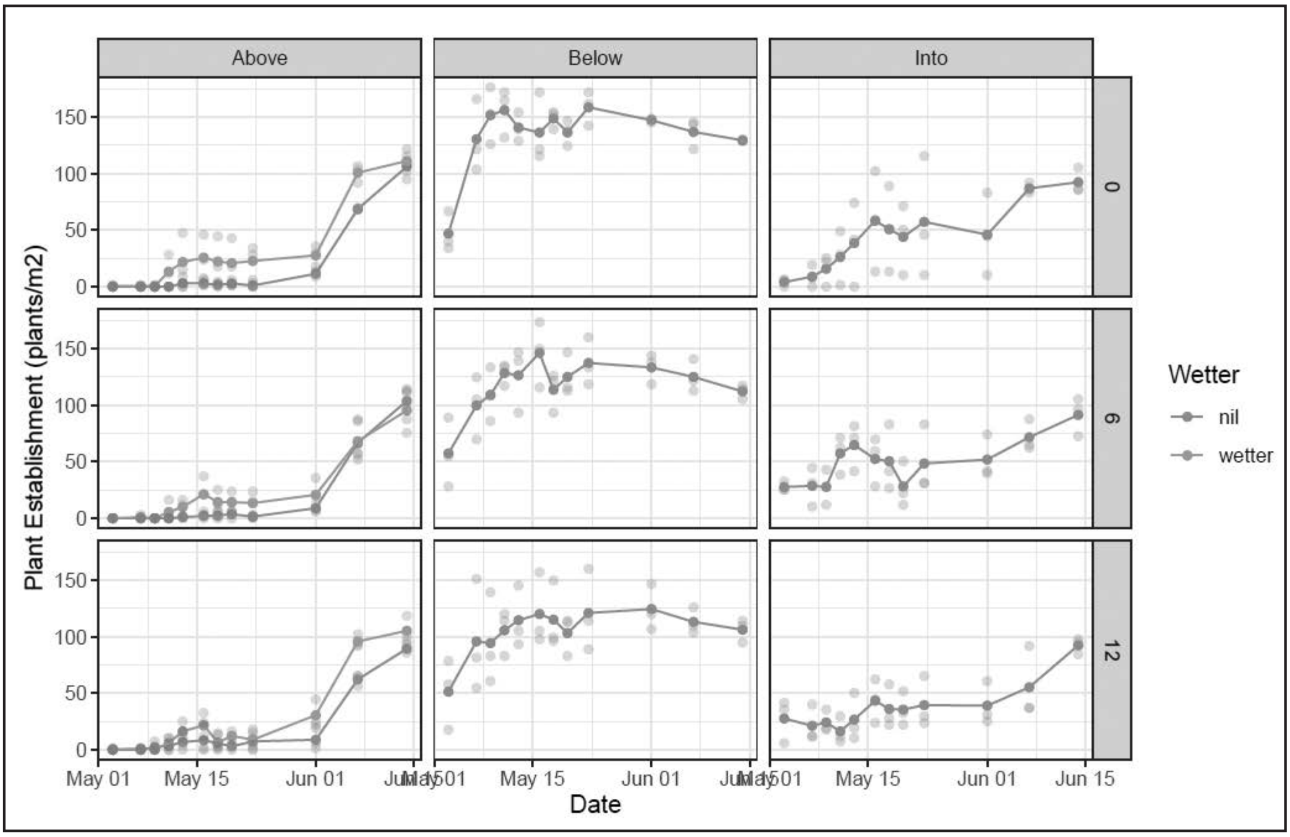


Figure 3. Crop establishment for the 12 treatments over a 6 week period post-sowing (Coloured lines represent the mean values of 3 replicates) - see Table 1 for details on treatment labels.

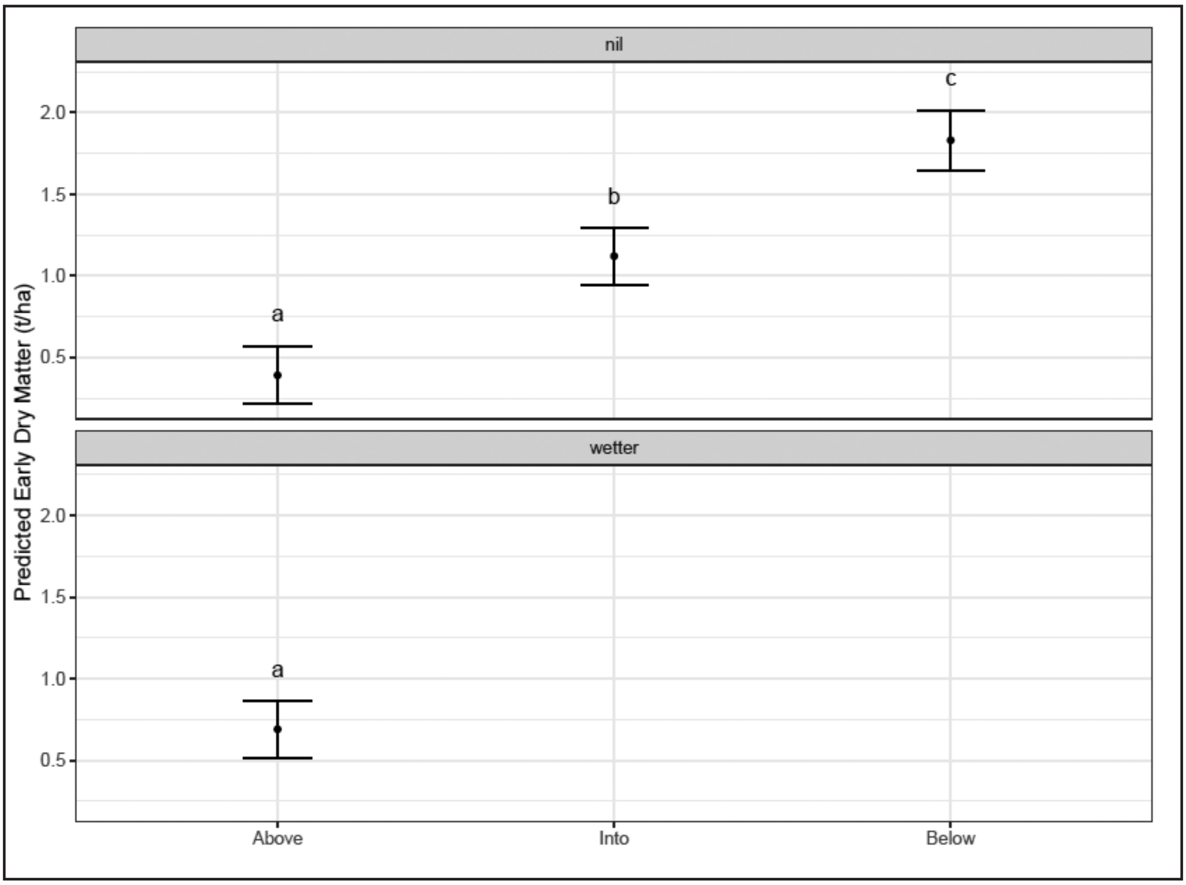


Figure 4. Main effects of soil wetter and seeding position on early dry matter. Different letters indicate significantly different means.

Farming Systems

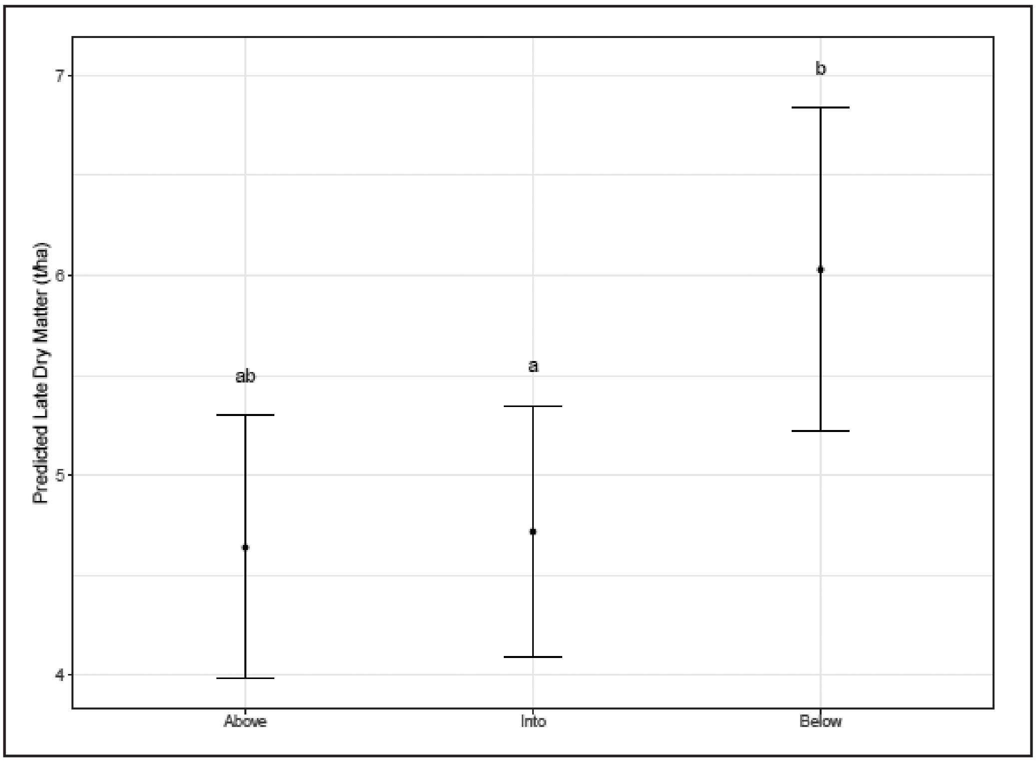


Figure 5. Main effect of seeding position on late dry matter. Error bars represent the 95% confidence intervals and different letters indicate significantly different means.

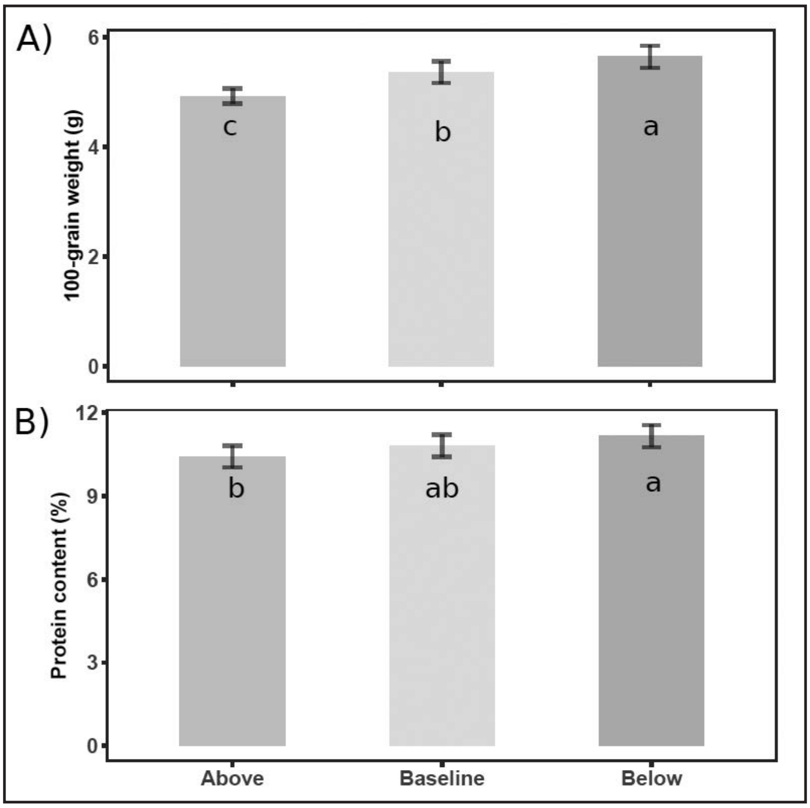


Figure 6. Main effect of seeding position on wheat seed 100-grain weight (left) and protein content (right).

What does this mean?

This research provided evidence for the potential role of novel sowing strategies for improving crop performance biomass of wheat on a non-wetting sand.

Overall, the results confirmed the importance of deeper seeding into greater soil moisture to potentially benefit both quality and productivity of wheat production in sandy soil conditions. The deeper seeding treatment (30 mm below the moisture front) using a long coleoptile wheat variety (AGT Calibre, 105-110 mm coleoptile) showed clear benefits at the crucial stages of emergence and initial crop growth, carrying through to late crop development. Under a decile 9 season with significant subsoil moisture storage pre-season, these deeper seeding benefits did not eventuate in grain yield benefits. A deeper sowing strategy however should provide extra benefits over summer with improved residue groundcover. The trial showed the potential complementary benefit - albeit limited - of applying a soil wetter in the seed zone, to facilitate seed germination and improve early crop growth, but with no persisting impact on late biomass production under the experimental conditions.

Although seed hydro-priming enhanced seed weight and triggered faster initial germination under laboratory conditions, it did not improve crop establishment in the field. In practice, primed seeds might readily lose absorbed water to surrounding soil when placed in sub-optimal conditions such as shallow seeding, thus cancelling any positive effect of priming. In contrast, deeper sowing into greater soil moisture (Table 2) would also provide more protected moisture levels, expected to allow seed priming benefits to be more reliably expressed. The significant but late post-seeding rainfall (Table 3a) also resulted in more favourable soil moisture levels, reducing the potential benefits of seed priming due to overly dry soil in the first 3 weeks. While any positive impact of seed priming was not detected in this first year of field trials, a longer seed priming duration may have been necessary.

Further assessment will be performed in 2023 to assess some of these hypotheses in both a small plot replicated trial and a paddock-scale demonstration.

Farming Systems

Acknowledgements

This research was funded by the Australian Government's Future Drought Fund Drought Resilience Innovation Grants (Project led by Mallee Sustainable Farming) and is supported by the SA Drought Resilience and Adoption Hub. Thank you to Katrina Brands, Marina Mudge and Rebbecca Tomney for their help with scoring and sampling and Greg Butler (SANTFA) for initial project input.

Long coleoptile wheats on Eyre Peninsula in 2022

Rhaquelle Meiklejohn and Andrew Ware
EPAG Research

Location
Cootra
Todd Matthews
Rainfall
Av. Annual: 338 mm
Av. GSR: 245 mm
2022 Total: 416 mm
2022 GSR: 304 mm
Yield
Potential: 4.9 t/ha (Yield Prophet)
Actual: 4.6 t/ha
Paddock history
2022: Barley
2021: Wheat
2020: Wheat
2019: Pasture
Soil type
Sand over sandy clay loam
Plot size
10 m x 1.8 m x 3 replicates
Trial design
RCBD
Yield limiting factors
Weed competition for deep sown varieties

Location
Cockleechie
Dan Adams
Rainfall
Av. Annual: 453 mm
Av. GSR: 336 mm
2022 Total: 593 mm
2022 GSR: 387 mm
Yield
Potential: 8.1 t/ha (Yield Prophet)
Actual: 5.6 t/ha
Paddock history
2022: Wheat
2021: Wheat
2020: Canola
2019: Wheat
Soil type
Clay loam over clay
Plot size
10 m x 1.8 m x 3 replicates
Trial design
RCBD
Yield limiting factors
Weed competition for deep sown varieties, foliar disease

Key messages

- **Plant establishment and grain yield of long coleoptile wheat was compromised when sown deeper (11 cm) than traditional sowing depths (4 cm) into a moist soil profile in 2022.**
- **Seeding at 8 cm may be an opportunity to make use of moisture just below the traditional seeding bed to establish crops in seasons where moisture at these depths exists.**
- **On-going work is still needed to optimise the use of long coleoptile genetics.**

Why do the trial?

The opportunity to establish a crop at a time of our choosing, harnessing the improved water use efficiency benefits of early sowing, whilst flowering at the optimum time to reduce damage by frost and heat, and not having to wait for season opening rainfall, presents as one of the largest opportunities to improve resilience in modern cropping systems.

Seeding deeper, into soil moisture stored 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 organ that protects the first shoot as it grows 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.

These trials aim to assess how long coleoptile wheat performs in modern Eyre Peninsula farming systems.

How was it done?

Two trials were established: one on a sand over sandy loam soil in the Cootra area (central EP), and the other on a heavy clay loam at Cockaleechie (lower EP).

Fourteen cultivars were selected for genetic differences in coleoptile length. For the purposes of reporting the 14 cultivars will be displayed in their genetic groups as cultivars within groups performed similarly. The groups are: LC18: cultivars containing the Rh18 long coleoptile gene (including the Mace derivate Mace.18), LC13: cultivars containing an alternative long coleoptile gene Rh13, Normal: containing the shorter coleoptile varieties that are widely grown (including Scepter), Normal Long: cultivars that don't have one of the new long coleoptile genes but do have comparatively longer coleoptiles than most currently grown varieties (including Yitpi and Calibre).

Each cultivar was targeted to be planted at three depths 40 mm, 80 mm and 120 mm.

The Cootra trial was sown on 29 April 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 92 kg/ha of nitrogen was applied post-emergent. A foliar application of 120 g/ha zinc, 150 g/ha manganese and 45 g/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. The Cootra site was harvested on 15 December 2022.

The Cockaleechie trial was sown on 12 May 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 138 kg/ha of nitrogen was applied post-emergent. A foliar application of 120 g/ha zinc, 150 g/ha manganese and 45 g/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. The Cockaleechie site was harvested on 19 December 2022.

Measurements were taken for: emergence, coleoptile length, longest leaf length, sub-crown internode length, seeding depth, tillers, above and below ground biomass (at Zadoks growth stages: 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 22.

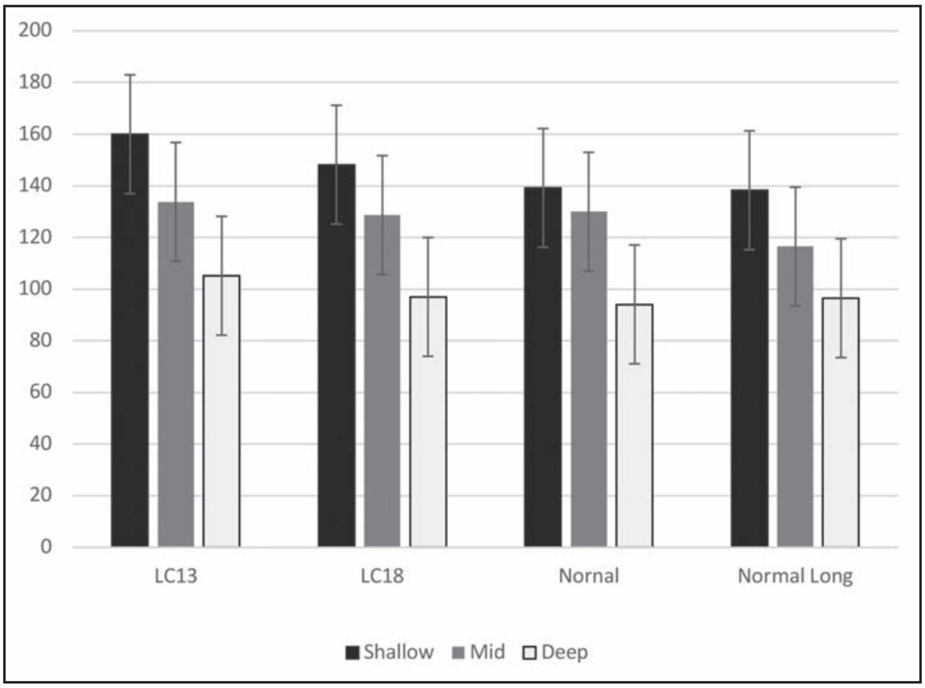


Figure 1. Plant establishment (plants/m^2) of coleoptile groups for wheat, 38 days after sowing at Cootra, 2022.

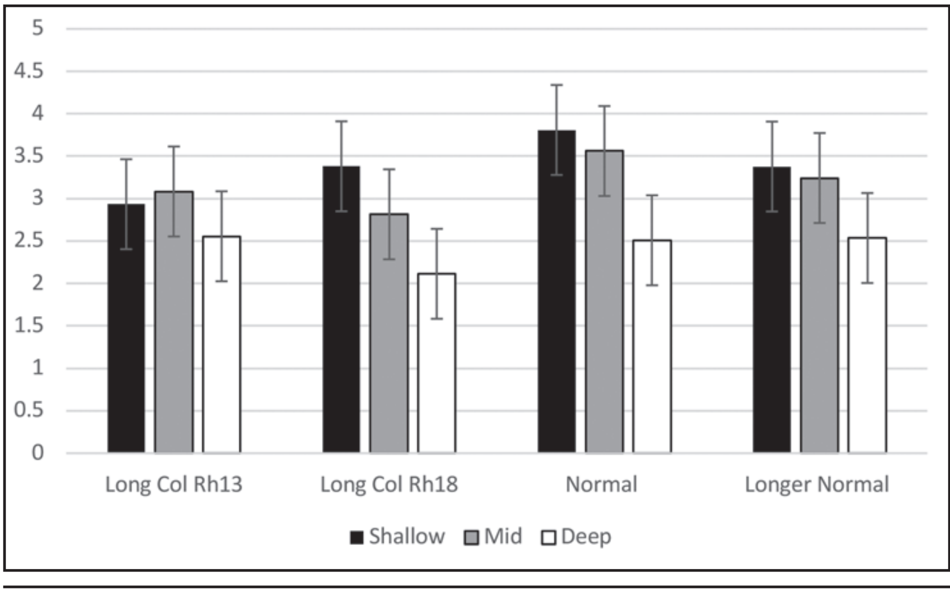


Figure 2. Grain yield (t/ha) at Cootra 2022.

Farming Systems

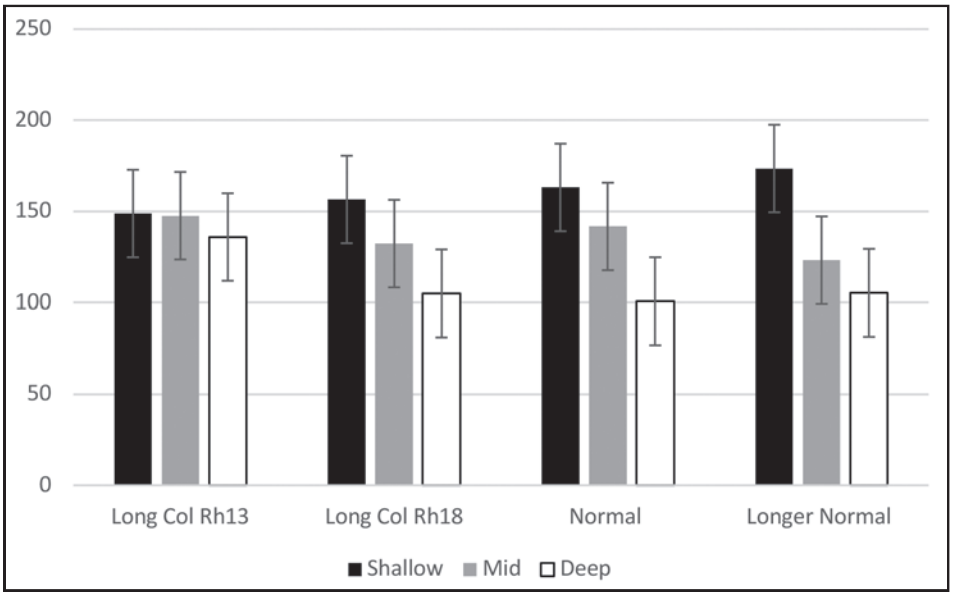


Figure 3. Plant establishment (plants/m^2) 41 days after sowing at Cockaleechie, 2022.

What happened?

Cootra Trial

Cootra actual seed depth achieved: shallow = 35 mm, medium = 85 mm and deep = 110 mm.

The shallowest sown treatments had more plants establish, regardless of coleoptile group (Figure 1).

Deep placement of seed (110 mm) reduced grain yield across all coleptile groups. Deeper sown treatments had higher levels of weed infestation which may have been due to lower plant establishment, poorer vigour from deeper sowing or less herbicide efficacy from deeper sowing.

Cockaleechie Trial

Cockaleechie actual seed depth achieved: shallow = 60 mm, medium = 95 mm and deep = 105 mm.

Plant establishment at Cockaleechie (Figure 3) showed a similar trend to the 2022 Cootra trial (Figure 1), where shallow sowing had higher establishment.

Yield data at Cockaleechie was compromised with high levels of disease, including eye spot, Septoria and powdery mildew, despite application of foliar fungicides (as timing of these was compromised due to paddock trafficability), and as such yield data is not reported here.

What does this mean?

The large amount of summer and autumn rain that fell across Eyre Peninsula in early 2022 meant that the traditional seed bed was moist enough to germinate wheat seed at any time from early April onwards. This resulted in the benefit of being able to establish a crop earlier through deeper sowing being nullified.

Both plant establishment and grain yield were negatively affected by sowing as deep as 110 mm for all coleoptile groups. These data are contrary to the 2021 trial at Cootra that demonstrated that the long coleoptile genetics were able to establish better from deeper sowing.

There are several possibilities for the difference between the two seasons but we are only able to speculate on the causes at this stage. However, trials conducted in 2022 suggest that successful establishment of wheat from deeper sowing may not be as simple as adopting a variety with a longer coleoptile.

Sowing to a depth of 80 mm did not reduce grain yield as much as the deepest sowing (110 mm). This may offer growers the possibility of using a range of currently available, short coleoptile, high yielding genetics to sow into moisture at that depth when opportunities arise.

Acknowledgements

DAFF Drought Innovation Fund Robust Ground Cover: Developing robust ground cover to enable resilience in low rainfall mixed farms for providing the funding. CSIRO for providing the long coleoptile germplasm. Todd Matthews, Dan Adams and families for providing the trial sites. Rebekah Fatchen, Gary Miller, Mark Saunders, Ashley Flint and Jacob Giles of EPAG Research for their assistance. Thanks to SAGIT for funding the EP grains research intern program.

LongReach wheat time of seeding - targeting variety maturity for different seeding opportunities

Colin Edmondson

LongReach Plant Breeders Technical Development Manager - SA & Vic

Location
Minnipa Agricultural Centre
Rainfall
Av. Annual: 344 mm
Av. GSR: 255 mm
2022 Total: 487 mm
2022 GSR: 300 mm
2022 Summer Rainfall (Nov-March): 193 mm
Yield
Potential: 7.66 t/ha (French Schultz)
Potential yield (maximum WUE of 20 kg grain/ha per mm)
Actual: 5.58 t/ha Mohawk wheat (WUE of 14.6 kg grain/ha per mm)
Paddock history
2021: Legume pasture
2020: Wheat
2019: Canola
Soil type
Calcareous - red sandy loam
Soil test
0 - 10 cm - $pHCaCl_2$ 8.1, Colwell P 39 mg/kg, Total N 24 mg/kg
Plot size
10 m long x 1.6 m wide, sown with a cone seeding with 6 rows (0.255 m spacing)
Trial design
Experimental: 3 RCBD trials sown side by side as individual seeding time trials
Yield limiting factors
Season conditions suited high yield and matching maturity to suit the longer growing season was a major determinant of yield

Key messages

- **The 2022 growing season was set up for early seeding at Minnipa with extensive summer rainfall providing excellent security.**
- **Main season mid Spring variety Scepter had the best yield in the later May planting time but headed too early to maximise yield when sown in Mid-April.**
- **Mid-Slow maturity variety Trojan had higher yields and was better suited than Scepter to the excellent 2022 season, and it still showed slightly higher yields at the later seeding times.**
- **The Quick winter wheat Mowhawk had the highest yield overall, showing excellent adaption to all seeding times and significantly out yielding the Quick winter variety Longsword and other Slow Spring wheat varieties.**

Why do the trial?

The trial evaluated the value of early seeding in a season with excellent stored soil moisture and also compared the phenology of six different varieties and their yield responses to seeding time.

Minnipa was one of the key sites used as part of the "Management of Early Sown Wheat Project" (GRDC Project Code: 9175069) which evaluated the best performing wheat cultivars in a range of seeding times and environments in southern Australia between 2017 and 2019. This work showed that Mid (Scepter) and Mid-slow (Trojan) spring varieties are poorly suited to pre-April 20 sowing as they develop too quickly to maximise yield and avoid winter frosts. Of the slower maturity wheats tested, the highest yields in the <2.5 t/ha yield environments came from early - late April establishment with Quick-winter variety Longsword and Very-slow spring variety LRPB Nighthawk. The best yields of the slower maturing varieties sown early were similar to Scepter sown in its optimal main season window.

Previous research on matching crop variety development to environment was reported in EPFS Summary 2020 'Novel agronomy strategies for reducing the yield decline from delayed emergence', EPFS Summary p. 144.

How was it done?

Trial Details - Wheat variety trials were sown side by side at 3 Times of Seeding (TOS1, 21 April 2022; TOS2, 4 May 2022; TOS3, 20 May 2022) using a cone seeder with six rows at 0.255 m spacing. Six varieties (Table 1) were sown in a randomised complete block design at approximately 70 kg/ha (180 plants/m^2 target density). Fertiliser included DAP (80 kg/ha) at seeding and urea (45 kg/ha) in crop. Herbicides applied over the season included: Roundup DST (2.5 L/ha), Trifluralin 480 g/L (2 L/ha), Sakura (0.118 kg/ha) and Lontrel Advanced (0.1 L/ha) + LVE MCPA 500g/L (0.7 L/ha). The trials were harvested in mid-December using a plot harvester.

- Measurements - Establishment (plants/m^2) was assessed after seeding, while plant development was compared at two dates using Zadoks growth stage scores during spring. Grain yield was recorded at the end of the season.

- Results were analysed using LongReach AMETA Breeding program with Row + Col Spatial correlation model using the 3 times of seeding trials as separate sites to compare overall effects.

What happened?

- With the substantial soil moisture bank at seeding and cool seasonal conditions, yield for all varieties was much higher than typical for the upper EP with an average yield across the site of 4.8 t/ha (Figure 1).
- The highest yielding variety was the Quick winter type Mowhawk (5.6 t/ha). Its vernalisation requirement kept it vegetative in winter which was ideal to hold back heading until early to mid-spring at all seeding times. In TOS 1 Mowhawk headed on about 10 September which was almost a month later than Scepter sown at the same time. Mowhawk showed very stable yield even at the late May seeding time.
- For the other slow maturing varieties, LRPB Nighthawk performed next best while LRPB Bale and Longsword had similar overall yields. Longsword was the only variety to show significant grain abortion at TOS1 with its reported vulnerability to floret sterility under cold conditions being observed with missing grains in heads later in the season. This appears to be the driver of the lower yield Longsword delivered at TOS1.
- Of the main season varieties Trojan out performed Scepter, which is to be expected with the excellent potential of the season. Its Mid-slow maturity gave it more time to build biomass and yield potential. Both varieties showed a trend of higher yield at the later seeding times as they headed too early in the cooler August conditions to maximise yield in TOS1.
- The vernalisation controls of both the Quick winter varieties Mowhawk and Longsword allowed the varieties to speed up when sown later in the season compared to the stronger photoperiod (daylength) controls in the Slow spring varieties, LRPB Bale and LRPB Nighthawk (Table 2). The Quick winter types moved forward substantially in reproductive development at TOS3 showing they are more flexible and better adapted to the Upper EP where speed of grain fill is critical in most seasons.

Table 1. Details of wheat varieties evaluated in the trial at Minnipa, 2022. (Res = resistance)

Variety	Maturity	Leaf Rust Res.	Stem Rust Res.	Stripe Rust Res.	Black Point Res.	Powdery Mildew Res.	Septoria Tritici Res.	Yellow Leaf Spot Res.	Quality Southern Zone
Scepter	Mid Spring	MSS	MRMS	MSS	MS	SVS	S	MRMS	AH
LRPB Trojan	Mid-slow Spring	MR#	MRMS	S	MS	S	S	MSS	APW
LRPB Bale	Slow Spring	MSS	MRMS	MRMS	S	MSS	MSS	SVS	APW
Longsword	Quick Winter	MR#	MR	R/S	MS	MSS	MS	MRMS	AWW
Mowhawk (LPB19-14343)	Quick Winter	MRp	RMRp	MRMSp	MSp	MRp	MSSp	MRMSp	TBC (APW/AH expected 2023)
LRPB Nighthawk	Very-slow Spring	MSS	MRMS	MRMS	MS	SVS	MS	MS	APW

NVT Disease ratings and Longreach Breeder rating 14/2/23. p=provisional.

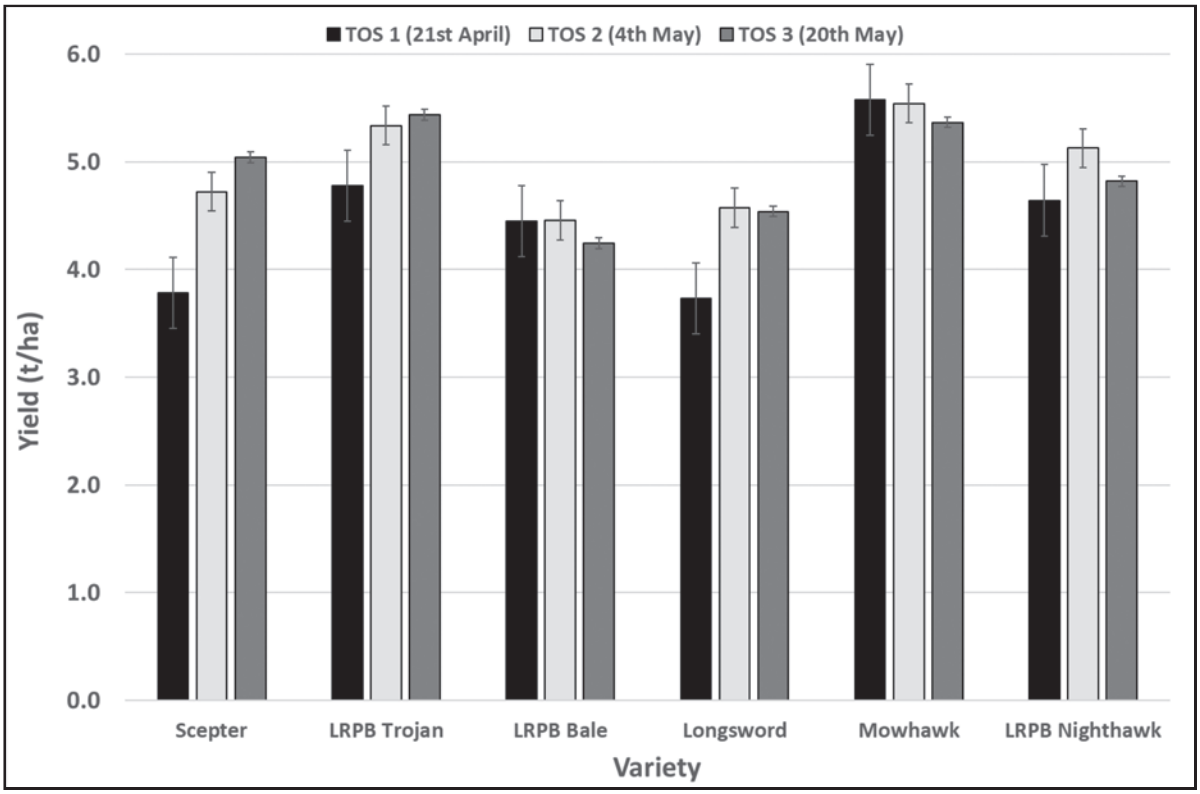


Figure 1. Yield performance for six wheat varieties at 3 different Times of Sowing (TOS), Minnipa 2022.

Table 2. Comparative Zadoks growth stage at two dates in Spring.

Date scored	Zadoks Score 23/8/22			Zadoks Score 8/9/22			Maturity Group
Variety	TOS 1	TOS 2	TOS3	TOS 1	TOS 2	TOS 3	
Scepter	74	61	45	80	76	59	Mid Spring
LRPB Trojan	70	58	43	75	72	56	Mid-slow Spring
LRPB Bale	53	43	36	71	55	46	Slow Spring
Longsword	47	43	32	62	55	47	Quick Winter
Mowhawk	47	42	31	59	50	45	Quick Winter
LRPB Nighthawk	48	39	31	60	47	39	Very Slow Spring
Mean	57	47	36	68	59	49	
CV%	1.73	1.29	1.74	1.29	1.42	1.89	
LSD (P=0.005)	*1.80*	*1.15*	*1.19*	*1.61*	*1.57*	*1.97*	

Z40 Start Booting, Z50 Start Heading, Z60 Start Flowering, Z70 Start Grain Developing.

What does this mean?

- Early Seeding before Anzac Day is better suited to slower developing wheat varieties, even in a low frost risk slow season like 2022, as main season varieties like Scepter head too early to maximise yield.
- The Quick winter variety Mowhawk showed the best adaptation to early seeding, confirming previous findings from the "Management of Early Sown Wheat Project" of the suitability of this maturity type.
- The luxuriant conditions in 2022 helped the slower maturing varieties outperform Scepter, previous work has shown that they have the ability to match the yield of Scepter when sown in its optimal window even in tougher seasonal conditions.
- While the robustness of slower maturing varieties still needs continued evaluation, the results of all the early seeding work conducted at Minnipa in a range of seasons show they are well suited when seeding opportunities arise in the first half of April on the upper EP.

Acknowledgements

Staff of the Minnipa Agricultural Centre who conducted this trial and undertook all management over the season. The trial was funded by LongReach Plant Breeders Agronomy support for new varieties program.

Section Editor:
Amy Keeley
SARDI

Section 3

Break Crops

Table 1. Eyre Peninsula 2022 NVT canola trial yields in t/ha and expressed as a percentage of the site mean.

Nearest Town	Lock			Minnipa		
Variety Name	**t/ha**	**%**	**Oil (6% moisture)**	**t/ha**	**%**	**Oil (6% moisture)**
Hyola Equinox CL	3.50	79	47.15	1.49	96	52.02
Pioneer 43Y92 (CL)	4.72	106	47.00	1.46	94	51.19
Pioneer 44Y94 CL	5.15	116	47.95	1.60	103	51.05
Site Mean (t/ha)	**4.45**			**1.54**		
CV (%)	8.05			7.52		
Probability	<0.001			0.09		
LSD (t/ha)	*0.57*			*0.24*		
Sowing Date	6 May 2022			22 Apr 2022		
Variety Name	**t/ha**	**%**	**Oil (6% moisture)**	**t/ha**	**%**	**Oil (6% moisture)**
ATR Bluefin	3.24	84	46.60	1.28	82	50.42
ATR Bonito	3.23	84	46.95	1.35	86	49.68
ATR Stingray	3.19	83	45.55	1.37	88	50.66
ATR Swordfish	4.00	104	46.70	1.28	82	50.87
Bandit TT	2.84	74	45.75	1.59	102	49.29
Hyola Enforcer CT	3.08	80	45.45	1.75	112	49.48
HyTTec Trident	4.16	108	46.50	1.71	110	49.68
HyTTec Trophy	4.38	114	45.40	1.73	111	49.59
HyTTec Velocity	4.09	106	44.86	1.54	98	49.82
InVigor LT 4530P	4.22	109	44.75	1.97	126	49.83
InVigor T 4510	4.21	109	45.50	1.68	107	48.69
InVigor T 4511	4.26	110	47.05	1.44	92	50.59
Renegade TT	4.01	104	45.30	1.81	116	48.79
RGT Capacity TT	3.58	93	44.91	1.48	95	49.08
SF Spark TT	3.88	101	47.05	1.27	81	50.73
Site Mean (t/ha)	**3.86**			**1.56**		
CV (%)	9.24			6.88		
Probability	<0.001			<0.001		
LSD (t/ha)	*0.58*			*0.18*		
Sowing Date	6 May 2022			22 Apr 2022		

Table 1. Eyre Peninsula 2022 NVT canola trial yields in t/ha and expressed as a percentage of the site mean

Nearest Town	Lock		
Variety Name	**t/ha**	**%**	**Oil (6% moisture)**
DG Lofty TF	3.87	91	48.65
Hyola 410XX	3.43	80	49.05
Hyola Battalion XC	4.00	94	47.60
Hyola Garrison XC	3.66	86	47.50
InVigor R 4022P	4.37	102	47.55
InVigor R 4520P	4.69	110	46.10
Nuseed Emu TF	4.08	96	45.60
Nuseed Hunter TF	4.73	111	48.25
Nuseed Raptor TF	4.50	105	48.05
Pioneer 44Y27 (RR)	4.54	106	47.65
Pioneer 44Y30 RR	4.65	109	48.20
Site Mean (t/ha)	**4.27**		
CV (%)	8.35		
Probability	<0.001		
LSD (t/ha)	*0.57*		
Sowing Date	6 May 2022		

Harvesting Minnipa GRDC National Variety Trials, 2022.

Break Crops

Growing lentils on the upper Eyre Peninsula in 2022

Sarah Day[1,2], Amy Keeley[1], Brianna Guidera[1] and Penny Roberts[1,2]
[1]SARDI; [2]University of Adelaide

Location
Kimba
Andrew Baldock
Buckleboo Farm Improvement Group
Rainfall
Av. Annual: 349 mm
Av. GSR: 247 mm
2022 Total: 545 mm
2022 GSR: 248 mm
Soil type
Neutral to alkaline loamy clay
Soil test
0 - 10cm: pH ($CaCl_2$) 7.8, Colwell P 22, Nitrate N 13, Organic Carbon 1.47%
10 - 30cm: pH ($CaCl_2$) 7.9, Colwell P 12, Nitrate N 18, Organic Carbon 0.98%
Plot size
12 m x 1.5 m x 3 reps
Trial design
RCBD
Yield limiting factors
Grass and broadleaved weed competition

Key messages

- **Lentil variety selection should be based on the need for herbicide tolerance characteristics and disease resistance, to reduce grain yield loss from weed competition and disease infection.**

Why do the trial?

Lentil production area has increased by 4000 hectares in the last decade across the Western and Eastern Eyre Peninsula regions (PIRSA, 2022). The majority of pulse management research and variety evaluation occurs in the medium and high rainfall zones, and strategies or recommendations developed in these environments are often not suitable for low rainfall production. Lentils in dry environments can be sensitive to herbicides, including applications that are on-label and commonly used. Two lentil field experiments were established near Kimba in 2022. A lentil variety by seeding rate field experiment aimed to assess variety performance for grain yield and if reduced seeding rates impact lentil production. The second field experiment at Kimba focused on pre-emergent herbicide management in lentil with the aim to identify safe, efficient, and economic options for use in lentil. These trials build upon previous field experiments in lentil herbicide management, seeding rates (Day, 2019; Day & Keeley, 2022; Day *et al*., 2021) and lentil variety selection for low rainfall environments (Day *et al*., 2020).

How was it done?

A variety by seeding rate field experimental trial was sown near Kimba on 4 May 2022. The field experimental trial tested six varieties of lentil (Table 1) sown at three seeding rates with three replicates (Table 2). The two aims of the experimental trial were; (1) assess lentil variety grain yield and (2) assess lentil variety performance when sown at reduced sowing rates compared to the recommended rate.

A pre-emergent herbicide field experiment was sown near Kimba on 4 May 2022 with one variety of lentil, PBA Hallmark XT. A total of 16 herbicide treatments were applied to the lentil trial, combined from four herbicide products, two applications rates (Table 3) and two application timings. All herbicide products were applied both incorporated by sowing (IBS) or post sowing pre-emergent (PSPE) and received the same two rates regardless of application timing.

Plant establishment, normalised difference vegetation index (NDVI), biomass dry matter production, grain yield and grain quality were measured in both field experiments. Both field experiments had three replicates. Both experimental trials were harvested on 5 December 2022. Data was statistically analysed using ANOVA and Fisher's least significant difference test in Genstat 21st Edition.

What happened?

Varieties

PBA Jumbo2 is a non-herbicide tolerant lentil variety and was on average the lowest yielding variety at Kimba, averaged across seed rates, in 2022 (Table 1). There were no differences in grain yield between herbicide tolerant varieties at this site in 2022. Botrytis grey mould (BGM) infection occurred in lentil varieties in a replicated trial near Lameroo. As PBA Jumbo2 has a high level of disease resistance to BGM it was one of two highest yielding varieties at Lameroo in 2022 (data not shown).

Seeding rates

Reducing the seeding rate of lentil from 120 to 90 plants/m^2 did not reduce grain yield production at Kimba, 2022, however, a difference was recorded in grain yield between the recommended and half seeding rates (Table 1). This is similar to previous findings from lentil seed rate trials in low rainfall environments (Day & Keeley, 2022; Day *et al*., 2021).

Table 1. Grain yield (t/ha) of lentil varieties sown at different seeding rates in the variety by seeding rate field experimental trial at Kimba, 2022. Different letters in the same column or row indicate a significant difference between those treatment values (P < 0.05). ns = not significant.

Variety	Grain Yield (t/ha) at different seeding rates			Average
	Grain Yield (t/ha)	60 plants/m^2	90 plants/m^2	120 plants/m^2
PBA Hallmark XT	3.35	3.71	3.34	3.47 a
PBA Highland XT	3.60	3.59	3.85	3.68 a
PBA Hurricane XT	3.66	3.85	3.68	3.73 a
PBA Jumbo2	2.66	2.87	3.18	2.91 b
CIPAL2122	3.35	3.87	4.05	3.76 a
GIA Lightning	3.23	4.00	4.16	3.79 a
Average	*3.31 b*	*3.65 a*	*3.71 a*	*3.56*
LSD (P < 0.05)				
Variety		0.43		
Seeding rate		0.34		
Variety x seeding rate		ns		

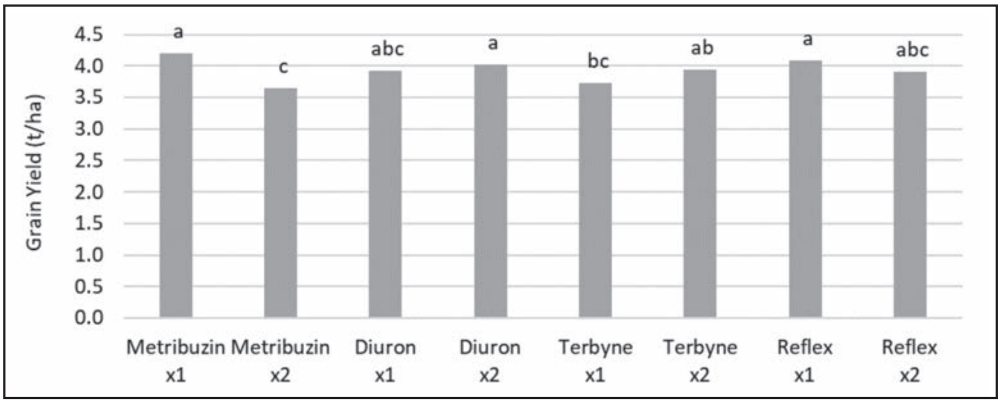


Figure 1. Grain yield (t/ha) of PBA Hallmark XT lentil influenced by the application of different pre-emergent herbicides and rates applied to the pre-emergent herbicide field experimental trial at Kimba, 2022. Bars labelled with the same letters are not significantly different (P<0.05).

Table 2. Target plant density (plants/m^2) and seeding rate (kg/ha) of lentil varieties sown at Kimba, 2022.

Seeding Rate	Lentil		Vetch	
	Plants/m^2	kg/ha*	Plants/m^2	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 3. Herbicide products, active ingredients and application rates applied as treatments to PBA Hallmark XT lentil at Kimba, 2022.

Product	Active Ingredient	Herbicide rate (mL or g per ha)	
		x1 rate	x2 rate
Metribuzin	750 g/kg Metribuzin	120	240
Diuron	900 g/kg Diuron	400	800
Terbyne Xtreme	875 g/kg Terbuthylazine	600	1200
Reflex	240 g/L Fomesafen	500	1000

Pre-emergent herbicides

Herbicide type, rate and application timing is important to reduce risk associated with lentil production, as lentils can be sensitive to herbicide use in dry conditions. Minor crop injury from herbicide applications occurred, with an average of 6% plot injury at Kimba, 2022 (Table 4). This herbicide crop injury varied across the site and there were no differences between treatments (P > 0.05). Herbicide crop injury can result in reduced grain yield, nitrogen fixation and crop competition. Despite the low and varied level of crop injury, herbicide treatments still had an influence on grain yield (Figure 1). Applying Metribuzin at a higher rate (x2) reduced grain yield by 570 kg/ha.

Table 4. Crop injury scored as a percentage of plot severity (%) from herbicide treatments applied to Hallmark XT lentil in the pre-emergent herbicide field experimental trial at Kimba, 2022. ns. = not significant (P>0.05).

Herbicide	Incorporated by sowing (IBS)		Post-sowing pre-emergent (PSPE)		Average crop injury (%)
	x1 rate	x2 rate	x1 rate	x2 rate	
Metribuzin	13	10	12	3	10
Diuron	3	3	8	2	4
Terbyne Xtreme	10	1	2	2	4
Reflex	0	17	3	3	6
Average crop injury (%)	7	8	6	3	6
LSD (P<0.05)					
Herbicide	ns				
Rate	ns				
Timing	ns				
All interactions	ns				

What does this mean?

Lentil can be sensitive to herbicide use 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.

2022 was a high disease risk season in most regions of South Australia due to the increased rainfall and mild growing conditions (Blake *et al*., 2023). While the field experimental trials at Kimba were not infected with botrytis grey mould, this was not the case for many other field experiment sites and cropping regions. Therefore, selecting varieties with improved disease resistance is important in all regions and seasons to reduce the risk of disease infection and reduce the need for multiple foliar fungicide sprays.

Acknowledgements

The research undertaken as part of this project is made possible by the significant contributions of growers through both trial cooperation and the support of the GRDC (UOA2105-013RTX – 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 teams at Clare and Pt Lincoln is gratefully acknowledged and appreciated.

References

Blake, S., Khani, M., Day, S., Trengove, S., Sherriff, S., Gontar, B., Kimber, R., & Roberts, P. (2023). 2022 Pulse disease wrap up. GRDC Grains Research Updates, Adelaide.

Day, S. (2019). *Lentil herbicide management in southern low rainfall environments* (Eyre Peninsula Farming Systems 2018 Summary.

Day, S., & Keeley, A. (2022). *Improving lentil and vetch management and mitigating risk in the low rainfall zone* (Eyre Peninsula Farming Systems 2021 Summary.

Day, S., Oakey, H., Saunders, R., & Roberts, P. (2020). *Break crop selection for Eyre Peninsula low rainfall farming systems* (Eyre Peninsula Farming Systems 2019 Summary.

Day, S., Roberts, P., & Gutsche, A. (2021). *Lentil and vetch management and alternative end use in the low rainfall zone* (Eyre Peninsula Farming Systems 2020 Summary.

PIRSA. (2022). *Crop and Pasture Reports South Australia*. https://www.pir.sa.gov.au/primary_industry/crops_and_pastures/crop_and_pasture_reports

Taking South Australian canola profitability to the next level

Andrew Ware
EPAG Research

Location
Yeltukka (15 km NW Cummins)
Michael Treloar
Rainfall
Av. Annual: 424 mm
Av. GSR: 324 mm
2020 Total: 431 mm
2020 GSR: 365 mm
2021 Total: 421 mm
2021 GSR: 377 mm
2022 Total: 539 mm
2022 GSR: 406 mm
Yield
Potential: Canola 4.8 t/ha (Modified French/Schultz, 14 kg/mm)
Actual: 6.1 t/ha
Paddock history
2022: Canola
2021: Wheat
2020: Wheat
Soil type
Sand over clay loam with calcrete in sub-soil
Soil test
0-10 cm pH 6.25
Plot size
10 m x 2 m x 4 reps
Split plot x RCBD
Yield limiting factors
Some broadleaved weeds in Yeltukka trial

Location
Coomunga (15 km NW Port Lincoln)
Peter Russell
Rainfall
Av. Annual: 616 mm
Av. GSR: 499 mm
2020 Total: 681 mm
2020 GSR: 563 mm
2021 Total: 700 mm
2021 GSR: 554 mm
2022 Total: 850 mm
2022 GSR: 585 mm
Yield
Potential: Canola 7.3 t/ha (Modified French/Schultz, 14 kg/mm)
Actual: 6.9 t/ha
Paddock history
2022: Canola
2021: Lupins
2020: Wheat

Key messages

- **Having high nitrogen (N) levels in the soil prior to seeding was the biggest driver of canola yield in 2022 compared to a range of other nutritional and rotational treatments.**
- **Canola yield was not influenced by the previous crop (wheat compared to pulse) where adequate N nutrition was present.**
- **Higher rates of trace elements and sulphur did not have any impact on canola yields above district practice in a situation where soil and plant tissue tests met current critical values.**
- **The 2022 wheat crop grown on a pulse in (2020) (canola in 2021), yielded higher than wheat (2020).**

Why do the trial?

Practices such as early sowing, matching cultivar phenology and sowing time to critical flowering period, the development of high yielding hybrid varieties and fungicide use to control blackleg have added to improvements in canola yield in recent years. After these practices have been adopted, what is the scope to further improve canola yields?

These trials were designed to determine the relative significance of key canola yield drivers once disease and phenology are optimised, primarily targeting crop sequences and nutrition packages in highly productive systems. This will provide information to better target and refine input costs and improve the profitability.

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 2021 blocks of wheat and lupin (Coomunga) and wheat and faba bean (Yeltukka) were grown in preparation for canola in 2022. In each block, separate treatments of high rates of nitrogen (N), phosphorous (P), sulphur (S), and trace elements (TE) were applied to create differences for the canola to be sown into in 2022.

In 2022 Pioneer 44Y94CL canola treated with Saltro seed dressing was sown on 5 May at both sites, targeting establishment of 45 plants/m^2.

In 2022 each site was sown with 150 kg/ha 19:13:0 and flutriafol 500 @ 200 mL/ha. A total of 148 kg/ha N (district practice) was applied to each site prior to early flowering. Weeds were controlled with propyzamide @ 1 L/ha, clethodim @ 500 mL/ha, and Lontrel Advanced @ 50 mL/ha. Aviator Xpro @ 600 mL/ha was applied at 30% bloom to control upper canopy blackleg. Pyrinex Super @ 500 mL/ha was applied post-sowing and alpha-cypermethrin @ 100 mL/ha was applied during grain fill to prevent insect damage.

Additional nutrition was applied during 2021 and 2022 as detailed in Table 1 to increase levels of individual nutrients in the soil.

Soil type
Sand loam over ironstone clay loam
Soil test
0-10 cm pH 5.3
Plot size
10 m x 2 m x 4 reps
Split plot x completely randomised block design
Yield limiting factors
Nil

Phosphorous was applied at sowing in 2020 and nitrogen was applied as urea at stem elongation in 2021.

The "TE High" and "Everything High" treatments also received 1.7 kg/ha zinc, 5 kg/ha calcium, 2.6 kg/ha manganese, 1 kg/ha copper, 40 g/ha boron, 2 g/ha molybdenum, and 1.35 kg/ha iron in 2020, through streaming nozzles. These treatments 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.

Chicken manure at 20 t/ha (Chook) was applied to high input plots to determine if grain yield could be further increased through high rates of organic fertiliser.

Single superphosphate at 200 kg/ha (+Fert) was applied to four replicates of the High P treatment, early post-seeding 2022.

Gypsum at 500 kg/ha was applied to four replicates of the High S treatment early post seeding 2022.

Yields presented are hand cut yields, collected at 80% seed colour change, as this represents the most accurate method of determining canola yield in small plot trials (John Kirkegaard pers comm).

These trials were replicated in adjacent paddocks where pulse or wheat was planted in 2020, followed by canola in 2021. In 2022 the 2021 trials were over-sown with wheat to determine if there were any residual effects of the treatments imposed.

What happened?

Site 1: Coomunga

2021 Results:
Sown on 12 May 2021, wheat (cv Scepter) yielded 4.0 t/ha and lupin (cv Wonga) yielded 2.4 t/ha.

Site 2: Yeltukka

In the set-up year sown 13 May 2021, Scepter wheat yielded 4.2 t/ha and Bendoc faba beans yielded 2.4 t/ha.

Table 1. Rates (kg/ha) of nitrogen (N), phosphorous (P) and trace elements (TE) applied to each treatment at Coomunga and Yeltukka in 2021 and 2022.

Fertiliser applied	Year	Treatment				
		District practice	P high	N high	TE high	Everything high
Nitrogen	2021	9 (+125)*	9 (+125)	159 (+125)	9 (+125)	159 (+125)
	2022	100	100	100	100	100
	Total	109 (+125)	109 (+125)	259 (+125)	109 (+125)	259 (+125)
Phosphorus	2021	18	36	18	18	36
	2022*	22	22 (+18)	22	22	22 (+18)
	Total	40	58 *(+18)*	*40*	*40*	*58 (+18)*

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

Table 2. Results of soil tests taken at Coomunga 2022, prior to canola being sown.

2021 Treatment	Total mineral N 0-100 cm (kg/ha)	Organic carbon (%)	Colwell P (mg/kg)
Wheat - Everything High	219	1.99	30
Wheat - District Practice	77	1.94	35
Lupins - Everything High	195	1.96	30
Lupin - District Practice	76	2.21	27

Table 3. Grain yield (t/ha) of canola 2022 at Coomunga following the different 2021 crops.

2021 Crop	Yield (t/ha)
Lupin	6.28
Wheat	6.23
LSD (P = 0.05)	*ns*

Table 4. Grain yield (t/ha) and oil content (%) of canola 2022 at Coomunga as a result of treatments applied.

Treatment	Yield (t/ha)	Oil (%)
District Practice	5.91	46.3
Everything High+Chook	6.91	45.5
Everything High+Fert	6.80	45.7
N High	6.52	45.3
P High	6.16	45.9
P High + Fert	6.30	45.9
S High	5.89	46.1
TE High	5.55	45.9
LSD (P=0.05)	*1.6*	*ns*

Table 5. Results of soil tests taken at Coomunga 2022, prior to wheat being sown.

2020 Treatment	Total mineral N 0-100cm (kg/ha)	Colwell P (mg/kg)
Lupins - Everything High	66	26
Lupins - District Practice	80	39
Wheat - Everything High	65	26
Wheat - District Practice	74	30

Break Crops

Table 6. Grain yield (t/ha) of 2022 wheat sown into 2021 canola.

Treatment	Yield (t/ha)
District Practice	5.06
Everything High	5.09
N High	5.25
P High	5.01
S High	5.06
TE High	5.27
LSD (P=0.05)	*ns*

Table 7. Grain yield (t/ha) of wheat in 2022 at Coomunga following the different 2020 crops and canola in 2021.

2020 Crop	Yield (t/ha)
Lupin	5.30
Wheat	4.90
LSD (P=0.05)	*0.13*

Table 8. Results of pre-seeding soil tests taken at Yeltukka 2022.

2021 Treatment	Total Mineral N 0-100 cm (kg/ha)	Organic C (%)	Colwell P (mg/kg)
Faba Bean - Everything	115	0.94	25
Faba Bean - District Practice	74	1.16	22
Wheat - Everything	132	0.96	24
Wheat - District Practice	52	1	27

Table 9. Grain yield (t/ha) of canola 2022 at Yeltukka following the different 2021 crops.

2021 Crop	Yield (t/ha)
Faba bean	6.02
Wheat	5.49
LSD (P=0.05)	*ns*

Table 10. Grain yield (t/ha) and oil content (%) of canola 2022 at Yeltukka as a result of treatments applied.

Treatment	Yield (t/ha)	Oil (%)
District Practice	4.92	44.7
Everything High+Chook	7.19	45.2
Everything High+Fert	6.85	45.4
N High	6.60	45.2
P High	5.07	44.8
P High+ Fert	5.51	45.7
S High	5.26	46.0
TE High	4.65	44.9
LSD (P = 0.05)	*1.6*	*ns*

Table 11. Results of pre-seeding soil tests taken at Yeltukka 2022, prior to wheat being sown.

2020 Treatment	Total mineral N (kg/ha) 0-100cm	Organic C (%)	Colwell P (mg/kg)
Faba bean - Everything	87	1.35	26
Faba bean - District Practice	95	1.19	27
Wheat - Everything	121	1.38	34
Wheat - District Practice	98	1.15	21

Table 12. 2022 grain yield (t/ha) of wheat sown into 2021 canola.

Treatment	Yield (t/ha)
District Practice	5.90
Everything High	6.12
N High	5.94
P High	5.86
S High	5.96
TE High	5.90
LSD (P = 0.05)	*ns*

Table 13. Grain yield (t/ha) of wheat 2022 at Yeltukka following the different 2020 crops and canola in 2021.

2020 Crop	Yield (t/ha)
Faba bean	5.98
Wheat	5.85
LSD (P = 0.05)	*0.07*

What does this mean?

Where nitrogen levels were higher in the soil prior to sowing canola at both sites in 2022, canola yield was higher compared to all other treatments. In this instance the higher N levels were created by adding high urea to both pulses and wheat later (around head emergence) in the growing season in the year prior to growing canola.

The viability of being able to re-create this across a wider landscape still requires sorting out some detail around longevity and return on investment. However, the message of having higher fertility levels available in the soil that can be drawn on to capitalise on better growing seasons holds true regardless of how higher fertility levels are created.

All other treatments (district practice and where higher levels of sulphur, trace elements, and phosphorous were added) all yielded similarly. This indicates that current soil and tissue testing critical values (complete range of soil and plant tests conducted not displayed) appear to be accurate for canola and that canola has a strong ability to scavenge and find these nutrients.

There was no effect of the previous crop (either pulse or wheat) on canola yield. However at both sites the wheat crop following the canola grown in 2021 yielded higher following pulse (faba beans/lupins compared to wheat), indicating a longer-term benefit of growing the pulse crop.

Acknowledgements

This work was funded by the SAGIT/AIR EP project 'Taking canola profitability to the next level' project code: LEA120. Michael Treloar and family for hosting the Yeltukka trial and Peter Russell and family for hosting the Coomunga trial. Gary Miller, Mark Saunders, Rebekah Fatchen, Rhaquelle Meiklejohn and Ashely Flint of EPAG Research for their assistance.

Brianna Guidera, SARDI presenting GRDC National Variety Trial results at Minnipa Agricultural Field Day, 7 September, 2022.

AIR EP
Ag Innovation & Research
Eyre Peninsula

EPAG
RESEARCH

SAGIT

Section 4

Section Editor:
Amanda Cook
SARDI

Cereals

New wheat and barley varieties in 2022

Amy Keeley and Kaye Ferguson
SARDI

Wheat NVT

The 2023 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 2022 bread wheat releases Brumby⚶, Kingston⚶, LRPB Anvil⚶CL Plus and Reilly⚶.

New released wheat variety notes (Compiled from 2023 South Australia Crop Sowing Guide).

Brumby⚶ is a mid-maturing APW wheat variety. Development speed of this variety is best suited to early May sowings but evaluation in NVT is limited so far. Brumby⚶ offers good disease resistance to stem rust (MR) and powdery mildew (R), but is susceptible to leaf rust (SVS). Released in 2022 (tested as IGW6683), seed is available from local resellers or InterGrain Seed club members. EPR $3.50 ex-GST

Kingston⚶ is mid-maturity AH wheat. It is a compact plant type and with broad adaptability. Kingston⚶ is susceptible to all rusts and very susceptible to powdery mildew (SVS); it has moderate resistance to CCN (MRMS). Released in 2022 (tested as BSWDH04-062) by BASF. Seed is available through Seednet. EPR $3.50 ex-GST.

LRPB Anvil⚶ **CL Plus** is a quick-maturity, two-gene imidazolinone-tolerant AH wheat that can be sprayed by label rates of registered imidazolinone herbicides. Quick to maturity with a similar if not faster development pattern to Vixen⚶. It has good early vigour, providing good weed competition early. LRPB Anvil⚶ CL Plus has good final grain size and is well suited to the low-medium rainfall zones, providing a fast-maturing, imidazolinone - tolerant variety choice to growers. It is very susceptible to Septoria tritici blotch and powdery mildew and will need to be monitored. Released in 2022, the variety was originally bred by Grains Innovation Australia with further development by LongReach Plant Breeders. Seed is available through Pacific Seeds. EPR $4.25 ex-GST.

Reilly⚶ is a mid-maturity AH wheat. Best suited to the low to medium-rainfall zone, it has a medium plant height. Reilly has moderate resistance to stem (MR), stripe rust (MRMS) and CCN (MRMS), but is susceptible to Septoria tritici blotch, yellow leaf spot and powdery mildew. Released in 2022 (tested as BH120020S-11) by BASF. Seed is available through Seednet. EPR $3.50 ex-GST.

Barley NVT

New release barley variety notes (Compiled from 2023 South Australia Crop Sowing Guide).

The 2023 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 2022 barley releases Combat⚶, Titan AX⚶ and Zena⚶ CL.

Combat⚶ is a quick-mid maturing feed barley. It has a semi-prostrate growth habit that will provide improved weed competition over the erect growth habit of Rosalind⚶ and similar varieties. While evaluation of Combat⚶ in SA's NVT is so far limited, 2021 yields were promising, achieving comparable yields to Rosalind⚶ with good grain size. Combat⚶ has good resistance to net form net blotch and moderate resistance to both spot form net blotch and leaf rust. It was released in 2022 (tested as IGB1944), and is bred by InterGrain. Seed is available from local resellers or InterGrain Seedclub members. EPR $3.50 ex-GST.

Titan AX is a quick-maturing variety with tolerance to Sipcam Aggressor® (Group 1) herbicides. It is the world's first CoAXium® barley variety bred out of a partnership between AGT, Sipcam Australia and Albaugh (a US-based crop protection company). It is derived from Compass and provides similar agronomic characteristics with the added benefit of being tolerant to Group 1 herbicides. It was released in 2022 (tested as AGTB0325) and is bred and marketed by AGT. Seed is available through AGT Affiliates. EPR $4.55 ex-GST.

Zena CL is a quick to mid-maturing imidazolinone-tolerant variety that is undergoing malt evaluation with Barley Australia, with a decision expected by 2024. Closely related to RGT Planet, it performs well in medium to high-rainfall zones. However, evaluation in NVT is limited. Zena has good levels of resistance to powdery mildew and scald but both net form and spot form net blotch levels will need to be monitored. It was released in 2022 (tested as IGB20125T) and is bred by InterGrain. Seed is available through InterGrain Seedclub members. EPR $3.50 ex-GST.

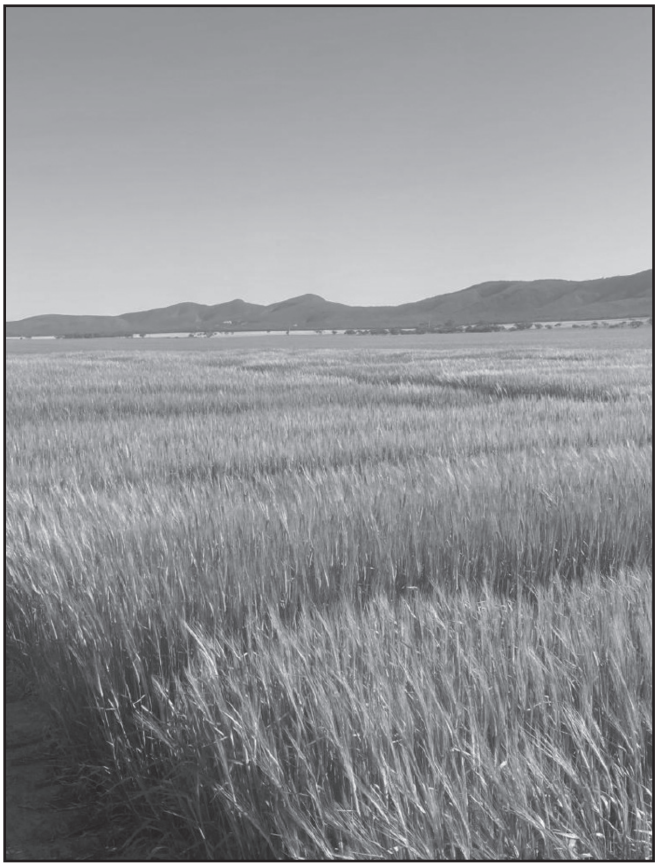


Figure 1. NVT barley at Darke Peak, September 2022.

Figure 2. NVT main season wheat at Kimba, June 2022.

Table 1. Eyre Peninsula 2022 NVT wheat trial yields in t/ha and expressed as a percentage of the site mean.

Region	Lower EP				Upper EP													
Nearest Town	Rudall		Wanilla		Kimba		Minnipa		Mitchellville		Nunjikompita		Penong		Piednippie		Warramboo	
Variety Name	t/ha	%	t/ha	%	t/ha	%	t/ha	%	t/ha	%	t/ha	%	t/ha	%	t/ha	%	t/ha	%
Ascot	6.29	108	6.84	112	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ballista	5.91	101	6.06	99	6.44	108	5.18	114	3.84	104	3.66	109	2.62	114	4.38	106	6.32	106
Boree	6.02	103	6.46	106	6.42	107	4.56	100	3.53	96	3.50	104	2.35	102	4.34	105	5.98	100
Brumby	6.16	106	6.34	104	6.00	100	4.77	105	3.56	97	3.50	104	2.04	88	4.28	103	6.53	109
Calibre	6.09	104	6.06	99	6.14	103	4.75	104	3.96	108	3.60	107	2.35	102	4.37	105	6.22	104
Catapult	6.09	104	5.96	98	5.74	96	4.80	105	4.40	120	3.66	109	2.24	97	4.54	110	6.18	104
Chief CL Plus	5.42	93	5.73	94	5.22	87	3.38	74	2.43	66	3.21	95	1.88	82	3.99	96	5.47	92
Cosmick	5.86	100	6.24	102	5.88	98	3.98	87	3.31	90	3.19	95	2.44	106	4.15	100	5.84	98
Cutlass	6.05	104	6.36	104	6.04	101	4.07	89	4.68	127	3.35	99	2.31	100	4.09	99	5.91	99
Denison	6.37	109	6.08	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Devil	6.14	105	6.27	103	6.03	101	5.03	110	3.51	95	3.49	104	2.39	104	4.52	109	5.99	100
EG Titanium	5.51	94	5.43	89	5.90	99	4.40	96	4.60	125	3.63	108	2.25	98	4.14	100	5.51	92
Emu Rock	4.91	84	5.38	88	5.84	98	4.72	104	3.82	104	3.04	90	2.10	91	3.75	90	5.69	95
Grenade CL Plus	5.00	86	5.25	86	5.17	87	4.41	97	3.37	92	3.08	92	2.31	100	3.67	89	5.35	90
Hammer CL Plus	5.19	89	5.91	97	5.16	86	3.90	86	3.21	87	3.02	90	1.86	81	3.76	91	6.02	101
Kingston	6.02	103	6.26	103	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Kord CL Plus	4.97	85	5.62	92	4.94	83	3.03	67	2.52	68	2.70	80	1.89	82	3.21	77	5.27	88
LRPB Anvil CL Plus	4.92	84	5.94	97	4.59	77	3.55	78	2.58	70	2.70	80	2.08	90	3.73	90	6.08	102
LRPB Arrow	5.50	94	6.09	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LRPB Cobra	5.84	100	6.80	111	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LRPB Dual	5.49	94	6.02	99	5.46	91	3.94	86	4.14	113	2.68	80	2.34	102	3.45	83	5.04	84
LRPB Trojan	6.23	107	5.57	91	6.53	109	4.86	107	4.23	115	3.42	102	2.30	100	4.27	103	5.84	98
Mace	5.52	95	5.69	93	5.15	86	4.31	95	2.93	80	3.16	94	2.07	90	3.99	96	5.73	96
Razor CL Plus	5.26	90	5.29	87	5.51	92	4.25	93	3.25	88	3.18	94	2.42	105	3.75	90	6.33	106
Reilly	5.61	96	5.71	94	5.62	94	4.56	100	4.43	121	3.10	92	2.54	110	3.74	90	5.70	95
RockStar	6.26	107	6.67	109	6.65	111	5.47	120	3.93	107	3.90	116	2.46	107	4.89	118	6.41	107

Table 1. Eyre Peninsula 2022 NVT wheat trial yields in t/ha and expressed as a percentage of the site mean. (Continued).

Region	**Lower EP**				**Upper EP**													
Nearest Town	**Rudall**		**Wanilla**		**Kimba**		**Minnipa**		**Mitchellville**		**Nunjikompita**		**Penong**		**Piednippie**		**Warramboo**	
Variety Name	**t/ha**	**%**	**t/ha**	**%**	**t/ha**	**%**	**t/ha**	**%**	**t/ha**	**%**	**t/ha**	**%**	**t/ha**	**%**	**t/ha**	**%**	**t/ha**	**%**
Scepter	6.02	103	6.36	104	5.80	97	4.89	107	3.35	91	3.39	101	2.27	98	4.40	106	6.38	107
Sheriff CL Plus	5.23	90	5.67	93	5.90	99	4.99	110	3.32	90	3.67	109	2.14	93	4.24	102	5.79	97
Sunblade CL Plus	5.84	100	6.04	99	6.23	104	5.06	111	4.13	112	3.44	102	2.64	115	4.33	104	6.40	107
Sunmaster	6.05	104	6.21	102	6.31	106	4.66	102	3.41	93	3.51	104	2.18	95	4.23	102	6.44	108
Valiant CL Plus	5.95	102	5.83	96	6.04	101	4.40	96	4.05	110	3.66	109	2.50	109	4.14	100	5.80	97
Vixen	6.11	105	6.67	109	6.95	116	5.02	110	3.64	99	3.48	103	2.63	114	4.23	102	6.33	106
Yitpi	5.47	94	5.79	95	5.98	100	3.96	87	4.54	124	3.19	95	2.25	98	3.88	94	5.32	89
Zen	5.76	99	5.51	90	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Site Mean (t/ha)	**5.84**		**6.10**		**5.98**		**4.56**		**3.68**		**3.36**		**2.30**		**4.14**		**5.97**	
CV (%)	2.77		7.07		2.89		2.93		5.02		3.05		3.22		3.33		2.50	
Probability	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001	
LSD (t/ha)	*0.27*		*0.71*		*0.30*		*0.23*		*0.32*		*0.18*		*0.13*		*0.25*		*0.26*	
Sowing Date	24/05/2022		16/05/2022		10/05/2022		05/05/2022		09/05/2022		10/05/2022		29/04/2022		06/05/2022		26/05/2022	

Cereals

Table 2. Eyre Peninsula 2022 NVT barley trial yields in t/ha and expressed as a percentage of the site mean.

Region	Lower EP				Upper EP							
Locality	**Wanilla**		**Wharminda**		**Darke Peak**		**Elliston**		**Minnipa**		**Piednippie**	
Variety Name	**t/ha**	**%**	**t/ha**	**%**	**t/ha**	**%**	**t/ha**	**%**	**t/ha**	**%**	**t/ha**	**%**
Alestar	5.92	99	5.43	93	7.06	98	7.07	104	3.82	83	4.43	90
Beast	5.55	93	5.75	99	7.07	99	6.72	99	4.89	106	4.90	100
Bottler	5.91	99	6.00	103	-	-	-	-	-	-	-	-
Buff	5.89	99	5.64	97	6.70	93	6.00	88	3.36	73	4.31	88
Combat	6.37	107	6.44	111	7.76	108	7.20	105	4.93	107	5.54	113
Commander	5.75	96	5.44	94	7.16	100	5.89	86	4.81	104	5.00	102
Commodus CL	5.57	94	5.42	93	6.89	96	6.04	88	4.20	91	4.26	87
Compass	5.30	89	5.70	98	7.23	101	6.41	94	3.96	86	4.14	84
Cyclops	6.10	102	5.80	100	7.16	100	7.35	108	4.94	107	5.26	107
Fandaga	6.37	107	6.48	111	-	-	-	-	-	-	-	-
Fathom	6.00	101	5.57	96	6.57	92	6.68	98	5.24	114	4.51	92
La Trobe	5.43	91	5.61	96	6.28	88	6.55	96	3.71	80	4.79	98
Laperouse	6.22	104	5.84	100	7.33	102	6.59	97	5.07	110	4.45	91
Leabrook	6.17	104	5.76	99	7.39	103	6.59	97	4.35	94	4.22	86
Maximus CL	6.09	102	5.57	96	6.52	91	7.40	108	4.07	88	4.75	97
Minotaur	6.64	111	6.15	106	8.08	113	7.91	116	5.31	115	5.66	116
RGT Planet	6.52	109	6.49	112	8.18	114	7.81	114	4.85	105	5.56	113
Rosalind	6.61	111	6.19	106	7.29	102	8.12	119	4.77	103	5.61	115
Scope CL	-	-	-	-	6.01	84	5.80	85	3.98	86	4.70	96
Spartacus CL	5.00	84	5.49	94	6.64	93	6.17	90	4.42	96	4.53	93
Titan AX	6.00	101	5.74	99	7.71	108	6.59	96	4.80	104	4.74	97
Yeti	5.97	100	5.79	100	6.89	96	6.62	97	4.74	103	5.06	103
Zena CL	6.26	105	6.03	104	8.30	116	7.59	111	4.92	107	5.37	110
Site Mean (t/ha)	**5.96**		**5.81**		**7.17**		**6.83**		**4.62**		**4.90**	
CV (%)	*6.40*		*2.99*		*3.77*		*3.24*		*4.63*		*5.06*	
Probability	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001	
LSD (t/ha)	*0.63*		*0.29*		*0.47*		*0.38*		*0.35*		*0.42*	
Sowing Date	16/05/2022		13/05/2022		26/05/2022		11/05/2022		5/05/2022		6/05/2022	

Table 3. Eyre Peninsula 2022 NVT early season wheat trial yields in t/ha and expressed as a percentage of the site mean.

Region	**Upper EP**	
Nearest Town	**Minnipa**	
Variety Name	**t/ha**	**%**
Catapult	4.59	97
Coota	4.64	98
Cutlass	4.80	101
Denison	5.33	112
DS Bennett	5.18	109
DS Pascal	5.06	107
EG Titanium	4.38	92
EGA Wedgetail	4.13	87
Illabo	4.58	96
Longsword	3.17	67
LRPB Bale	4.39	92
LRPB Nighthawk	4.84	102
RockStar	4.64	98
Sheriff CL Plus	3.94	83
Stockade	5.91	124
Valiant CL Plus	4.37	92
Yitpi	4.62	97
Site Mean (t/ha)	**4.75**	
CV (%)	2.40	
Probability	<0.001	
LSD (t/ha)	*0.19*	
Sowing Date	19/04/2022	

Cereals

Growing high quality oaten hay

Alison Frischke[1] and Courtney Peirce[2,3]
[1]Birchip Cropping Group (BCG); [2]SARDI; [3]University of Adelaide

Location
Nullawil, VIC
Ferrier Family
Rainfall
Av. Annual: 352 mm (Nov-Oct)
Av. GSR: 236 mm
2022 Total: 497 mm (Nov-Oct)
2022 GSR: 384 mm, decile
Yield
Potential: Oaten hay
Actual: GS61 4.5 t/ha, GS71 6.4 t/ha
Paddock history
2021: Lentils
Soil type
Sandy clay
Soil test
pH: 0-10 cm: 8.6, 10 - 100 cm: 8.9 - 9.8 Deep N (0-100 cm): 80 kg N/ha
Plot size
10 m x 6 rows
Trial design
Completely randomised
Yield limiting factors
Winter moisture stress

Key messages

- **In 2022, which was characterised by a wet spring, mid-quick Koorabup and longer season varieties Kingbale, Wintaroo and Wallaby had the highest hay yields when cut at the watery ripe growth stage.**
- **Increasing oaten hay plant density can promote finer stems but may not increase hay yields.**
- **60kg of applied N has been sufficient to maximise hay yields when soil N levels are >70-80kg N/ha. Higher rates may be beneficial when soil N levels are low or wanting to reserve soil N for the following crop.**
- **Research has shown hay quality is maintained for longer as hay crops mature in soft, wet springs compared to dry finishes.**

Why do the trial?

The aim of the trial was to evaluate how yield and quality of oaten hay are affected by variety and plant growth stage at cutting, sowing rate, and nitrogen (N) rate and application timing.

Preferred hay quality characteristics - visual, physical and chemical - and their target values, vary widely due to buyer and customer demand differences. Careful planning and attention to hay crop agronomy, testing hay quality and understanding buyer needs, are central to achieving the parameters sought for the desired appearance, nutrient content and subsequent livestock intake required by target markets.

We know how to maximise hay biomass using a range of management tools, but until recently we knew less about the effect of those yield drivers on hay quality, particularly for newer varieties.

For the past four seasons, the AgriFutures Export Fodder Program has been supporting National Hay Agronomy research across Australia to develop our understanding of how the different agronomic levers affect oaten hay yield and quality. Additional research has been supported by BCG members through their membership.
In Victoria, BCG hosted agronomy trials at Kalkee, Rupanyup, Curyo and Wallup. Results from 2022 at Nullawil (available at time of reporting) and summarised findings from the 2019-2021 trials are discussed.

How was it done?

Replicated field trials were sown with completely randomised designs at Nullawil in the southern Mallee of Victoria. Across trials, target plant density was 320 plants/m^2, except for the plant density treatments.

Treatments are presented for Variety x cutting growth stage (4 reps) in Table 1, Variety x plant density (4 reps) in Table 2, and Nitrogen rate and timing (3 reps) in Table 3.

The trial was sown on 9 May 2022 with knife points + splitter boot (70 mm split) and press wheels at 30 cm row spacing.

All treatments received Granulock® Supreme Z + Flutriafol (400 ml/100 kg) @ 60 kg/ha at sowing.

Variety (V) x growth stage (GS) and Variety x plant density (PD) treatments were top-dressed with 120 kg/ha of urea at GS13 (3 June).

N rate and N timing x rate treatments had urea top-dressed at sowing, mid-tillering (6 weeks after sowing), early (GS31) or late (GS37-39) stem elongation, at rates that met the N treatment amounts (as per Table 3).

The trial was managed as per best practice for herbicides, insecticides and fungicides.

Assessments included soil analysis and moisture, plant establishment, NDVI (data not shown), hay biomass at GS61 (V x GS trial only) and GS71 calculated from samples cut and dried in an oven, plant height, lodging, and stem diameter (V x GS and V x PD trials only). NIR (including DairyOne calibration) was being analysed at the time of writing and will be reported once data is available.

What happened?

2019 - 2021 Results

Trial reports for 2019, 2020 and 2021 research can be found in the corresponding year of the Eyre Peninsula Farming Systems Summary.

2022 Results

Measured in March, plant available water was 91 mm and soil N to 1m was 80 kg N/ha.

The 2022 growing season at Nullawil began after 39 mm rain fell in the second half of April, though little rain fell in the week before sowing on 9 May. Trials established evenly, but became moisture limited on the clay soil during winter. This stress was visible in the trial with leaf tipping across all varieties. For the first four months, rainfall was recorded frequently, but only eight rain events exceeded 4 mm. From 8 September, conditions improved, becoming very wet with regular rainfall for the rest of the month.

Crops recovered well with spring rain and the growing season grew to a decile 10, however hay yields were limited to an average of 6.4 t/ha by GS71 due to the timing of the rainfall and moisture stress experienced during winter.

Hay yield was affected by oaten hay variety, growth stage and N timing, but not N rate or sowing rate. Physical hay characteristics were affected by variety, cutting growth stage and plant density.

Variety and cutting growth stage

Hay yield responded to variety and growth stage at cutting time. Despite differences in maturity, all varieties responded similarly to the time of cutting (no interaction effects).

Oat crops cut early at the start of flowering (GS61) averaged 4.5 t/ha across varieties but panicles were not fully emerged. Wintaroo and Kingbale yielded highest, closely followed by Wallaby and Kultarr.

Crops cut at the standard cutting time of watery ripe (GS71), when panicles were further emerged, benefited greatly from the delay in cutting date, averaging 6.4 t/ha. Hay yield was highest for varieties previously shown to have a slower development speed. These were Wintaroo and Kingbale, Koorabup a mid-maturing variety and the new variety Wallaby, which all yielded 7 t/ha or more at GS71 (Figure 1). Kultarr, Brusher and Yallara also yielded similarly, achieving more than 6.5 t/ha.

Plant height was influenced by both variety and cutting growth stage, with varieties responding differently to the cutting growth stage. At GS61 Kingbale and Wintaroo were noticeably taller than other varieties, reaching 74 cm, then Brusher grew quickly to reach a similar height by GS71, with Kingbale reaching 98 cm, Wintaroo 94 cm and Brusher 92 cm.

Kingbale and Wintaroo also had wider stem diameter, but Brusher was 0.5 cm finer. Stem width was influenced by cutting growth stage ($P < 0.001$), widening on average from 3.9 mm at GS61 to 4.4 mm by GS71. Stem widths of all varieties responded similarly to cutting time (no interaction) and were of good quality at less than 6 mm (Table 1).

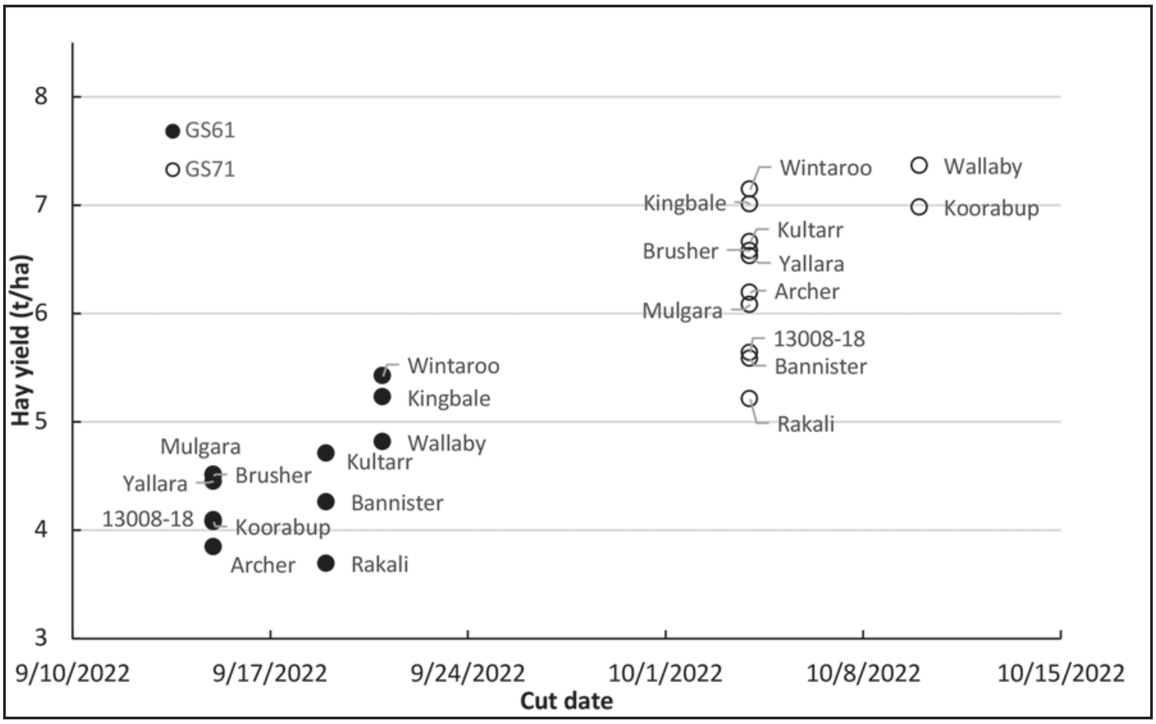


Figure 1. Oaten hay yield response to growth stage at cutting, Nullawil 2022.
Stats for varieties at GS61: P<0.001, LSD 0.6 t/ha, CV 9.5%
Stats for varieties at GS71: P<0.001, LSD 0.6 t/ha, CV 10%

Cereals

Plant density

Mulgara and Yallara were sown at the recommended plant density for hay of 320 plants/m^2 and compared to medium and lower densities at 220 plants/m^2 and 120 plants/m^2. The corresponding sowing rates are shown in Table 2.

For both varieties, establishment counts achieved the target plant density for lower densities 120/m^2 and 220/m^2 but didn't quite reach the desired plant density of 320 plants/m^2, possibly due to greater competition for moisture after sowing (Figure 2).

Plants compensated for lower plant densities with no plant density effect on hay yield, averaging 5.8 t/ha across the different sowing rates.

As plant density changed from 120 plants/m^2 to 220 plants/m^2, stems became 5.7 cm shorter and 0.5 cm finer. Since establishment didn't reach the desired target plant density for the higher sowing rate, there were no further changes to plant height or stem diameter at the highest sowing rate.

Nitrogen rate and timing

Nitrogen rate

There was no response in oaten hay biomass or plant height to increasing N rates from 20 to 90 kg/ha applied to Mulgara in 2022. This is unsurprising due to the moisture stress experienced during stem elongation limiting hay yields and N mineralisation during winter. The crop was unlikely to have been nitrogen limited as the available soil N in March was 80 kg N/ha to a depth of 1m following a relatively poor lentil crop in 2021, although rain in April could have mineralised further N before sowing.

Table 1. Oaten hay variety height and stem diameter response to growth stage, Nullawil 2022.

Variety	**Variety characteristics**[1]			**Height (cm)**		**Stem diameter (mm)**
	End use	**Height**	**Maturity**	**GS61**	**GS71**	
13008-18[2]	-	-	-	46.0	62.5	3.8
Archer	Imi tolerant, Hay	Medium	Mid	53.2	72.3	4.2
Bannister	Milling	Tall dwarf	Quick	47.5	58.3	4.3
Brusher	Hay/Grazing/ Feed grain	Tall	Quick	58.5	91.8	3.9
Kingbale	Imi tolerant, Hay	Tall	Mid-Slow	74.4	97.8	4.4
Koorabup	Hay	Mod tall	Mid-Quick	55.6	78.3	3.8
Kultarr	Hay	Tall	Mid-Quick	63.0	85.4	3.8
Mulgara	Hay/Feed grain	Tall	Quick	61.0	83.7	4.2
Rakali	-	-	-	46.3	58.8	4.2
Wallaby	Hay	Mod tall	Mid-slow	54.9	71.9	3.9
Wintaroo	Hay/Grazing	Tall	Mid	74.3	94.0	4.4
Yallara	Milling/Hay	Mod tall	Quick	58.9	81.7	4.1
Sig diff.						
Variety				<0.001		4.0
Growth stage				<0.001		1.6
Variety x Growth stage				<0.001		5.6
LSD (P=0.05)						
Variety				0.003		0.4
Growth stage				<0.001		0.2
Variety x Growth stage				NS		NS
CV%				5.9		9.3

[1]Brown S (Ag Vic), 2022, 2023 Victorian and Tasmanian Crop Sowing Guide
[2]Intergrain breeding line

Table 2. Sowing rates of Mulgara and Yallara oats, Nullawil 2022.

Hay variety	1000 grain weight (g)	Plant density treatment	Target plant density (plants/m²)	Sowing rate (kg/ha)
Mulgara	35.1	Low	120	50
		Medium	220	92
		High	320	133
Yallara	33.5	Low	120	47
		Medium	220	87
		High	320	126

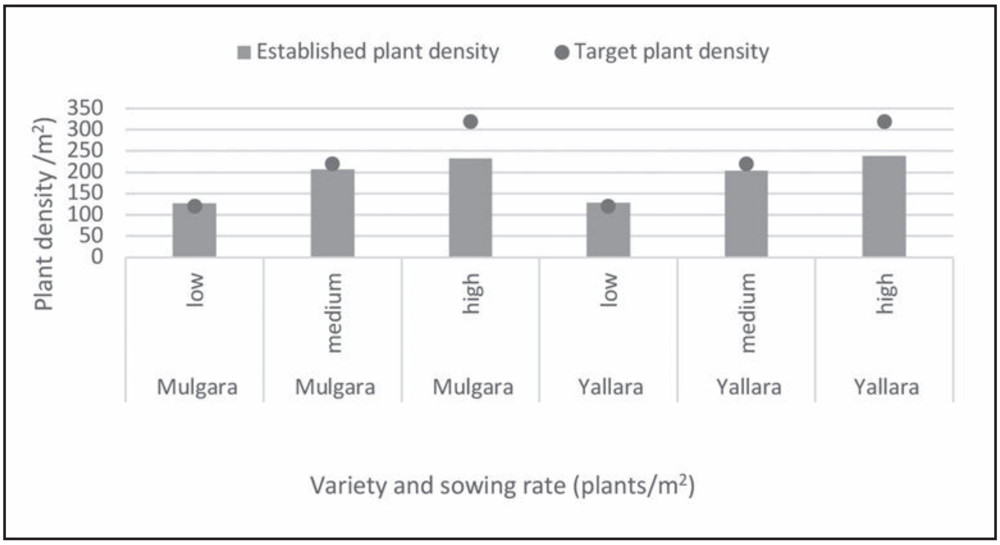


Figure 2. Target and established plant densities for Mulgara and Yallara oats, Nullawil 2022.

Nitrogen rate and timing

There were no differences in hay yields when the 60 or 90 kg N/ha rates were applied to Mulgara, but there was a hay yield response to the application timing (Table 3).

Applying N at the start of stem elongation offered a yield benefit over applying it all upfront, likely due to the timing of in-season rainfall. Applying N very late (flag leaf emergence) didn't offer a yield benefit, but we are interested to see if delaying the in-crop N application can change the protein quality of hay.

There were no plant height responses to N treatments and stem thickness was not measured due to funding limitations.

What does this mean?

To determine hay quality, visual indicators such as hay colour, stem thickness, texture and smell, are combined with feed testing measures to determine palatability, animal intake and performance. Generally, high quality hay has soft textured, thin stems (<6mm), with high water-soluble carbohydrates (WSC) >22%, crude protein (CP) >4-10%, metabolisable energy (ME) >9.5 MJ ME/kg DM, and is low in fibre (require NDF <50-57% and ADF <27-35%).

The following summarises some of the key lessons about varieties and agronomic levers on hay quality relevant to Victorian growers from the National Hay Agronomy research conducted across 2019 to 2022.

Nitrogen rate and timing
Nitrogen rate

There was no response in oaten hay biomass or plant height to increasing N rates from 20 to 90 kg/ha applied to Mulgara in 2022. This is unsurprising due to the moisture stress experienced during stem elongation limiting hay yields and N mineralisation during winter. The crop was unlikely to have been nitrogen limited as the available soil N in March was 80 kg N/ha to a depth of 1m following a relatively poor lentil crop in 2021, although rain in April could have mineralised further N before sowing.

Nitrogen rate and timing

There were no differences in hay yields when the 60 or 90 kg N/ha rates were applied to Mulgara, but there was a hay yield response to the application timing (Table 3).

Table 3. Hay yield response to N application timing, Nullawil 2022.

N timing treatment	Proportion and timing of N application				Hay yield (t/ha)
	Sowing 9 May	6 WAS 20 June	GS31 3 August	GS37-39 6 September	
All upfront	1	0	0	0	6.7[b]
Standard hay	2/3	1/3	0	0	7.0[ab]
Late	2/3	0	1/3	0	7.4[a]
Very late	2/3	0	0	1/3	6.5[b]
Sig. diff.					0.02
LSD (P=0.05)					***0.5***
CV%					6

Applying N at the start of stem elongation offered a yield benefit over applying it all upfront, likely due to the timing of in-season rainfall. Applying N very late (flag leaf emergence) didn't offer a yield benefit, but we are interested to see if delaying the in-crop N application can change the protein quality of hay.

There were no plant height responses to N treatments and stem thickness was not measured due to funding limitations.

What does this mean?

To determine hay quality, visual indicators such as hay colour, stem thickness, texture and smell, are combined with feed testing measures to determine palatability, animal intake and performance. Generally, high quality hay has soft textured, thin stems (<6mm), with high water-soluble carbohydrates (WSC) >22%, crude protein (CP) >4-10%, metabolisable energy (ME) >9.5 MJ ME/kg DM, and is low in fibre (require NDF <50-57% and ADF <27-35%).

The following summarises some of the key lessons about varieties and agronomic levers on hay quality relevant to Victorian growers from the National Hay Agronomy research conducted across 2019 to 2022.

Variety

- Dual-purpose variety Yallara (quick) was the best performing of 10 varieties, with comparable hay yield to the specialist hay varieties, Brusher (quick) and Wintaroo (mid maturing), but better quality. Yallara had the highest WSC and lowest ADF and NDF fibre levels, combined with thin stems. Note, as you head south from the southern Mallee to the medium rainfall Wimmera, Yallara becomes a bit too quick in better seasons.
- The new specialist hay variety, Koorabup (mid-quick), was generally disappointing when benchmarked against Brusher, yielding 0.5t/ha lower, and a higher ADF and NDF risk, lower WSC, but similar hay greenness and stem diameter.
- The release of Imi-tolerant varieties Kingbale (mid-slow) and Archer (mid) has offered oaten hay growers an option for weed control for brome and barley grass (IBS application only), or to sow into stubble containing Imi-residues.
- Other new hay varieties to watch include Kultarr (quick-mid) and Wallaby (mid-slow). Kultarr offers a taller height for the lower-rainfall regions whilst Wallaby has shown consistent high qualityand maintains good yields.
- Hay quality was high across all varieties and seasons in Victoria and South Australia, but was more variable in other regions where large yields and fibrous stems reduced quality.

Time of sowing

- In general, earlier sowing increased the crop water use efficiency and opportunity to maximise hay yields, but does not always maximise hay quality.
- Variety response to sowing date was variable and not easily predicted before the season started or when the crop was planted.
    - In a season with a dry spring, crops sown earlier yielded higher, with faster varieties Brusher, Mulgara, Yallara, and the mid-maturing Wintaroo yielding better
    - For good spring years, delaying sowing until the end of May grew more hay when autumn was wet but winter was dry. However, if autumn was dry but the winter was wet, the time of sowing did not affect hay yield. In a season with a softer spring, longer season varieties like Wintaroo performed better.
- Due to variable seasons and inconsistencies between years, conclusions about the variety and sowing date interactions on hay quality were hard to make.

Nutrient management – N rate

- Nitrogen drives more biomass, taller plants, and can increase the risk of lodging in susceptible regions and seasons.
- Varieties responded the same to changing N (0-150 kg N/ha) rates, across a range of seasons.
- The tipping point for yield was 90N across Australia, although 60 N was adequate when sites received below-average rain during critical periods, or if soil N was >80kg N/ha.
- The season and variety were generally a larger factor in determining hay quality than the rate of N applied, except for CP which increased, and WSC which decreased with increasing N.
- Applying more than 90 kg N/ha increased the risk of not meeting industry WSC limits for premium hay of more than 22 per cent. Fortunately, in Victorian trials >90 kg N/ha dropped WSC but it still remained >25 per cent.
- Protein rose with increasing N rate from about 5.5 to 8.5 per cent – this is still in livestock maintenance range at higher N levels.

- Even though varieties responded the same, variety choice still determines how much N can be applied. Varieties with the highest inherent hay quality will allow you to maximise hay yield and returns driven by higher fertiliser N rates. Planting varieties with lower hay quality, particularly WSC, limits how much N can be applied before quality drops and discounting occurs.
- N management requires early decisions – understand soil moisture and soil N at sowing to decide on an appropriate rate. The least risk N strategy for hay is to sow with starter N and then by six weeks being able to respond with in-crop N (two-thirds at sowing, one-third in-crop) to a seasonal outlook that is hopefully increasing in confidence.

Cut timing

- At watery ripe, GS71 is considered the ideal cutting time for optimising yield and achieving quality targets for cereal hay. In reality, considering logistics and weather, it can be challenging to cut hay at exactly GS71 – 2022 was a perfect example where weather conditions stopped some growers accessing paddocks for cutting on time.
- From trials in 2020 we found if spring growing conditions became water limited, WSC, ADF, NDF and leaf chlorophyll were maintained between GS59 (full panicle emergence) and GS71, but deteriorated as crops matured past GS71. CP declined progressively after growth stage Z59. Waiting for the increase in yield can be outweighed by lower quality, causing overall return per hectare to fall.
- Quality didn't decline as rapidly past GS71 if spring conditions were wet and mild.
- Aim to cut after full head emergence GS59 and by watery ripe GS71. Cutting in this window helps minimise curing time before quality starts to rapidly decline. Cutting before full head emergence, as occurred in 2022 for the GS61 cut (when the panicles had started flowering), can lead to increased curing time due to moisture pockets when panicles are stuck in the boot.

Sowing rate/Target plant density

- To target higher quality oaten hay, the crop should be set up at the beginning of the season with higher target plant densities than grain-only crops.
- As plant density increases, hay yield is maintained or may improve, and stem diameter can reduce improving quality. Both responses depend on the seasonal conditions, however our trials have not shown reductions in yield or quality with increasing plant density.

Acknowledgements

This research was part of the 'National Hay Agronomy project' extension year, funded by the AgriFutures™ Export Fodder Program. It is a southern Australia collaboration between South Australian Research and Development Institute (SARDI), BCG and the Hart Field Site Group.

The sowing rate trial was supported by BCG members through their membership.

Results summarised in the Commercial Practice section were from the 'National Hay Agronomy' project PRJ 011029 funded by the AgriFutures™ Export Fodder Program. This was a collaboration between the Department of Primary Industries and Regional Development (DPIRD) in WA, South Australian Research and Development Institute (SARDI), Agriculture Victoria, New South Wales Department of Primary Industries (NSW DPI) and grower groups BCG and Hart Field Site.

Utilising novel genetic diversity to increase barley yields

Anh-Tung Pham, Jason A. Able, and Julian Taylor
School of Agriculture, Food and Wine, University of Adelaide

Key messages

- **Wild barley can provide new genes to improve the yield of Australian barley.**
- **Twelve lines with genes transferred from wild barley yielded at least 5% higher than the Australian parents at more than four sites out of two sites across two years.**
- **Higher yields were associated with changes in maturity (early flowering time and quick maturity in low rainfall environment, and late flowering and late maturity in high rainfall environments) and higher harvest index.**
- **Selection for wild barley genes may improve barley yield and grain size.**

Why do the trial?

A previous GRDC-funded project (UA00148) identified genomic regions in wild barley that increased biomass, grain number per ear (2-4 grains/ear), and thousand-grain weight (up to 13%) under drought in controlled conditions. These beneficial wild barley genomic regions were backcrossed into Compass, LaTrobe, and GrangeR using molecular markers linked to the traits to develop experimental lines. Field trials were conducted to examine whether the wild barley genetics improve the yields in these lines with Australian genetic background, and if there are any unwanted traits associated with them. This project aims to conduct field validation of the effect of genomic regions from the wild barley on yield and drought tolerance as identified from the GRDC-funded project UA00148 in Australian genetic backgrounds, as well as developing a package of superior germplasm with the genomic regions from the wild barley conditioning enhanced drought tolerance and higher yield than the current Australian best varieties (Compass, RGT Planet, LaTrobe, GrangeR).

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 a wild barley line and three Australian varieties, which included 50 lines that derived from crosses with Compass, 33 lines from crosses with GrangeR, and 25 lines from crosses with LaTrobe. All lines were genotyped to confirm they carried the eight regions of interest from wild barley. The three chosen sites in 2020 were located in Bordertown, Roseworthy (RAC), and Tarlee, South Australia (Table 1).

In 2021, there were nine (9) yield trials sown across Australia with 4, 2, and 3 sites placed in South Australia (SA), New South Wales (NSW), and Western Australia (WA), respectively (Table 1). For the SA field trials in 2021, a set of 63 experimental lines and nine control varieties were selected for sowing if the yield data obtained from 2020 trials was higher or not statistically different from LaTrobe. Thirty five experimental lines with yield higher or not significantly different from those of Granger and Compass were selected for trials in WA and NSW, and they were a subset of the lines used for trials in SA. Trials in all states shared the same set of control varieties.

The experimental design was a randomized complete block design, with three replicates at each of the three sites. Eight traits were measured including flowering time (as days from sowing to Zadoks growth stage 49), plant height at maturity (HEI), lodging (LOD), grain number per ear (GPE), fertile tiller at harvest (TIN), thousand-grain weight (TGW), test weight (TW), harvest index (HI), and final grain yield. Additionally, disease scores for net form net blotch (NFNB), spot form net blotch (SFNB), and barley leaf rust (BLR) were also recorded.

Multi-environment trial statistical modelling analyses were conducted using the software package ASReml-R available in the R Statistical Computing Environment. The relative performance (RP), in terms of yield, of an experimental genotype was calculated as: RP = (Estimated yield of line - Estimated yield of backcross parent)/Estimated yield of backcross parent x 100%. This reflected the estimated percentage difference in terms of yield of an experimental line compared to its backcrossing parent.

What happened?

1. Overall performance and trait correlation

Across two years, Tarlee (SA) in 2020 was the environment with highest average yield while Minnipa (SA) in 2021 had the lowest yield (Figure. 1). Bordertown (SA) had the highest amount of rainfall during growing season (April-October, GSR) while Minnipa (SA) had the lowest.

There was no correlation between rainfall and mean grain yield across environments observed for these experiments, suggesting that soil fertility, management practices (i.e. sowing dates) and other environmental conditions had a greater influence than rainfall in determining grain yield in this experiment.

Genotype and genotype × environment interactions were both found to be significant for all traits (P<0.05) at all sites, except for Muresk (WA) in 2021. In both 2020 and 2021, disease incidences were mild and well-controlled by timely fungicide applications, therefore, the trials were quite clean of diseases.

The trend that shorter plants usually had higher yields was observed in most environments except for Merredin and Muresk in 2021 where taller plants yielded higher. In drier environments such as Minnipa and three sites in WA in 2021, higher-yielding genotypes flowered earlier to escape the heat and terminal drought stress. However, in high rainfall environments like Narrabri 2021 and those where trials were sown later than usual like Roseworthy, Tarlee, and Bordertown in 2021, late maturity genotypes yielded higher than the early flowering counterparts as the later the plants flower the more biomass they can accumulate.

2. Twelve lines that had greater than 5% improvement in grain yield (Relative performance > %) than the backcrossing parents at more than four tested environments

Across 2020-2021, 12 experimental lines yielded 5% or higher than the corresponding parents in at least four out of 10 tested environments (Fig. 2). Anh-27 had yields 5% or higher than that of its parent, Compass, at the most tested environments (n=6).

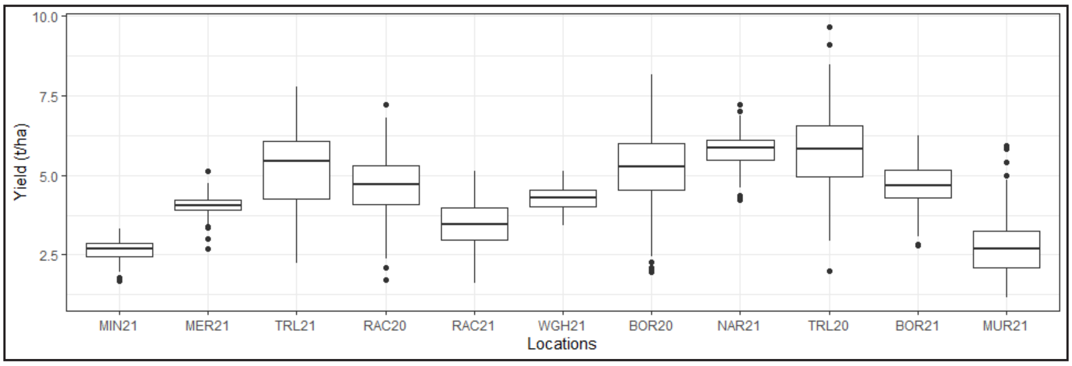


Figure 1. Boxplot showing grain yield across eleven sites in 2020-2021. The sites were ordered by the amount of growing season rainfall (GSR) received at each location in 2021 as the following: MIN21- Minnipa SA, 2021 (210 mm), MER21-Merredin WA, 2021 (240 mm), TRL21-Tarlee SA, 2021, (281 mm), RAC20- Roseworthy SA, 2020 (284 mm), RAC21- Roseworthy SA, 2021 (298 mm), WGH21- Wongan Hills WA, 2021 (310 mm), BOR20-Bordertown SA, 2020 (343 mm), NAR21- Narrabri NSW, 2021 (352 mm), TRL20- Tarlee SA, 2020 (353 mm), BOR21- Bordertown SA, 2021 (362 mm), MUR21- Muresk WA, 2021 (485 mm).

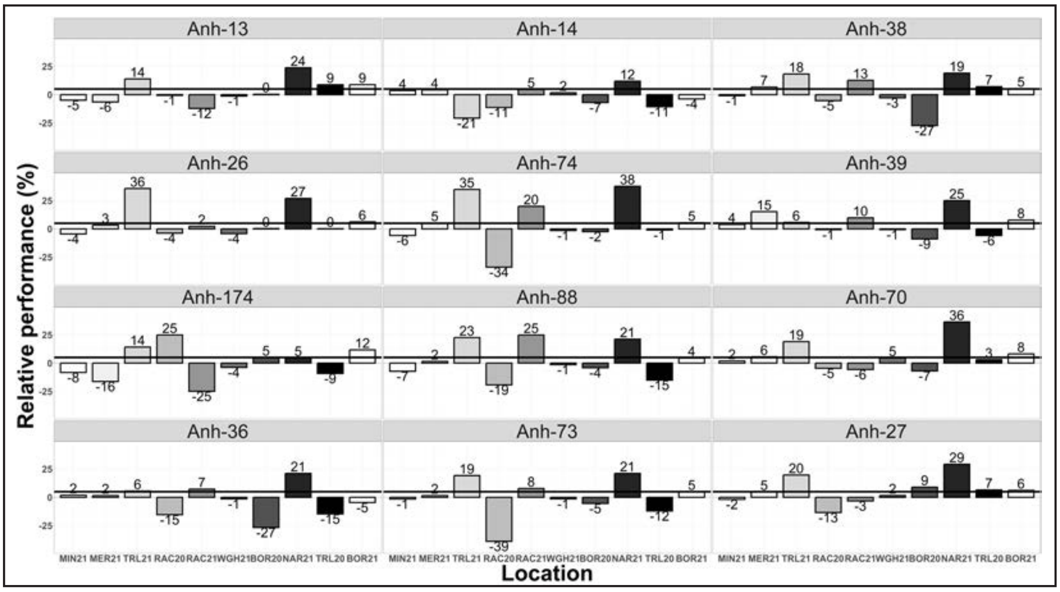


Figure 2. Barplot showing the relative performance (%) in term of yield of 12 experimental lines compared to their corresponding parents across 10 sites in 2020-2021. In the x-axis, the sites were ordered by the amount of growing season rainfall (GSR) received at each location in 2021 as the following: MIN21- Minnipa SA, 2021 (210 mm), MER21-Merredin WA, 2021 (240 mm), TRL21-Tarlee SA, 2021, (281 mm), RAC20- Roseworthy SA, 2020 (284 mm), RAC21- Roseworthy SA, 2021 (298 mm), WGH21- Wongan Hills WA, 2021 (310 mm), BOR20-Bordertown SA, 2020 (343 mm), NAR21- Narrabri NSW, 2021 (352 mm), TRL20- Tarlee SA, 2020 (353 mm), BOR21- Bordertown SA, 2021 (362 mm). Horizontal line indicates the threshold of 5% yield improvement.

In 2021, Minnipa (SA) was the experimental site that received the least GSR (210 mm) in two years with lines Anh-39 and Anh-14 having yields statistically indifferent from the highest-yielding line, Rosalind. In addition, they out-yielded RGT Planet by 2-5%. At this location, eight lines yielded 5% higher than RGT Planet, including Beast, Rosalind, Anh-39, Anh-14, Anh-70, Anh-75, Anh-120, and Anh-36. The consistent top performance of Anh-39 in the low rainfall environments tested in SA (Minnipa) and WA (Merridin) indicated that it could serve as a potential genotype for variety development in lower rainfall regions. In 2022, these two regions received nearly 300 mm of rainfall during the growing season which was 33% higher than the 20 year average, therefore, these two lines did not yield well compared to the lines, such as RGT Planet, that thrived in medium-high rainfall sites (data not shown).

At the Merredin site, which was the driest in WA, Anh-39 was the top-yielding line with yields 7% higher than Rosalind and Beast, 14% higher than RGT Planet, and 15% higher than its parent, Compass.

In 2021, in Narrabri (NSW), where the highest annual rainfall across all sites was received, Anh-74 had the highest yield, which was 1.2% higher than RGT Planet, although this was not statistically different. At Roseworthy (SA), Anh-88 was the top-yielding line with 5.6% higher yields than Beast, 11% higher than RGT Planet, and 25% higher than Compass.

At the remaining sites, RGT Planet was most often the highest-yielding line. However, there were always lines whose yields were only 1-3% lower than RGT Planet. It is noteworthy that the lower yields of Compass and RGT Planet in 2021 compared to 2020 in SA could be attributed to the later sowing of 2021 trials. To uncover the mechanism underlying the significant increase in yields in the 12 lines depicted in Fig. 2, the differences in 10 traits of these 12 lines compared to their corresponding parents were calculated. The data indicated that Anh-36, Anh-38, Anh-39, and Anh-70 flowered 2-3 days earlier than Compass, while most of the other lines flowered 5-6 days later than their corresponding parents. These 12 lines also had improved HI compared to their parents in most environments.

3. The effect of genomic regions from wild barley that improved grain number per ear (GPE) and thousand grain weight (TGW)

A number of lines that were selected based on the genes associated with grains per ear and thousand grain weight showed improvements in these traits, compared to their parents across all the sites in both years. In some cases, this led to improved yields.

Among four genes from wild barleys that enhanced GPE, only one on chromosome 4H had a strong and consistent effect in both 2020 and 2021. Four lines carrying this gene, Anh-20, Anh-26, Anh-27, and Anh-109, showed a GPE improvement at all environments across two years. The most improvements in GPE were seen in Anh-20 and Anh-27, with up to 2.5 more grains per ear (spike) compared to Compass. Among these lines, only Anh-27 exhibited a yield improvement effect at six out of ten environments.

Lines Anh-117, Anh-62, and Anh-125, who carried two TGW improving genes from wild barley had TGW higher than their corresponding parents in 9 of 11 environments. However, these differences were not large enough to be statistically significant. Among these lines, only Anh-125 showed yield improvements compared to its parent at two sites in 2020. Anh-69 had higher TGW than Compass in all 11 environments across two years, at five of which the differences were statistically significant. The performance and stability of TGW in Anh-69 was comparable with Beast. Furthermore, its yield performance was indifferent to Beast and more than 5% higher than Compass at Narrabri and Merredin in 2021. Another line that showed to have high TGW in 2020's trials, Anh-129, did not yield well in 2021 as it was usually in the lowest yielding three lines in all environments.

What does this mean?

Germplasm carrying genomic regions from wild barley allele that outyielded current benchmark control varieties of more than 5% were identified at some of the tested environments. The effect of the genomic regions from wild barleys was validated in three Australian genetic backgrounds, which will help private breeding programs move forward with confidence in utilising such materials. Whether germplasm developed in this project will be further refined before potential commercialisation and/or incorporated into their crossing program as parental stocks for early-mid generation germplasm enrichment will ultimately be at their discretion.

In providing reasonably adapted germplasm to Australia's barley breeders with potential yield enhancement, this project, therefore, contributed to ensuring that Australian barley growers have enduring profitability longer term.

Acknowledgements

The authors would like to thank Alistair Pearce and Ranjit Das, for their technical assistance with sowing, harvesting, and management of the field trials, and Linh Hoang Pham, Hue Thi Dang, and Hoa Thanh Nguyen for measuring and phenotyping in both field, and laboratory conditions. Thank you to the Minnipa Agricultural Centre staff for sampling and processing the Minnipa field trial. This study is being invested through the Grains Research and Development Corporation (Project ID 9177976).

Trial information

See Table 1.

Table 1. Trial information for two years 2020-2021.

Year	2020			2021								
Locations	Roseworthy (SA)	Tarlee (SA)	Bordertown (SA)	Minnipa (SA)	Roseworthy (SA)	Tarlee (SA)	Bordertown (SA)	Nowley (NSW)	Narrabri (NSW)	Merredin (WA)	Muresk (WA)	Wongan Hills (WA)
Sowing date	15-May	7-May	20-May	21-May	24-May	25-May	3-Jun	21-May	17-May	25-May	12-May	17-May
Harvest date	25-Nov	16-Nov	1-Dec	15-Nov	27-Nov	28-Nov	12-Dec	Aborted	4-Dec	28-Nov	11-Nov	19-Nov
Number of plots	264	264	264	180	180	180	180	132	132	132	132	132
Number of lines tested	108	108	108	63	63	63	63	32	32	32	32	32
Number of control varieties	12	12	12	9	9	9	9	9	9	9	9	9
Plot size	1.3 x 5.5 (m)	1.3 x 5.5 (m)	1.3 x 5.5 (m)	1.52 x 6 (m)	1.3 x 5.5 (m)	1.3 x 5.5 (m)	1.3 x 5.5 (m)	2 x 6 (m)	2 x 6 (m)	1.61 x 10 (m)	1.61 x 10 (m)	1.61 x 10 (m)
Trial design	RCBD 3 reps	RCBD 3 reps	RCBD 3 reps	RCBD 3 reps	RCBD 3 reps	RCBD 3 reps	RCBD 3 reps	RCBD 3 reps	RCBD 3 reps	RCBD 3 reps	RCBD 3 reps	RCBD 3 reps
Soil type	Calcareous loam	Calcareous loam	Brown and grey cracking clay	Reddish brown sandy loam	Calcareous loam	Calcareous loam	Brown and grey cracking clay	Basaltic	Brown and grey cracking clay	Alkaline red brown clay loam	Brownish grey loamy	Yellow loamy
Annual rainfall (mm)	337	427	484	358	404	371	431	824	896	342	638	428
Growing season rainfall (GSR)	284	353	343	210	298	281	362	349	352	240	485	310
Average yield (t/ha)	5.43	6.44	6.27	2.6	3.4	5.2	4.6	NA	5.8	4.1	2.8	4.3
Yield limiting factor	Leaf rust (mild)	NA	Frost and snail	Boron toxicity	Insects	NA	Snail	Flood	NA	NA	NA	NA

Section Editor:

Fiona Tomney

SARDI

Section 5

Weeds

Improving the management of Group 1 resistant barley grass in Eyre Peninsula farming systems

Amanda Cook[1,2], Ian Richter[1], Craig Standley[1] and Sharon Nielsen[3]

[1]SARDI; [2]University of Adelaide; [3]Sharon Nielsen Statistical Consulting and Training.

Location
Mount Cooper
Rainfall
Av. Annual: 411 mm
Av. GSR: 326 mm
2022 Total: 478 mm
2022 GSR: 346 mm
Soil type
Red loam
Paddock history
2022: Wheat
2021: Self-regenerating medic pasture
2020: Wheat
Plot size
10 m x 1.7 m x 3 replicates

Location
Minnipa S3
Rainfall
Av. Annual: 325 mm
Av. GSR: 241 mm
2022 Total: 529 mm
2022 GSR: 332 mm
Soil type
Red sandy loam
Paddock history
2022: Hay cut - Barley
2021: Wheat
2020: Canola
Plot size
10 m x 1.7 m x 3 replicates

Key messages

- **New herbicides with different chemistries will provide future opportunities for grass weed management.**
- **Clear separation of herbicide and seed is important when using Luximax®; greater than 3 cm crop sowing depth is needed to ensure crop safety and adequate crop establishment.**
- **There was very little bleaching from Overwatch® at either site in 2022.**
- **Mateno Complete® has an early post sowing option which may provide an additional early management option for grassy paddocks in wheat when partnered with an adequate pre-emergent herbicide.**
- **Sakura® is still a good option for barley grass weed control in cereals.**

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 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.

The research reported in this article aims to assess the impact of new herbicides, rotations 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. It will also monitor several farmer paddocks where barley grass escapes have occurred and identify if environmental factors and management strategies are affecting the efficacy of current herbicides. This research paper covers the second season of a three-year research program.

How was it done?

New chemistries have recently been released for grass weed management. These new chemistries were compared against current herbicide options for barley grass weed management in 2021 and 2022. 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 crop safety comes from separation of the seed from the chemical layer. Registration does not include barley as crop damage is too severe for that crop.
- Mateno Complete® is a herbicide which has the active ingredients aclonifen 400 g/L (Gp 32), diflufenican 66 g/L (Gp 12), pyroxasulfone 100 g/L (Gp 15). It controls grass and broadleaf weeds in wheat and barley, with flexible IBS, or early post sowing applications, in wheat before growth stage Z23.
- Overwatch® is a new group 13 or Q herbicide whose active ingredient is 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.
- Ultro® 900 herbicide (Carbetamide 900 g/kg) is a new mode of action (Group 23) for grass weeds in all pulse crops. It is a residual pre-emergent solution to control annual ryegrass, barley grass and brome grass.
- Reflex® is a Group14 herbicide (Fomesafen 240 g/L) for broadleaf weed control in pulses, especially for hard-to-control broadleaf weeds such as turnip, Indian hedge mustard and sowthistle. It has a 9 month and 250 mm plant back period for cereals and pulses.

In 2021 a three-year rotational trial site with a cereal, pulse, two year break and IMI systems trial was established at Mount Cooper. For the 2021 trial details and management treatments refer to 'Improving the management of Group 1 resistant barley grass in Eyre Peninsula farming systems', EPFS Summary 2021, p.166.

In 2022 the previous 2021 pulse trial with treatments of either peas, vetch or medic was over sown with Scepter wheat on 2 May, with the treatments listed in Table 2. In 2022 the 2021 cereal herbicide trial of Scepter wheat was over sown with Butler Peas or annual strand medic on 3 May, with the treatments listed in Table 3. The two-year break systems were sown with a second year rotational break on 2 May, see Table 4. The IMI systems trial was sown on 3 May with IMI residue tolerant cereals with treatments listed in Table 5.

A further herbicide trial on cereal was sown at Minnipa Agricultural Centre on 4 May with Scepter wheat @ 75 kg/ha. At Minnipa plant establishment was assessed on 5 July, early dry matter and grass weed measurements on 13 July. Late dry matter and grass weed assessments were taken on 6 October. The trial was harvested on 24 November.

Trial 1. Controlling grass weeds in cereals, 2022 - Mount Cooper and Minnipa

Scepter 75 kg/ha with MAP @ 60 kg/ha. Knockdown herbicide: Weedmaster 470 @ 2 L/ha. Herbicide treatments are listed in Tables 1 and Table 2.

Trial 2. Break crops

Butler peas @ 85 kg/ha or Seraph strand medic (PM-250) @ 7.5 kg/ha, both with MAP @ 60 kg/ha.

Knockdown herbicides: Weedmaster 470 @ 2 L/ha and pre sowing Trifluralin @ 2 L/ha, except nil control.

Trial 3: Two-year break

Studencia vetch @ 65 kg/ha, Seraph strand medic (PM-250) @ 7.5 kg/ha, Canola ATR-Stingray @ 3 kg/ha or Kingbale Oats @ 85 kg/ha (haycut), all with MAP @ 60 kg/ha.

Knockdown herbicides: Weedmaster 470 @ 2 L/ha and pre sowing Trifluralin @ 2 L/ha, except Kingbale Oats.

Trial 4: IMI system

Razor CL wheat, Spartacus CL barley @ 75 kg/ha or Kingbale Oats @ 85 kg/ha (haycut), all with MAP @ 60 kg/ha. Knockdown herbicide: Weedmaster 470 @ 2 L/ha.

At Mount Cooper plant establishment and early grass weed numbers were assessed on 16 June, early dry matter was measured on 4 July. Mid season weed numbers were assessed on 30 September. Late dry matter and grass weeds were assessed on 10 October. The trials were harvested on 7 and 8 November.

The Mount Cooper statistical analysis was undertaken by Sharon Nielsen and used a linear mixed model using restricted maximum likelihood to analyse the data using ASReml-R Butler (2009) and the R Core Team (2016) package biometry assist Nielsen *et al*. (2022). Due to lower than predicted barley grass weed numbers and the uneven coverage of barley grass weeds across the site, it was decided the background level of coverage in the plot from the previous year was to be used as a covariate in the model. The model had a fixed effect for the treatment and a random effect for block. Predicted values are presented and the Tukey's multiple comparison test is used to indicate rankings flagging statistical differences between treatments where the treatment was found to be significant in the model.

The Minnipa results were analysed using GENSTAT 64, Version 21, as a randomised complete block design with an ANOVA analysis.

Herbicide efficacy

During 2022 barley grass samples were collected from five paddocks on upper Eyre Peninsula and have been sent to a private laboratory to be tested for resistance to Clethodim herbicide at 500 ml/ha, and Clethodim @ 500 ml/ha + Butroxydim (Factor) @ 100 g/ha.

Dormancy

Barley grass seeds from 30 paddocks across upper EP were sown in shallow trays of soil at MAC in 2021 and will be assessed again in 2023 for length of seed dormancy and germination patterns.

What happened?

The 2022 season was an ideal growing season with stored soil moisture due to good February rains and an early seeding opportunity from a break of the season on 26 April. 2022 had above average rainfall for the year in most regions on the Eyre Peninsula and very little crop stress. Cool mild grain fill conditions supported high grain yields but reduced grain protein levels. Mount Cooper had decile 8 annual rainfall in 2022 and Minnipa a decile 9 growing season.

Trial 1. Controlling grass weeds in cereals

Both the Minnipa and Mount Cooper sites were sown into good soil moisture. At Minnipa average crop establishment was 130 plants/m^2, regardless of herbicide treatments (Table 1).

At Mount Cooper, lowest crop establishment occurred with Luximax (111 plants/m^2) and highest with Sakura (Table 2). In 2022 there was very little bleaching from Overwatch® at either site.

Early barley grass plant density was lower than in the nil control for all herbicide treatments except glyphosate only at Minnipa (Table 1). Treatments did not change early barley grass numbers at Mount Cooper which only averaged 5 plants/m^2 across the trial (Table 2).

At Minnipa, Luximax resulted in the lowest early dry matter of wheat with the Nil Control and the glyphosate the only treatments having higher early dry matter. Luximax also caused the lowest early dry matter at Mount Cooper with the highest occurring in the Nil Control and with Mateno®, following peas with Ultro® in 2021 (Table 2).

All treatments had similar levels of late barley grass and ryegrass density, barley grass weed seed heads or grain yield at Minnipa in 2022 with an average of six barley grass/m^2 and one ryegrass/m^2. Grain yields were well above average for Minnipa at 4.1 t/ha across the site regardless of treatments.

At Mount Cooper, wheat with Mateno Complete® following a 2021 application of Ultro® in either peas or vetch had lower late barley grass weed numbers than the Nil Control (Table 2). Wheat with Mateno Complete® following a 2021 medic hay freeze had substantially lower dry matter than wheat with Mateno Complete® following a vetch brown manure. Grain yields followed a similar pattern to late dry matter (Table 2).

Trial 2. Break crops

The break crop trial at Mount Cooper established well (Table 3). Early dry matter or early barley grass plant density were similar for all herbicide treatments applied on the pulses and medic. Mean early dry matter was 0.73 t/ha and the early barley grass density averaged 8.6 plants/m^2.

Peas with Trifluralin 2 L/ha following a 2021 wheat with Luximax® plus Avadex® had low barley grass weed numbers compared to peas with Trifluralin 2 L/ha following wheat on Sakura and peas with Trifluralin following Overwatch® plus Voraxar® (Table 3).

Annual strand medic had lower dry matter than Butler peas (Table 3). There were no differences between herbicide treatments for late barley grass density, barley grass weed seed heads or pea grain yield at Mount Cooper in 2022 with an average of 9 barley grass/m^2. Average pea grain yield was 5.6 t/ha.

Trial 2. Break crops

The break crop trial at Mount Cooper established well (Table 3). Early dry matter or early barley grass plant density were similar for all herbicide treatments applied on the pulses and medic. Mean early dry matter was 0.73 t/ha and the early barley grass density averaged 8.6 plants/m^2.

Peas with Trifluralin 2 L/ha following a 2021 wheat with Luximax® plus Avadex® had low barley grass weed numbers compared to peas with Trifluralin 2 L/ha following wheat on Sakura and peas with Trifluralin following Overwatch® plus Voraxar® (Table 3).

Annual strand medic had lower dry matter than Butler peas (Table 3). There were no differences between herbicide treatments for late barley grass density, barley grass weed seed heads or pea grain yield at Mount Cooper in 2022 with an average of 9 barley grass/m^2. Average pea grain yield was 5.6 t/ha.

Trial 3. Two-year break

This trial at Mount Cooper established well with all break crops achieving adequate plant numbers (Table 4). However, early dry matter of canola was lower than for Kingbale oats (Table 4).

Late barley grass numbers were high in the canola rotations. Late dry matter was higher in Kingbale oats and canola than in medic and vetch (Table 4). Vetch was brown manured in September with Glyphosate DST 2.5 L/ha and the Kingbale Oats was processed as a hay cut, so neither were harvested for grain. The were no differences in canola yields due to the herbicide treatments.

Table 1. Early wheat performance and barley grass numbers at Minnipa in 2022.
IBS – incorporated by sowing, PSPE – post sowing pre-emergent.

2022 Treatment	Crop establishment (plants/m^2)	Early barley grass (plants/m^2)	Early dry matter of wheat (t/ha)
Wheat - Nil Control	139	20.9 a	1.07 a
Glyphosate only	136	10.9 ab	1.02 a
Diuron 300 g and Metrabuzin 100 g	129	6.5 b	0.97 ab
Boxer® Gold 2.5 L/ha IBS	123	3.5 b	0.95 ab
Mateno Complete® 1 L/ha IBS	133	6.1 b	1.06 a
Trifluralin 1.8 L/ha plus Diuron	125	1.3 b	0.99 a
Sakura® (118 g/ha) IBS	133	2.6 b	0.98 ab
Trifluralin 2 L/ha	111	10.2 b	0.86 ab
Mateno Complete® 1 L/ha early post emergent (EPE)	144	0.4 b	0.75 b
Luximax® 500 ml/ha IBS (sown below 3 cm)	115	6.1 b	0.46 c
Overwatch® (1.25 L/ha)	146	6.1 b	0.92 ab
LSD (P=0.05)	*ns*	*10.6*	*0.24*

Table 2. Wheat performance and density of barley grass heads at Mount Cooper in 2022, adjusted for 2021 barley grass populations. Letters indicate Tukey's multiple comparison test between predicted model terms. Means followed by a common letter (within a column) are not significantly different by the Tukey's-test at the 5% level of significance. The adjusted means were predicted at the average barley grass population level for 2021 (17 plants/ m^2).

2022 Treatment	2021 Break Crop Chemical Treatment	Wheat establishment (plants/m^2)	Early Dry Matter of wheat (t/ha)	Late barley grass (heads /m^2)	Grain Yield of wheat (t/ha)
Wheat Nil Control	Vetch Control Trifluralin 1.8 L/ha	130 ± 5.5 abc	1.04 ± 0.1 b	21.01 ± 8.0 b	5.07 ± 0.15 ab
Mateno Complete® 1 L/ha IBS	Vetch Ultro® (1.1 kg/ha) plus propyzamide Rustler® 0.7 kg/ha	138 ± 5.8 abc	0.95 ± 0.1 ab	0.73 ± 0.3 a	5.59 ± 0.17 bc
Mateno Complete® 1 L/ha IBS	Vetch with Ultro® (1.1 kg/ha) plus Reflex® 500 gm/ha PSPE	148 ± 6.2 c	1.0 ± 0.1 ab	1.13 ± 0.4 a	5.35 ± 0.16 bc
Luximax® 500 ml/ha IBS	Vetch with Ultro® (1.1 kg/ha) plus Reflex® 500 gm/ha PSPE	114 ± 4.8 ab	0.65 ± 0.06 a	2.71 ± 1.04 ab	5.72 ± 0.17 bc
Luximax® 500 ml/ha IBS	Vetch with Ultro® (1.1 kg/ha)	111 ± 4.6 a	0.69 ± 0.07 ab	3.02 ± 1.15 ab	5.29 ± 0.17 bc
Mateno Complete® 1 L/ha IBS	Vetch propyzamide Rustler® 0.7 kg/ha	138 ± 5.8 abc	0.88 ± 0.09 ab	2.09 ± 0.83 ab	5.35 ± 0.16 bc
Mateno Complete® 1 L/ha IBS	Peas Terbyne® 850 ml/ha PSPE	140 ± 5.9 bc	1.03 ± 0.1 ab	0.62 ± 0.25 a	5.05 ± 0.15 ab
Mateno Complete® 1 L/ha IBS	Peas with Ultro® (1.1 kg/ha) IBS	148 ± 6.2 c	1.11 ± 0.11 b	2.79 ± 1.11 ab	5.01 ± 0.15 ab
Mateno Complete® 1 L/ha IBS	Peas with Ultro® (1.1 kg/ha) IBS plus Reflex® 500 gm/ha PSPE	146 ± 6.1 c	1.12 ±0.11 b	4.41 ± 1.7 ab	5.71 ± 0.17 bc
Mateno Complete® 1 L/ha IBS	Peas Simazine (1 kg/ha) IBS	143 ± 6.0 c	1.11 ± 0.11 b	2.41 ± 0.9 ab	5.34 ± 0.17 bc
Mateno Complete® 1 L/ha IBS	Peas 900diuron (500 gm/ha) IBS	151 ± 6.3 c	0.99 ± 0.1 ab	3.02 ± 1.15 ab	5.28 ± 0.16 bc
Sakura® (118 g/ha) IBS	Peas with Boxer® Gold (2.5 L/ha)	159 ± 13.1 abc	0.89 ± 0.09 ab	5.77 ± 2.2 ab	5.18 ± 0.16 abc
Mateno Complete® 1 L/ha IBS	Medic with propyzamide, Rustler® 0.7 kg/ha IBS	133 ± 5.6 abc	0.85 ± 0.08 ab	2.56 ± 1.1 ab	4.92 ± 0.17 ab
Mateno Complete® 1 L/ha IBS	Medic (hay freeze) with Weedmaster (1.5 L/ha)	131 ± 5.5 abc	1.01 ± 0.1 ab	5.77 ± 2.2 ab	4.51 ± 0.15 a
Mateno Complete® 1 L/ha IBS	Canola ATR-Stingray Overwatch® 1.25 L/ha	143 ± 6.0 c	0.79 ± 0.08 ab	2.08 ± 0.98 ab	4.82 ± 0.17 ab
Mateno Complete® 1 L/ha IBS	Brown Manure Vetch (Glyphosate DST 2.5 L/ha)	140 ± 5.9 bc	1.08 ± 0.11 ab	0.7 ± 0.28 a	5.91 ± 0.18 c
Standard error between means		*2*	*0.29*	*0.92*	*0.07*

Table 3. 2022 Break crop treatment and 2021 chemical treatment effects on crop establishment, barley grass weed numbers and dry matter at Mount Cooper in 2022. Means followed by a common letter (within a column) are not significantly different by the Tukey's-test at the 5% level of significance. The adjusted means were predicted at the average barley grass population level for 2021 (17 plants/m²).

2022 Break crop Treatment	2021 Chemical Treatment with Scepter wheat	Crop establishment (plants/m²)	Mid-season barley grass numbers (plants/m²)	Late dry matter (t/ha)
Nil Control - Peas	Trifluralin (1.8 L/ha)	50 ± 4.6 a	16.9 ± 8.8 abc	9.9 ± 1.6 bc
Peas with Trifluralin 2 L/ha	Boxer® Gold 2.5 L/ha IBS	56 ± 5.2a	6.3 ± 3.2 abc	11.2 ± 1.6 bc
	Trifluralin 1.8 L/ha plus Sakura® (118 g/ha) and Avadex® (500 g/L) 1.6 L/ha IBS	45 ± 4.2 a	10.4 ± 5.2 abc	10.7 ± 1.6 bc
	Mateno Complete® 1 L/ha IBS	51 ± 4.7 a	3.8 ± 1.9 abc	10.2 ± 1.6 bc
	Luximax® (500 ml/ha) plus Trifluralin (1.8 L/ha) IBS	50 ± 4.6 a	1.3 ± 0.7 abc	10.6 ± 1.6 bc
	Luximax® (500 ml/ha) plus Avadex® (500 g/L) 1.6 L/ha IBS	58 ± 5.3 a	0.6 ± 0.3 a	12.7 ± 1.6 bc
	Overwatch® (1.25 L/ha) with Voraxar® (100 ml/ha) IBS	51 ± 4.7 a	22.9 ± 11.5 bc	7.1 ± 1.6 b
	Sakura® (118 g/ha) and Avadex® (500 g/L) 1.6 L/ha IBS 10.43	51 ± 4.7 a	10.1 ± 5.1 abc	10.1 ± 1.67 bc
	Sakura® (118 g/ha) IBS	55 ± 5 a	28.2 ± 14.3 c	11.8 ± 1.6 bc
	Trifluralin 1.8 L/ha IBS - District Practice	46 ± 4.3 a	5.6 ± 2.7 abc	10.9 ± 1.6 bc
	Mateno Complete® 1 L/ha early post emergent (EPE)	52 ± 4.8 a	2.1 ± 1.1 abc	8.5 ± 1.67 bc
	Luximax® 500 ml/ha IBS (sown below 3 cm)	46 ± 4.3 a	0.9 ± 0.4 ab	11.6 ± 1.6 bc
	Overwatch® 1.25 L/ha plus Avadex® (500 g/L) 1.6 L/ha IBS	42 ± 3.9 a	5.6 ± 2.8 abc	11.6 ± 1.6 bc
	Overwatch® 1.25 L/ha plus Trifluralin (1.8 L/ha) IBS	50 ± 4.6 a	0.7 ± 0.4 abc	12.4 ± 1.6 c
	Overwatch® (1.25 L/ha)	51 ± 4.7 a	9.4 ± 4.7 abc	10.1 ± 1.6 bc
Strand Medic	Sakura® (118 g/ha) with Voraxar® (100 ml/ha) IBS	147 ± 13.6 b	2.2 ± 1.1 abc	1.3 ± 1.6 a
	Trifluralin 1.8 L/ha plus Avadex® (500 g/L) 1.6 L/ha IBS	138 ± 12.8 b	0.6 ± 0.3 ab	1.1 ± 1.6 a
	Luximax® (500 ml/ha) with Voraxar® (100 ml/ha) IBS	140 ± 13 b	3.9 ± 1.9 abc	0.7 ± 1.6 a
Standard error between predicted means		*1*	*1.4*	*0.6*

Weeds

Table 4. 2022 Break crop treatment and 2021 chemical treatment effect on crop establishment, barley grass weed numbers and dry matter at Mount Cooper in 2022. Means followed by a common letter (within a column) are not significantly different by the Tukey's test at the 5% level of significance. The adjusted means were predicted at the average barley grass population level for 2021 (28 plants/m²).

2022 Second year break and Chemical Treatment	2021 Break Crop Chemical Treatment	Crop establishment (plants/m²)	Early-season barley grass numbers (plants/m²)	Early dry matter (t/ha)	*Late barley grass (heads/m²)	Late dry matter (t/ha)
Medic with propyzamide, Rustler® 0.7 kg/ha IBS	Medic with propyzamide, Rustler® 0.7 kg/ha IBS	139 ± 15.4 bc	1.6 ± 0.36 a	0.52 ± 0.12 a	6 b	1.05 ± 0.14 a
Trident Canola	Canola ATR-Stingray with propyzamide, Rustler® 0.7 kg/ha IBS	78 ± 8.6 a	11.2 ± 3.28 b	0.49 ± 0.12 a	16 a	6.4 ± 0.86 b
Vetch with Ultro® (1.1 kg/ha)	Canola ATR-Stingray	81 ± 8.9 a	1.2 ± a	0.81 ± 0.12 ab	6 b	1.3 ± 0.17 a
Trident Canola	Strand Medic	86 ± 9.8 ab	21.6 ± b	0.51 ± 0.12 a	15 a	7.1 ± 1 b
Kingbale oats (haycut)	Strand Medic	170 ± 18.7 c	33.9 ± 7.2 b	1.13 ± 0.12 b	6 b	8.8 ± 1.2 b
Strand Medic	Brown Manure Vetch (Glyphosate DST 2.5 L/ha)	137 ± 15.4 c	25.4 ± b	0.71 ± 0.12 ab	6 b	1.5 ± 0.14 a
Standard error between predicted means		*11*	*13.6*	*0.03*	*5.3*	*0.74*

**For Late barley grass (heads/m²) a suitable linear mixed model (where the model assumptions were met) could not be found. Therefore, this response was analysed using a non-parametric alternative test (Kruskal-Wallis).*
From the Krusal-Wallis test there is significant effect due to Treatment, P value = 0.006.

Table 5: Cereal and barley grass weed numbers, and yield of IMI cereals at Mount Cooper in 2021, adjusted for 2021 barley grass populations using average weed numbers of 1.8 barley grass/m². Letters indicate Tukey's multiple comparison test between predicted model terms.

2022 Imidazolinone (IMI) Treatment	2021 Imidazolinone (IMI) Treatment	Crop establishment (plants/m²)	NDVI	Early dry matter (t/ha)
Maximus CL Barley with Intercept (500 ml/ha)	Scepter Wheat with Trifluralin 1.8 L/ha plus Sakura® (118 g/ha) IBS	111 ± 7 a	0.43 ± 0.02 a	0.68 ± 0.14 a
Kingbale oats (haycut on residues)	Razor CL Wheat with Intercept (500 ml/ha)	181 ± 8 b	0.64 ± 0.02 b	1.01 ± 0.14 c
Razor CL Wheat no herbicide	Spartacus CL Barley with Intercept (500 ml/ha)	132 ± 7 a	0.43 ± 0.02 a	0.83 ± 0.14 b
Maximus CL Barley no herbicide	Razor CL Wheat with Intercept (500 ml/ha)	115 ± 7 a	0.41 ± 0.02 a	0.75 ± 0.14 ab
Standard error between predicted means		*8*	*0.03*	*0.05*

What does this mean?

The 2022 season with excellent seeding conditions and follow up rainfall events resulted in good early weed control with the herbicides applied. Luximax at Mount Cooper lowered crop density even though it was sown deeper than 3 cm. The label recommendation is that planting equipment should be set up to ensure seed is planted well below the treated band (minimum 3 cm sowing depth) as the separation between the herbicide and seed is very important. The reduction in plant numbers with Luximax at Mount Cooper also resulted in lower early dry matter. In 2022 there was little of the bleaching with Overwatch at plant establishment at either site which had been observed in the previous season.

At Minnipa all herbicide treatments reduced early barley grass numbers compared to the Nil control but there were no differences in late grass weed numbers despite having an average of six barley grass and one ryegrass weed/m^2. Reduced herbicide activity after six weeks on the later germinating Minnipa barley grass population may have contributed to this outcome.

In the pulses and medic treatments at Mount Cooper the annual strand medic had better plant establishment but lower dry matter than the Butler peas. There were no differences between herbicide treatments for late barley grass density, barley grass weed seed heads or pea grain yield, which averaged 5.6 t/ha.

The break crops had higher early and late barley grass and therefore higher barley grass weed seeds numbers than in the canola rotations. Kingbale oats sown at a high rate for hay-cutting had greater growth and competition with barley grass. The medic treatment was spray topped to prevent seed set. The imidazolinone system with cereals had very low grass weed numbers for the second season.

These new chemistries from different herbicide groups will provide future opportunities for grass weed management. Continued evaluation of these new herbicides in lower rainfall regions will determine their best management practices. The rotation trial at Mount Cooper will be ongoing until 2023 to provide growers with more information about management strategies and herbicides which will reduce the impact of Group 1 herbicide resistant barley grass and also lower barley grass weed numbers in low rainfall systems.

Paddock monitoring for herbicide efficacy showed there will be some paddocks on the upper EP where management results in herbicide applications not being as effective as they could be. However, there are also paddocks with high levels of herbicide resistance and these levels vary with different populations across the paddock. To ensure Group 1 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 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 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 then ensure the best application of appropriate herbicides to maximise the efficacy of the operations.

Acknowledgements

This research was funded by SAGIT through the 'Improving management of Group 1 resistant barley grass in current farming systems' (SAGIT SUA121). Thank you to the Kelsh family for hosting the field trials, and to Katrina Brands, Marina Mudge and Rebbecca Tomney for field work and processing samples.

Broadleaf weed control and crop safety in lentils

Jordan Bruce[1], Navneet Aggarwal[2,3], Stuart Sherriff[1], Sam Trengove[1] and Penny Roberts[2,3]

[1]Trengove Consulting; [2]SARDI; [3]University of Adelaide.

Key messages

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

Why do the trial?

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

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

How was it done?

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

Trial establishment

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

Rainfall conditions

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

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

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

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

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

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

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

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

What happened?

Crop safety

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

Plant establishment

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

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

Stunting

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

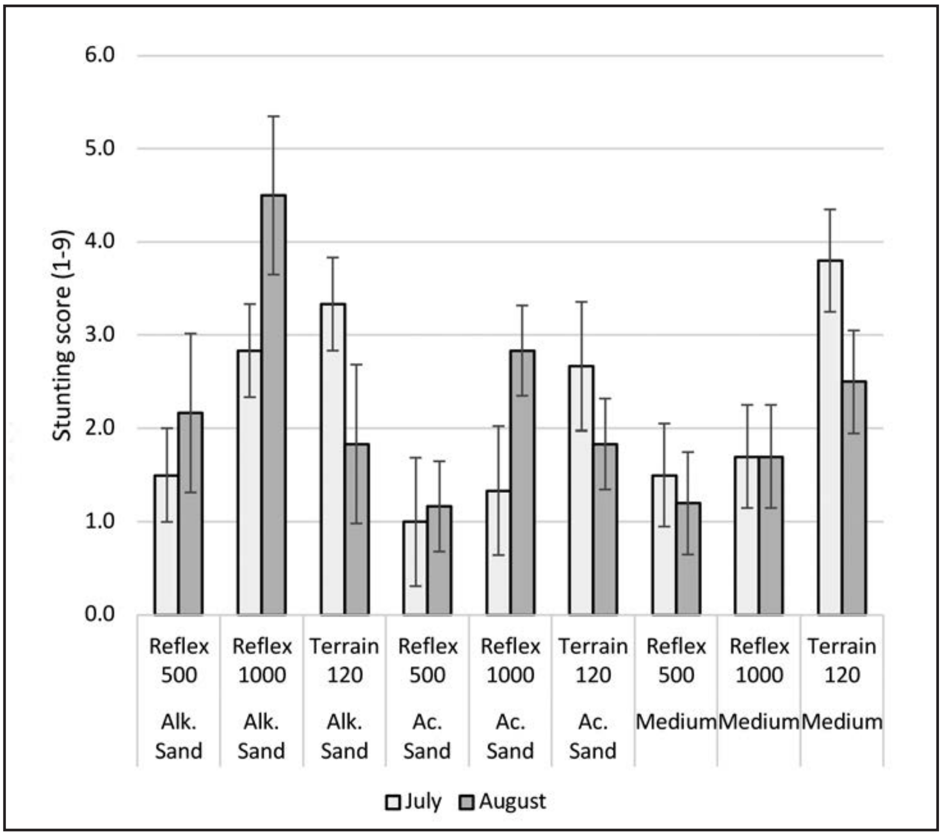


Figure 1. Stunting scores (1 = no stunting, 9 = plant death) for Reflex® and Terrain® treatments recorded on 21 July and 15 August at all sites in 2022. Error bars show LSD (P=0.05) for 21 July and 15 August are each respective site.
Alk. = Alkaline, Ac. = Acidic

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

Chlorosis

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

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

Springtime NDVI/biomass

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

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

Grain yield

Over the two seasons, the grain yield differences caused by the preceding herbicide damage was generally consistent across the two sandy sites (Table 3). Herbicides, diuron and Reflex® applied alone were more damaging at the alkaline sand sites, which aligns with recorded spring NDVI values. Reflex® yield loss is rate responsive with the 500 mL/ha rate averaging 6% yield loss compared to the control treatment, whilst the 1000 mL/ha rate averaged 21% yield loss across sites and years. When Reflex® was applied with diuron, the herbicide damage and resulting yield loss compared to the control was larger. Terrain® averaged 95% and 97% yield of the control on average at the alkaline sand sites and acidic sand sites, despite losing 40% and 25% of plants on average, respectively. Over the two seasons and soil types in this project, Terrain® herbicide behaviour appears to be influenced less by the soil pH of sands than some other herbicides.

Rolling timing

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

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

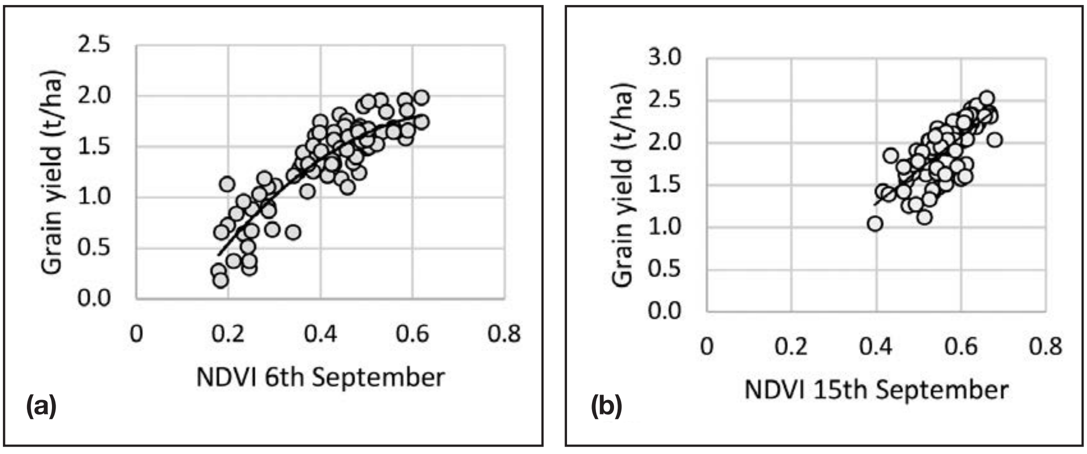


Figure 2. The relationship for Greenseeker NDVI and grain yield recorded (a) 6 September for the alkaline sand trial at Alford in 2021 (y = –5.2444x2 + 7.3026x – 0.706, R^2 = 0.77), and (b) 15 September for the alkaline sand trial at Wards Hill in 2022 (y = 3.955x – 0.2994, R^2 = 0.56).

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

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

**f/b = followed by*

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

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

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

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

Broadleaf weed control

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

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

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

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

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

Further, Reflex® was effective in controlling bifora by reducing its seed set from 6724 seeds/m^2 in unsprayed control plots to 475 seeds/m^2 when applied at 500 mL/ha, and to <1 seed/m^2 at 750 and 1000 mL/ha (Table 5). Similarly, Reflex® reduced bifora seed set by 94–98% in 2021 trials (Bruce *et al*. 2022). Application of Intercept®, on its own or in combination with Reflex®, provided excellent control of bifora, reducing seed set to 0–4 bifora seed/m^2 compared to existing pre-emergent herbicide options metribuzin and Terbyne recording 6416 and 8010 bifora seeds/m2, respectively. Terrain® did not prove effective for bifora control (11664 seeds/m^2), and a subsequent post-emergent application of Intercept® was needed to achieve improved control with weed seed set reducing to 58 plants/m^2.

The Paskeville site had a background population of marshmallow. The level of marshmallow control improved with increasing Reflex® rates from 500 mL/ha (807 pods/m^2) to 1000 mL/ha (231 pods/m^2) (Table 5). Terrain® proved as effective (286 pods/m^2) as Reflex® applied at 750 mL/ha (196 pods/m^2) or 1000 mL/ha for controlling marshmallow and was better than Reflex® at 500 mL/ha. Both Group 14 herbicides proved superior to Group 5 herbicides metribuzin (1176 pods/m^2) and Terbyne (660 pods/m^2) for marshmallow control. A follow up application of Intercept® was needed after Reflex®/Terrain® IBS to achieve effective control of marshmallow (<1 pod/m^2). Intercept® also achieved effective control of marshmallow without an upfront herbicide. But the IBS herbicides will be reducing selection pressure on Intercept®. Similarly, Intercept® was the standalone treatment for controlling medic up to 100% in lentil, likewise in 2021 research trials (Bruce *et al*. 2022), with the next best herbicide treatment Terrain® + diuron reducing weed population by 79% (Table 7).

What does this mean?

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

Acknowledgements

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

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

References

Bruce J, Aggarwal N, Sherriff S, Trengove S, Roberts P (2022) Crop safety and broadleaf weed control implications for various herbicides and combinations in lentil. Proceedings GRDC Grains Research Update, Adelaide, February 2022, p. 72–80.

GRDC (2022). Pre-emergent herbicides fact sheet. GRDC.

Trengove Consulting

Alternatives to glyphosate

Christopher Preston[1] and Amanda Cook[2]
[1]University of Adelaide; [2]SARDI

Key messages

- **Mixtures of Liberty with Voraxor or Terrad'or could be used as a replacement for glyphosate for knockdown weed control prior to seeding.**
- **Higher rates of herbicides appear to make the mixtures more consistent.**
- **These products will be more expensive than glyphosate highlighting the need for growers to work to protect glyphosate.**

Why do the trial?

The aim of the trial was to test mixtures of Liberty + newer Group 14 herbicides as an alternative to the use of glyphosate for knockdown weed control.

Glyphosate is under threat for use in several markets, most importantly Europe. One possible consequence of the banning of glyphosate in overseas markets is that pressure is applied to Australian growers to avoid glyphosate in order to access certain international markets for grain or other agricultural products. Other threats to glyphosate include the evolution of weed resistance and poor use of the herbicide by growers leading to market concern. Glyphosate is the preferred herbicide for knockdown weed control in Australia as a result of its ease of use, high efficacy across multiple weeds and relatively low cost. Identifying an alternative to glyphosate for this use will be challenging. Recent research in the USA demonstrated that Group 14 herbicides are able to synergistically improve the efficacy of glufosinate (Basta or Liberty) on broadleaf weeds (Takano *et al*. 2020). However, glufosinate provides inconsistent control of grass weeds (particularly annual ryegrass), which are a key issue in Australia. Recently released Group 14 herbicides, such as Voraxor and Terrad'or, have better activity on grass weeds and offer new opportunities to develop an alternative to glyphosate for knockdown herbicide use.

How was it done?

- The trial had 10 treatments (Table 1) and 3 replicates of each treatment.
- Treatments were applied on 24 June at Wangary and 7 August at Minnipa Agricultural Centre (MAC). Measurements made were % brownout at 17 and 28 days after treatment (DAT) and dry biomass at 28 DAT.
- Data were analysed by ANOVA following square root transformation. Means were separated using Tukey's test.

What happened?

- Glyphosate + Hammer reduced biomass at Wangary by 96% and at MAC by 81% (Table 1). Liberty alone at the low rate was less effective than glyphosate at MAC; however, the higher rate performed better. The mixtures of Liberty with Group 14 herbicides were as effective as glyphosate + Hammer, except for the low rate of Liberty + Voraxor at MAC.
- The MAC trial was established late as a display for the field day. Previous work has shown that Liberty is less effective at controlling some weed species, notably annual ryegrass and wild radish, during winter. Had the herbicides been applied at the normal pre-sowing timing, it is expected that Liberty and the mixtures would have performed better.
- Higher rates of Liberty and the Group 14 products tended to work better, suggesting synergism in these mixtures is unlikely.

What does this mean?

- Mixtures of Liberty with some Group 14 herbicides were as effective as glyphosate + Hammer in both trials, suggesting they could be useful as replacement knockdown herbicide options.
- Higher rates of herbicides in the mixtures tended to provide more consistent control, meaning these mixtures will be considerably more expensive to use than glyphosate.
- There is a pressing need for growers to help protect glyphosate from both resistance and market concern.

Acknowledgements

This project is part of a joint initiative with the South Australian Drought Resilience Adoption and Innovation Hub and forms part of the Australian Government's Agricultural Innovation Hubs Program.

References

Takano, H.K., Beffa, R., Preston, C., Westra, P. and Dayan, F.E., 2020. Glufosinate enhances the activity of protoporphyrinogen oxidase inhibitors. Weed Science 68, 324-332.

Weeds

Table 1. Effect of various alternative mixtures on dry matter at Wangary and Minnipa in 2022.

Treatment no.	Herbicide	Wangary	Minnipa
		DM (g/m²)	
1	Nil	163.2 a	106.9 a
2	Liberty @ 1.875 L/ha	28.0 b	65.3 ab
3	Liberty @ 3.75 L/ha	12.3 b	27.6 bc
4	Liberty @ 1.875 L/ha + Terrad'or @ 20 g/ha + Banjo @ 1%	32.2 b	32.6 bc
5	Liberty @ 1.875 L/ha + Terrad'or @ 40 g/ha + Banjo @ 1%	40.7 ab	14.0 c
6	Liberty @ 3.75 L/ha + Terrad'or @ 20 g/ha + Banjo @ 1%	29.9 b	22.3 c
7	Liberty @ 1.875 L/ha + Voraxor @ 100 mL/ha + Hasten @ 1%	39.9 b	78.8 a
8	Liberty @ 1.875 L/ha + Voraxor @ 200 mL/ha + Hasten @ 1%	9.6 b	57.1 ab
9	Liberty @ 3.75 L/ha + Voraxor @ 100 mL/ha + Hasten @ 1%	5.1 b	27.0 bc
10	Glyphosate @ 1.5 L/ha + Hammer @ 20 mL/ha + Hasten @ 0.5%	6.7 b	20.8 c

Different letters indicate means that are significantly different ($P < 0.05$) within each column.

Section Editor:
Brian Dzoma
SARDI

Pastures

Mixed legume pastures for the upper Eyre Peninsula and other dryland farming systems

Fiona Tomney[1,2]
[1]SARDI; [2]Flinders University

Location
MAC Airport
Rainfall
Av. Annual: 324 mm
Av. GSR: 241 mm
2022 Total: 529 mm
2022 GSR: 332 mm
Paddock history
2021: Barley
2020: Wheat
2019: Lentil
Soil type
Red sandy clay loam
pH ($CaCl_2$)
7.9
Plot size
10 m x 1.5 m x 3 reps
(25.4 cm row spacing)

Key points

- **Seraph strand medic grown in a mixture with Jester barrel medic, Volga vetch or trigonella; and Studenica common vetch grown as a monoculture were the most productive pasture options in early spring.**
- **Seraph grown as a monoculture was also highly productive in early spring.**
- **The mid-season clovers (SARDI rose and Bartolo bladder) did not respond to the above average rainfall.**
- **Arrowleaf clover was productive in late spring, however it 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 - 2021). 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 EPFS Summary 2018, p. 153; EPFS Summary 2019, p. 209 and EPFS Summary 2020, p. 186).

This project evaluated 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 (EP). The aim was to evaluate pasture species that will extend the available feed on offer beyond that currently offered by early season medics (*Medicago* spp.) which generally senesce in October, 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 EP 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.

This article reports on the second and final growing season for this trial at the Minnipa Agricultural Centre (MAC).

How was it done?

The trial was sown following 15 mm of rain, on 26 May 2022 at the MAC Airport paddock (red sandy clay loam) fertilised with 60 kg/ha DAP. All seed was inoculated with its required rhizobia prior to seeding (see Table 1). Trials were arranged in a randomised complete block design with three replications. Early DM cuts were completed on 27 September 2022. Late DM cuts were taken on 11 November 2022.

Table 1. Mixed Annual Legume Pasture Treatments.

Pasture Mixture	Legume Species
Medic control	Seraph (PM-250) strand medic @ 10 kg/ha
Vetch control	Studenica vetch @ 40 kg/ha
Medic Mix	Seraph strand medic + Jester barrel medic @ 5 kg/ha each.
Medic + Vetch	Seraph strand medic + Volga vetch @ 10 kg/ha each.
Medic + Trigonella	Seraph strand medic @ 5 kg/ha + DL59 Trigonella @ 2.5 kg/ha
Medic + Clover	Seraph strand medic + SARDI rose clover @ 5 kg/ha each.
Medic + Clover + Late Clover	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	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	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	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.

What happened?

Overall early spring growth was excellent (Table 2) due to the above average rainfall received in August and September (Table 3). While the early winter rainfall was below average, the plants never became moisture stressed as the above average autumn rainfall added to the stored sub-soil moisture from the 100 mm of rain received over summer. The site averaged 3.31 t/ha of DM compared to 2.45 t/ha of DM in 2021. The Medic Mix of Seraph strand + Jester barrel medics was the most productive (4.89 t/ha), along with Medic + Vetch (Seraph + Volga), the Vetch Control (Studenica) and Medic + Trigonella (Seraph + DL59). The medic control of Seraph strand medic was less productive, but still yielded an above average 3.95 t/ha of DM (Table 2).

The vetch control (Studenica) had the highest late DM with 4.58 t/ha DM, however the senesced vetch vines were covered in mould due to the warm and wet conditions, so it would have been unsuitable for livestock feed. The Clover Mix (SARDI rose + Bartolo bladder + Cefalu arrowleaf clovers) had the second highest yield of late DM with 3.25 t/ha, mostly due to the growth of the late flowering arrowleaf clover which was the only line still actively growing. The Clover Mix had the poorest growth in early spring, which was a similar result to what was measured in the 2021 growing season. The remaining lines all had similarly reduced levels of late DM production as they had finished setting pods and had shed most of their leaves, however they were still well above the 2021 site average of 0.85 t/ha.

Table 2. Average Early (September) and Late (November) Dry Matter (DM) Production at Minnipa in 2021 and 2022.

Pasture Mixture	Early DM 28/9/21 (t/ha)	Late DM 23/11/21 (t/ha)	Early DM 27/9/22 (t/ha)	Late DM 11/11/22 (t/ha)
Medic Control	3.65 a	0.77 b	3.95 b	1.49 c
Vetch Control	1.41 c	0.70 b	4.11 a	4.58 a
Medic Mix	3.11 ab	0.91 b	4.89 a	1.69 c
Medic + Vetch	3.12 ab	0.75 b	4.65 a	1.86 c
Medic + Trigonella	3.03 ab	0.63 b	4.24 a	1.36 c
Medic + Clover	2.96 ab	0.90 b	3.02 c	1.88 c
Medic + Clover + Late Clover	2.62 b	0.73 b	3.06 bc	1.77 c
Alternative Mix	1.31 c	1.16 ab	2.36 cd	1.45 c
Ground Cover Mix	2.45 b	0.62 b	2.66 cd	1.75 c
Medic + Clover + Late Alternative	2.36 b	0.85 b	2.54 cd	1.48 c
Clover Mix	1.10 c	1.33 a	1.78 d	3.25 b
Six Species Mix	2.24 b	0.90 b	2.48 cd	1.77 c
LSD (P=0.05)	*0.70*	*0.32*	*0.91*	*0.85*

Table 3. The average monthly rainfall for Minnipa (mm) in 2021 and 2022 and the total growing season (GS) rainfall each year.

	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
2022	36.2	75.5	27.8	28.4	50.8	54.0	59.6	332.3
Average	17.9	34.0	42.7	45.0	43.0	32.4	25.8	240.7

What does this mean?

The 2022 growing season demonstrated the potential for legume pasture production on the upper Eyre Peninsula when moisture is not a limiting factor.

Seraph strand (medic control) sown as a monoculture was highly productive in early spring, producing the highest early DM in 2021 with 3.65 t/ha compared to other treatments. In 2022, the Seraph strand grown in a mixture with vetch, a barrel medic, trigonella; and the vetch control were more productive than the Seraph medic monoculture, however the Seraph medic monoculture (medic control) still produced 3.95 t/ha of early DM well above the site average of 3.12 t/ha. Seraph had lower late spring production as it had senesced, however late DM yields were similar to most of the other mixtures, with the arrowleaf clover the only cultivar still actively growing in late spring. The poor performance of the vetch control in 2021 was most likely due to it being grazed by rabbits, shortly after emergence.

When Seraph was grown in a mixture with more than one other pasture legume, overall production was decreased. In 2021 this appeared to be due to the clovers and alternative species sown with the medic, being slower to establish and then being moisture stressed with below average spring rainfall. In 2022 moisture was not a limiting factor, however these mixtures only increased their early DM yields by < 0.5 t/ha, whereas Seraph mixed with vetch, Jester barrel medic or trigonella showed yield increases of > 1.2 t/ha of DM. Seraph mixed with SARDI rose clover showed no increase in early DM yield, suggesting that the clover did not respond to the above average rainfall.

The Clover Mix (SARDI rose + Bartolo bladder + Cefalu arrowleaf clovers) had the poorest early DM production in both 2021 and 2022, highlighting its inability to respond to winter and early spring rainfall. In 2022 it had 3 t/ha less early DM than the Medic Mix. In 2021 it had the highest late DM due to the arrowleaf clover, but this was still < 1.5 t/ha. The trial showed that there is potential for the 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.

The poor growth of biserrula in response to the above average spring rainfall may have been a result of the high soil pH ($CaCl_2$) of 7.9, or the higher clay content. Biserrula is best adapted to well-drained acidic to neutral soils with a pH ($CaCl_2$) of 4.2-7.0, rather than alkaline soils.

Medic + Trigonella (Seraph + DL59) was consistently productive in early spring, however Trigonella is not commercially available to growers.

More productive pastures with a longer growing season provided soil cover throughout the growing season. Pasture residues remaining on the soil after summer will be assessed in early autumn prior to the 2023 growing season.

The 2021 and 2022 growing seasons at Minnipa showed that Seraph strand medic sown as a monoculture or in a mixture with a barrel medic or vetch, or vetch sown as a monoculture, are the most productive legume pasture options for the upper Eyre Peninsula. Arrowleaf clover is the most promising option for late season feed.

Acknowledgements

This project has been funded by the National Landcare Program – Smart Farms Small Grants Round 2.Mixed Legume Pastures for the Upper Eyre Peninsula and Other Dryland Farming Areas through Activity ID 4-FZ7PPZ9. The assistance from Minnipa Agricultural Centre staff Craig Standley and Kym Zeppel in sowing the trial, and Katrina Brands and Rebbecca Tomney in completing field work, was much appreciated.

The new barrel medic cultivars Penfield and Emperor perform well at Minnipa

Fiona Tomney[1,2] and David Peck[1,3]

[1]SARDI; [2]Flinders University; [3]University of Adelaide

Location
MAC Airport
Rainfall
Av. Annual: 324 mm
Av. GSR: 241 mm
2022 Total: 529 mm
2022 GSR: 332 mm
Paddock history
2021:Barley
2020: Wheat
2019: Lentil
Soil type
Red sandy loam
Plot size
10 m x 1.5 m x 3 reps
(25.4 cm spacing)

Key messages

- **Penfield is an early season spineless barrel medic and Emperor is a mid-season powdery mildew resistant barrel medic.**
- **Emperor stayed powdery mildew (PM) free throughout the 2022 growing season, despite the wet conditions.**
- **Penfield became infected with PM later than the Harbinger strand medic present in nearby paddocks.**
- **Both Emperor and Penfield were highly productive in spring, with DM yields comparable to Seraph strand medic.**

Why do the trial?

Two new barrel medic cultivars Penfield and Emperor were commercially available for the first time in autumn 2022. They were not grown on the upper Eyre Peninsula (EP) during their development. They were sown adjacent to the 'Mixed legume pastures for the upper Eyre Peninsula and other dryland farming systems' trial (see EPFS Summary 2021, p. 201 and EPFS Summary 2022, p. 143) to observe their performance on the upper EP and assess their production relative to Seraph strand medic. Seraph is a powdery mildew (PM) resistant strand medic cultivar and currently one of the most highly productive cultivar options for medic pastures on the upper EP.

Penfield and Emperor were developed in a partnership between Meat and Livestock Australia (MLA), S&W Seed Company Australia and SARDI. They were developed using rapid generation principles (also called speed breeding) where five generations were grown per year for Penfield and four generations per year for Emperor. Commercial seed was available within 6.5 years of breeding commencing, whereas Seraph which was developed without rapid generation techniques required 14 years for commercial seed to be available.

Penfield is an early season spineless barrel medic which was developed as farmers value the spineless trait and were planting spineless burr medics on soil better suited to barrel medics. Penfield also has the following traits: 1) tolerance of sulfonylurea (SU) herbicide residues; 2) resistance to bluegreen aphid (BGA) and spotted alfalfa aphid (SAA); 3) tolerance of high levels of boron.

Emperor is a mid-season barrel medic with powdery mildew (PM) resistance backcrossed into Paraggio from the PM resistant strand medic Seraph. Paraggio was chosen as the recurrent parent as it is late to develop PM, resistant to BGA, boron tolerant, and resistant to phoma. This means Emperor has resistance to the two most widely observed diseases in medics.

How was it done?

Seed of Emperor and Penfield were supplied by S&W Seeds. Inoculated seed was sown into moist soil on 26 May 2022 at the Minnipa Agricultural Centre (MAC) in the Airport paddock (red sandy loam) following 15 mm of rain. Seeding was done at the same time and using the same seeding rate of 10 kg/ha with 60 kg/ha of DAP, as the Seraph strand medic used in the adjacent 'Mixed legume pastures for the upper Eyre Peninsula and other dryland farming systems' trial. Plots were replicated three times.

What happened?

Early Dry Matter (DM) cuts were completed at Minnipa on 27 September 2022. Spring growth for Emperor and Penfield was excellent, with both cultivars responding to the above average growing season rainfall. Emperor yielded 4.18 t/ha of DM and Penfield 3.92 t/ha (see Table 1). These yields were similar to the Seraph strand medic grown in adjacent plots (3.95 t/ha), and above the site average of 3.42 t/ha of DM for all the annual legume pasture lines grown at the Minnipa Airport trial site. Late DM production was measured on 11 November 2022 with Emperor yielding 1.40 t/ha and Penfield 1.30 t/ha of DM. Those yields were also comparable to those of Seraph which produced 1.49 t/ha of late DM.

Table 1. Average Early (27 September) and Late (23 November) DM Production (t/ha) at Minnipa in 2022.

Medic Cultivar	Early DM (t/ha) 27/9/22	Late DM (t/ha) 11/11/22
Emperor barrel medic	4.18	1.40
Penfield barrel medic	3.92	1.30
Seraph strand medic	3.95	1.49
LSD (P=0.05)	*NS*	*NS*

Powdery mildew infected medic pasture was widely observed in spring throughout the upper EP, on regenerated medic pasture at MAC and on volunteer medic plants (mostly Harbinger strand medic) at the trial site. Emperor stayed free of PM, as did the adjacent Seraph. Penfield did become infected with PM; however, it was not observed until late October, much later than on Harbinger, and appeared to be a milder infection.

What does this mean?

Barrel medics are suitable for heavier soils than strand medics, so Emperor and Penfield were well adapted to the red sandy loam at MAC. In large paddocks a range of soil types can occur, so it is worth considering sowing a mixture of barrel and strand medics. A mid-maturing cultivar like Emperor can extend the growing season and if a wet spring occurs more DM will be produced. More plant growth provides more feed for livestock, and the higher the DM, the greater the N benefit to the following cereal or oil seed crop. Pasture legumes fix 25 kg N/t DM; even higher if roots are included. Recent work from WA (Loi *et al*. 2022) suggested that a single season of a legume-dominant pasture provides sufficient organic N in the soil to grow at least one crop, without the need for inorganic N fertiliser application.

In recent decades PM is increasingly being observed on medic plants. PM survives over summer on green bridges. With the wet summer in 2021/2022, the green bridge would have been larger than usual. This allowed PM to start to spread before the cold of winter and then be ready to become widespread in the wet spring of 2022. The strand medic Seraph and the barrel medic Emperor are resistant to PM which would have enabled their high biomass in response to the above average rainfall, to be fully utilised by livestock throughout the 2022 growing season. Penfield was later at becoming infected with PM than the Harbinger in the surrounding paddocks. This supports prior work whereby Harbinger, Herald, Angel and Jester are very susceptible to PM. The delay in Penfield indicates that even small improvements in PM resistance can be useful, however, to have more complete PM resistance Seraph or Emperor are more suitable.

Sheep producers who are interested in Penfield's spineless trait because they want to minimise pods in their wool, can also maximise their DM production by sowing a mix of Seraph and Penfield. Seraph has shorter spines than other strand medic cultivars so is less likely to contaminate wool. Seraph also has an indeterminate flowering habit and in a wet spring like 2022, it can keep producing green feed longer than other early season medic cultivars (Herald, Angel, Harbinger, Caliph, Sultan-SU and Penfield).

Both Penfield and Emperor performed as well as Seraph throughout the 2022 growing season at Minnipa and are worthy of consideration if interested in sowing barrel medics.

References

Loi A, Thomas DT, Yates RJ, Harrison RJ, D'Antuono M, Re GA, Norman HC, Howieson JG (2022). Cereal and oil seed crops response to organic nitrogen when grown in rotation with annual aerial-seeded pasture legumes. The Journal of Agricultural Science 160, 207-219. https://doi.org/10.1017/S0021859622000326

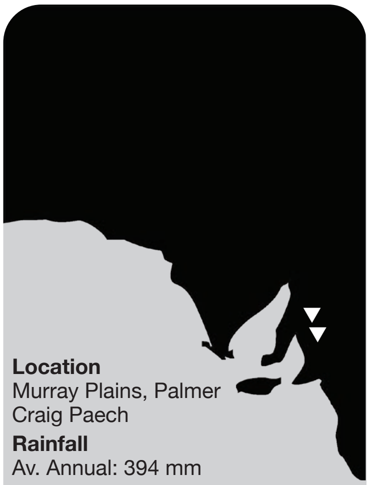
Acknowledgements

Thank you to S & W Seeds for supplying seed. Much appreciation to Craig Standley and Kym Zeppel for their assistance in sowing the trial; and Katrina Brands and Rebbecca Tomney for helping to hand weed and complete dry matter cuts.

Harvesting annual medic pods

David Peck[1,2], James Webb[1], Jeff Hill[1], Trevor Rowe[1] and Eric Watzke[1]

[1]SARDI; [2]University of Adelaide.



Location
Murray Plains, Palmer
Craig Paech
Rainfall
Av. Annual: 394 mm
Av. GSR: 227 mm
2022 Total: 389 mm
2022 GSR: 259 mm
Plot size
10 m

Location
Mid North, Rosedale
SARDI Turretfield Research Centre
Rainfall
Av. Annual: 469 mm
Av. GSR: 358 mm
2022 Total: 496 mm
2022 GSR: 370 mm
Plot size
10 m

Key points

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

Why do the trial?

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

What did we do?

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

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

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

What happened?

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

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

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

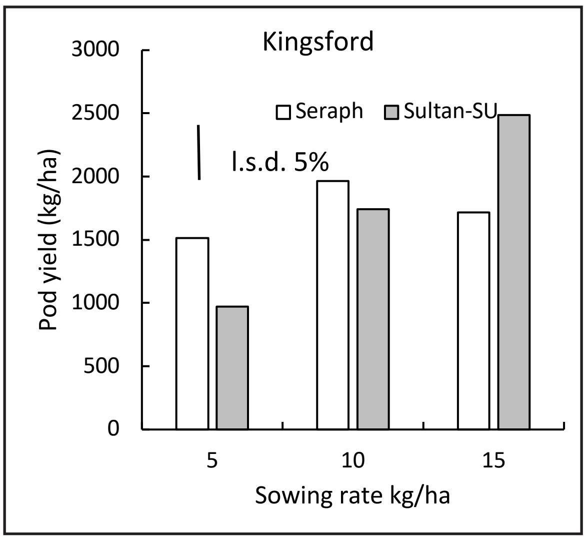


Figure 2. Pod yield at Kingsford 2023.

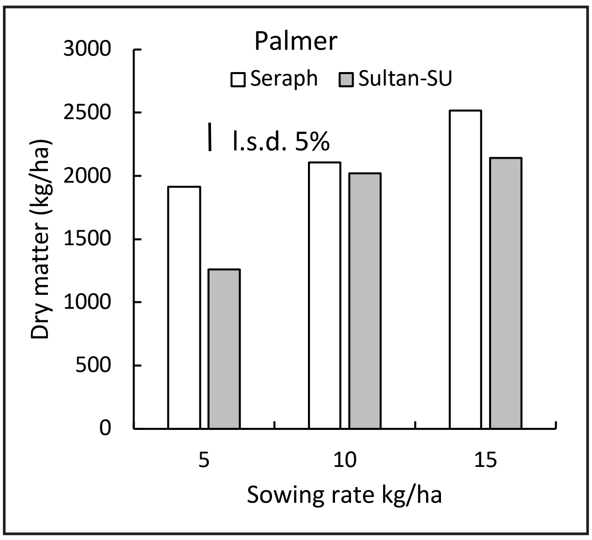


Figure 3. September dry matter at Palmer 2023.

What does it mean?

Harvesting pods

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

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

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

Broadcasting pods

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

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

Conclusions

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

References

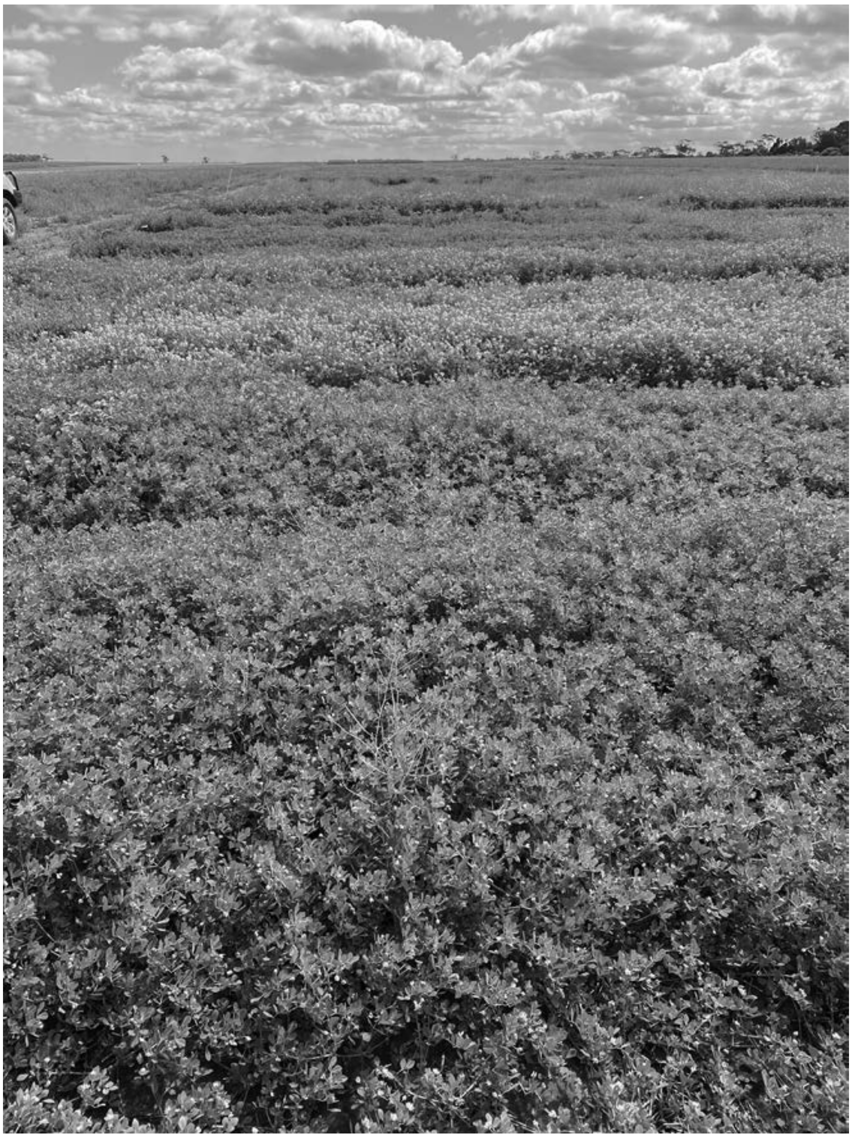
Loi A, Thomas DT, Yates RJ, Harrison RJ, D'Antuono M, Re GA, Norman HC, Howieson JG (2022). Cereal and oil seed crops response to organic nitrogen when grown in rotation with annual aerial-seeded pasture legumes. The Journal of Agricultural Science 160, 207–219.

Gallardo K, Le Signour C, Vandekerckhove J, Thompson RD, Burstin J 2003 Proteomics of Medicago truncatula seed development establishes the time frame of diverse metabolic processes related to reserve accumulation. Plant Physiology 133, 664-682.

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

Acknowledgments

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



Mixed annual legume pasture trial, Minnipa Airport, 2022.

THE UNIVERSITY of ADELAIDE

SAGIT

Government of South Australia
Department of Primary Industries and Regions

SARDI
SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE

Pastures

Use of ley legume pastures in a changing climate

David Peck[1,2], Dane Thomas[1,2], Peter Hayman[1,2], Bronya Cooper[1], Jeff Hill[1], Trevor Rowe[1], James Webb[1] and Eric Watkze[1]

[1]SARDI; [2]University of Adelaide.

Location
Murray Plains, Palmer
Craig Paech
Rainfall
Av. Annual: 349 mm
Av. GSR: 227 mm
2022 Total: 389 mm
2022 GSR: 259 mm
Plot size
1.5 m single spaced rows

Location
Upper Mid North,
Black Rock near Orroroo
Tom Kuerschner
Rainfall
Av. Annual: 333 mm
Av. GSR: 227 mm
2022 Total: 389 mm
2022 GSR: 259 mm
Plot size
1.5 m single spaced rows

Key points

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

Why do the trial?

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

How was it done?

The SARDI Pasture team tested a wide range of genetic material for future pastures in the low rainfall zone with experiments at Palmer and Orroroo. The material was sourced from the Australian Pastures Genebank (APG) which is managed by SARDI. Climate data from low rainfall regions of South Australia was matched to the origin of the accessions using the online data base Genesys. Climate analysis in Genesys was used to identify a short list of accessions. The selection was biased to include accessions from key species that have been grown commercially in Australia. Species that have shown potential to become commercial species were also used. Species from the *Medicago* (annual medics) and *Trifolium* (clovers) genera were most represented. We utilised a large data set of annual medics from the APG which included winter and spring dry matter (DM) production scores, days to flowering and length of spines (only accessions with short spines were included). Accessions with high DM scores and early flowering not on our original short list were added to our short list. More accessions were short listed than could be grown. Our final list was obtained by: 1) removing accessions with low DM scores; 2) choosing one accession at random when multiple accessions were collected in close proximity to each other. 327 accessions made the final list and 26 species were included.

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

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

What happened?

Accessions

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

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

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

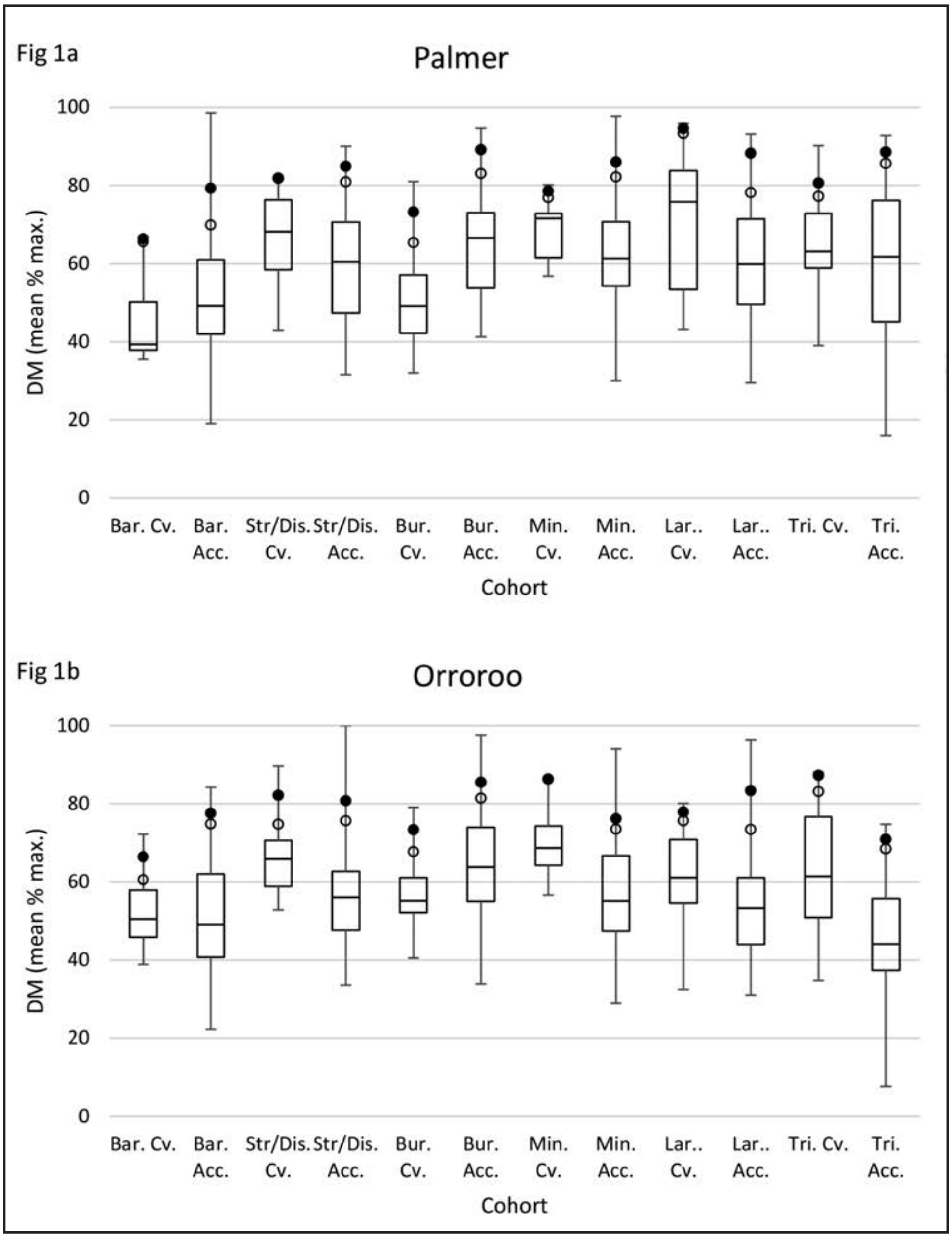


Figure 1. Box plot (minimum, 25%, 50%, 75%, maximum, 95% is indicated by solid circle and 90% by open circle) of dry matter (DM) (up to early Oct 2022) of cultivars (Cv.) and accessions (Acc.) for the different cohorts, namely barrel medics (Bar.), strand and disc (Str/disc), burr medic (bur), minor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

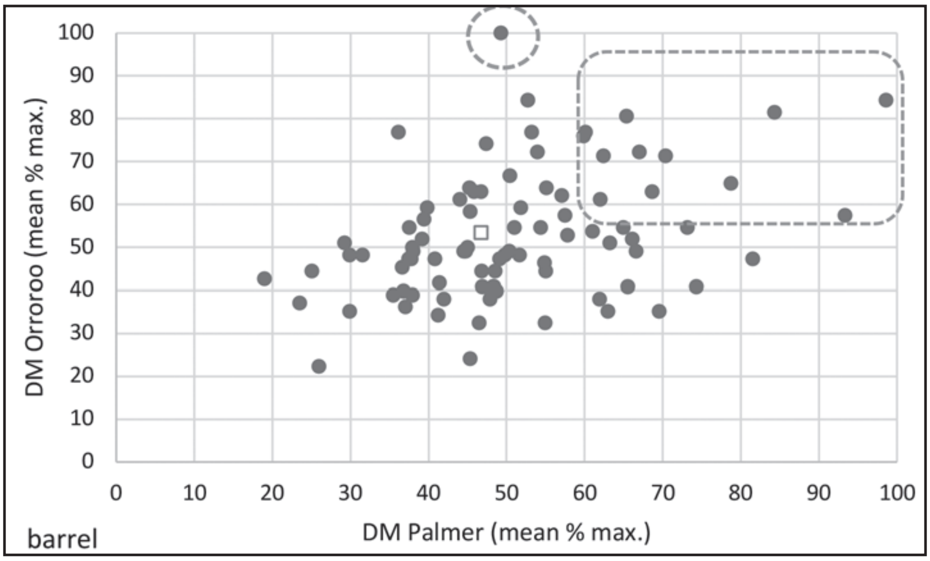


Figure 2. Barrel medic DM at Orroroo plotted against DM at Palmer. The dotted square is the cultivar Sultan-SU and accessions inside dotted area have been shortlisted.

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

Climate Analysis

We have compared climate change projections from the National Drought Fund, Climate Services for Agriculture website and the DEW (Nov 2022) document on projections for planning. We found consistent messages and very high confidence of increasing temperature.

Projections consistently show drying in winter and spring in southern Australia, but the rate of drying ranges between severe drying (>20%) which would precipitate transformational change and moderate drying which is more likely to be managed by incremental and systemic change. Communicating the different level of confidence on warming vs drying is important in discussion with the people who are managing low rainfall farming systems. An important message is that there are maps of the future not a single map.

Management decisions

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

What does it mean?

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

The world faces many challenges from current and future climate change and the need to reduce greenhouse gas emissions. Methane has a greater global warming effect than CO_2 (about 23 times more). *Medicago* species contain plant secondary compounds called saponins that are antimethanogenic (EPFS Summary 2021 p. 208). It is possible that some of the accessions can not only perform better in a changing climate, but also contribute to lessening climate change effects by reducing methane emissions and CO_2 emissions from the production and transport of nitrogen fertilisers.

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

Acknowledgements

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

Kym Walton and Fiona Tomney, SA Drought Hub at the Science to Practice Forum, Roseworthy 2022.

THE UNIVERSITY *of* ADELAIDE

Government of South Australia
Department of Primary Industries and Regions

SARDI
SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE

Regenerative opportunities for increasing resilience in low rainfall farming systems

Alison Frischke

Birchip Cropping Group (BCG)

Location
South Australian & Victorian Mallee
Rainfall
Av. Annual: 250 - 350 mm
Soil type
Sandy to sandy loam soils
Soil test
Neutral to alkaline soils
SOC: sands 0.3-0.5%, loams up to 0.9-1.1%
Paddock grid sampling
20 m x 20 m

Key messages

- **Practices that sustain soil, improving physical, chemical and biological properties on the surface, conserve more water, reduce runoff and erosion, and grow healthier plants and animals, build systems that are more resilient and regenerative in the Mallee.**
- **Minimising tillage, retaining stubbles and groundcover, growing diverse rotations and mixed pastures, careful grazing management and strategic use of fertilisers and pesticides, support carbon inputs and microbial function and diversity.**

Why do the research?

The aim of the research was to explore from an agronomic perspective, what science understands about managing soil health and reversing biodiversity loss under agricultural production, highlighting current practices and opportunities, and recognising gaps in knowledge for the low rainfall Mallee regions of South Australia and Victoria.

The relatively new appeal of 'Regenerative Agriculture' on farms across the world has the interest of many. Some are changing paths in their farming practices, some ponder what it means, while others continue to do what they know and do well.

A recent Australian Government's Future Drought Fund project 'Regenerative opportunities for increasing resilience in low rainfall farming systems' began to understand what it really means to be regenerative and identify suitable approaches to achieve the 'most regenerative' low rainfall agriculture.

Why do we need agricultural systems to be regenerative?

The change from native ecosystems to agricultural production areas has modified the landscape in most agricultural regions of Australia. Stocks of soil organic carbon have declined for more than 40 years, with carbon loss around 51 per cent in the top 10 cm of soil (Luo, *et al*., 2010), along with a subsequent reduction in nutrient stocks, particularly nitrogen (Farrell *et al*., 2021).

Conservation agriculture has reduced erosion in cropping systems substantially, resulting in significant shifts in microbial and faunal communities and biological functions compared with previous practice of multiple tillage passes (Gupta *et al*., 2019). However, it has often brought a loss of diversity in the system as rotations of monocultures intensified and longer-term mixed pasture phases incorporating legumes decreased. This has also led to increased reliance on pre-emergent and selective herbicides, insecticides and fungicides, with an associated rise in input costs and developing resistance to some of these chemicals.

In response to these pressures - along with a variable and changing climate, and growing consumer and trade demands for ethical production and stewardship of farmland - there is a need for agricultural systems that build and protect soil carbon and biodiversity. We are already seeing that change.

What does the term regenerative agriculture mean?

The definition of the word 'regenerative' means to regrow, be renewed or restored, especially after being damaged or lost. In turn, agriculture that is regenerative should replace or renew elements of natural capital and ecosystem services that may be altered by agriculture compared with the environments' original natural state.

There is no legal, regulatory or widely accepted definition of the term 'regenerative agriculture', and there are some disparities among definitions reflecting different goals between practitioners using the term, eg. whether it needs to be organic or certifiable. Nonetheless, most definitions share a suite of similar principles or farming outcomes (enhanced soil health and biodiversity), use of specific farming practices, or combinations of both.

Principles and practices of regenerative agriculture

The central emphasis of regenerative agriculture is on the renewal and resilience of the natural capital base (Robertson *et al*., 2022). Regenerative farming techniques aim to integrate management of soil, water, vegetation and biodiversity, to enhance natural resource use efficiency.

The main principles (and their practices) regarded for agriculture to be regenerative are to:

Improve soil health

- Minimise soil disturbances
- Keep groundcover
- Keeping living roots in the soil
- Encourage natural biological cycles and nutrient transfer

Increase biodiversity

- Increase plant diversity
- Integrate livestock.

Other practices regarded as regenerative can include:

- Using a holistic approach to management
- Slowing or capturing the flow of water
- Protecting waterways and implementing water reticulation for stock
- Investing in revegetation.

Many of these principles and practices are already adopted into management systems of Mallee agriculture.

Mallee farming system differences to other agricultural regions

Much of the attention on regenerative farming practices in Australia has occurred in higher rainfall regions with >500 mm rainfall per annum. Low rainfall, mixed farming Mallee areas of south east Australia have sandy to sandy loam soils, receiving 250-350 mm of annual rainfall, mainly between April and October, and unreliable summer rainfall.

We considered the relevance of the regenerative agriculture principles and their management practices in low rainfall, mixed farming Mallee regions of South Australia and Victoria from an agronomic perspective focusing on soil health, in particular soil organic carbon and biodiversity (microbial activity).

In the low rainfall zone, the biggest bottleneck to productivity and maintaining soil health is availability of water. Low rainfall farms must maximise water use efficiently to remain viable farm businesses.

The Mallee has low soil organic matter, which means:

- Stored soil moisture needs conserving in summer and autumn for the following winter crop or pasture.
- Nutrients must be applied to support agricultural production. Growers cannot rely on inherent soil fertility or acquired fertility after long term fertiliser use. Mallee soils have naturally low fertility, and high soil pH makes many nutrients (e.g. phosphorus) less available. Fertiliser rates for crops are lower than agricultural systems elsewhere.
- Growing a summer crop after the main winter crop affects the availability of water for the next winter crop - the main income earner. A second crop can compromise the total biomass production across a year, and groundcover when summer rainfall is unreliable and sporadic.
- At a minimum, groundcover targets are 50%. This can be difficult to achieve following drought years.
- Fully organic systems struggle to be viable in low production, low rainfall regions due to lower levels of plant available nutrients, and mechanical weed control does not support soil health.

What is the opportunity for more regenerative Mallee systems?

Soil organic carbon

Soil organic carbon levels in the South Australian and Victorian Mallee are typically low, starting as low as 0.3-0.5 per cent for sand, and ranging up to 0.9-1.1 percent for loam. Changing soil organic carbon levels in this environment is very difficult. Low rainfall results in lower biomass production, carbon inputs and microbial activity compared with high rainfall regions.

While studies show the potential for changing soil carbon in the Mallee is limited, providing carbon for microbial activity and function is essential for benefits such as nutrient cycling, organic matter turnover, disease control, soil structure, and agrochemical breakdown.

Soil microbial activity and diversity

To further understand the current status of soil biology, biological functions, carbon and resilience of biological capacity, soils from 35 paddocks were chosen for contrasting crop/soil management practice categories across the Victorian and South Australian Mallee. The categories used were considered relevant to the regenerative agriculture philosophy. They included tillage type, stubble management, ground cover/cover crops, grazing during pasture phase, crop diversity, and use of pesticides, fertilisers and manures.

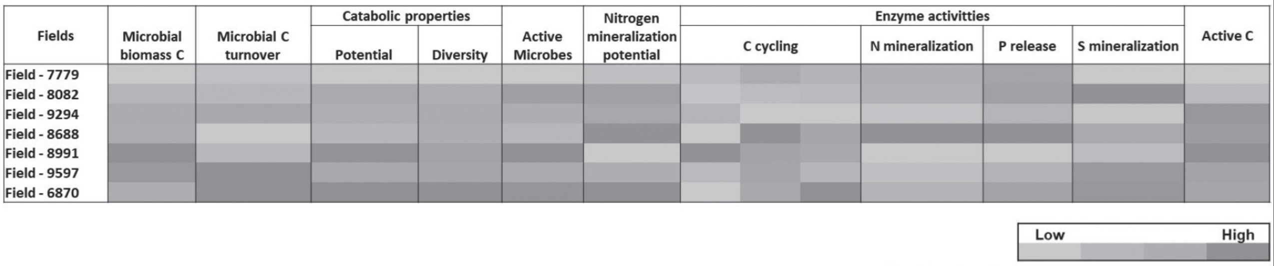
Soils were surface sampled (10 cm) in-crop in spring 2021, and after first rains considered as the season break in autumn 2022. Soils were analysed by CSIRO for their status of soil biological capacity and results related back to the paddock histories (Table 1). In Table 1, increasingly darker squares have a higher value for that soil biological property.

Measures included microbial biomass, carbon turnover and catabolic diversity, nutrient mineralisation and soil carbon status including changes in soil organic carbon pools such as 'active carbon' levels. A multifunctionality index was developed by standardising each function to a common scale against their mean across all the soils tested in this study, then bringing them together into a single metric for each soil sample (Figure 1). In Figure 1, soils with a higher (more positive) multifunctionality index have greater, collective soil biological value.

The results provided new information on the dynamics of soil biological capabilities during the two key periods in dryland Mallee farming systems, highlighting that:

- Rainfall and paddock management are the key drivers of soil biology, affecting the type of microbes and their population sizes, and their functional capacity in low organic matter soils of the low rainfall Mallee region.
- Management practices that reduce the amount of plant carbon inputs, such as grazing crops/stubble and hay removal, generally resulted in lower soil biological capacity and overall multi-functional biological index.
- Resistance and resilience of soil biological functional capacity in the sandy and sandy loam soils is generally low, therefore management practices that include pastures, stubble retention and reduced till systems are required to maintain and improve soil biological health and build soil carbon in the long term.

This also supports learnings from previous studies about practices on soil biota (Table 2).



Field – 7779: No-till, rotational grazing including hay crops, retained but grazed, fertilizers, multiple chemistry pesticides as required but drought last 5 years

Field – 8082: No-till, pasture-crop rotation but grazed, medium fertilizers, multiple chemistry pesticides as required

Field – 9294: No-till, crop rotation including vetch but grazed, stubble retained but grazed, pasture-crop, fertilizers, multiple chemistry pesticides as required

Field – 8688: No-till, rotational grazing, pasture (poor)-crop, fertilizers, multiple chemistry pesticides as required

Field – 8991: No-till, full stubble retention, no grazing, continuous cropping-crop rotation, fertilizers, multiple chemistry pesticides as required

Field – 9597: No-till, full stubble retention, Continuous cropping-crop rotation, hay crops, fertilizers, multiple chemistry pesticides as required

Field – 6870: No-till, full stubble retention, no grazing, Continuous cropping-crop rotation, high fertilizers, multiple chemistry pesticides as required

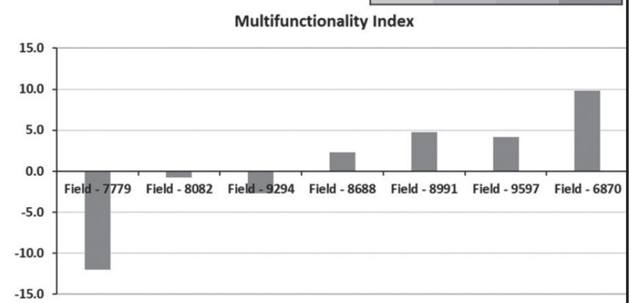


Table 1. Effect of different management practices on soil biological properties and multi-functionality index for soil samples from low rainfall Mallee paddocks during in-crop 2021. *Measurements are categorised in groups relevant for (i) microbial biomass, (ii) catabolic diversity and activity, (iii) N mineralisation and C, N, P, S cycling and (iv) active carbon levels.*

Table 2. Known and potential effects of management practices on soil biota and biological processes in South Australian and Victorian Mallee soils.

Tillage	• Tillage causes significant changes in microbial community composition • Alters N mineralisation-immobilisation processes
Stubble management	• Stubble is a critical source of C for soil microbes, microbial biomass and biological processes • Causes significant changes in composition of microbial community, both beneficial and deleterious
Grazing	• Removal of C inputs can affect microbial biomass and biological processes • Effects on microbial community composition are not known
Extensive groundcover (eg. cover crops, fallows)	• Source of C for soil microbes, microbial biomass and biological processes • Can cause significant changes in composition of microbial community, both beneficial and deleterious
Crop diversity	• Plant type-based differences exist in microbial community composition (beneficial and deleterious) • Differences in quantity and quality of C inputs between crops affecting biological processes
Pesticides	• Effects depend upon the chemistry, frequency and repeated applications, and mixtures
Fertilisers	• Essential for crop growth and C inputs above and below ground • Some effects on microbial community composition but only at very high rates

Soil health practice changes already made to Mallee farming systems

As part of adopting conservation agriculture, many management practices have already been integrated into Mallee farming systems, to protect soils and improve soil health.

These soil health practices include:

- Zero or minimum tillage/direct drilling using points or discs
- Controlled traffic
- Matching nutrient rates to potential crop requirements
- Movement away from continuous cereal cropping back to more diverse rotations using grain legumes, sometimes canola, and medic or vetch pastures
- New pasture varieties, diverse pasture mixes and using crops for grazing
- Stubble and residue retention: stubble is often grazed but burning is limited, no-till herbicide fallows and legume brown manures
- Rotational grazing, groundcover monitoring, use of containment areas
- Amending soils using deep ripping, clay spreading, delving and spading
- Integrated cropping and livestock enterprises to manage labour and risk, value add, enhance natural capital, reduce herbicide use and manage herbicide resistance

What other opportunities could be regenerative for Mallee soils

- We don't yet fully understand the long-term impacts of deep mechanical soil disturbance and manure amendments applied to Mallee soils.
- Biological additives vary widely between products and results in the field - often with no effect - but there are large investments occurring into inoculants for seed and crops so it is a field to watch.
- Further knowledge is needed to better understand soil biology, how to measure it and responses to farm practices, seed quality and treatments, and desirable pasture species including native browsing species.

What does this mean?

In summary, for the naturally low rainfall, low carbon soils in the Mallee, agriculture that is tangibly regenerative is supported by systems that optimise biomass grown and retained for soil carbon and soil biology.

Fitting with the principles and practices familiar to the regenerative agriculture approach, farming more regeneratively in the Mallee encompasses:

Improving soil health

- **Minimising soil disturbances:** Minimum or no-till practices that limit soil disturbances to help increase water retention, nutrient cycling, and retain topsoil.
- **Keeping groundcover:** Keep the soil covered using residue and stubble retention, winter cash and cover crops, and pastures to protect the soil from wind and water erosion, and reduce soil surface temperatures and evaporation.

Place livestock elsewhere or sell livestock before groundcover is compromised.

- **Focusing on living roots in the soil during the growing season:** To help stabilise the soil, keep soil biology active, retain excess water and prevent nutrient loss.

Use winter cash crops or forage cover crops, annual and permanent pastures (where able), shrubs and trees.

Conserve moisture over summer to support winter crops.

- **Encouraging natural biological cycles and nutrient transfer:** By supporting plant growth and subsequent carbon inputs with adequate nutrition using fertilisers and composts.

Rotations include legumes, brown manure legumes, or under-sowing of legumes, and stubble retention.

Increasing biodiversity

- **Increase plant diversity:** Helps build healthy soils with active microbial function and has ecosystem benefits for wildlife and pollinators.

Use diverse winter crop rotations, intercropping (sowing two or more crops together, or in close proximity), pasture cropping (where able), multi-species cover crops and borders planted for bees and other beneficial insects.

Invest in revegetation such as fodder shrubs and timbered areas. Exclude livestock or ensure these areas are strategically grazed.

- **Integrate livestock:** Carefully monitor and manage grazing to avoid depleting carbon inputs that support soil biology.

Rotationally graze where possible (use temporary fencing) to reduce selective overgrazing, camping and wastage, and enable plant regrowth and recycling of nutrients, building biodiversity and forage quality.

Graze stubbles until grain is eaten, then use standing crops, fodder shrubs and containment areas during summer.

Integrating whole-farm resources

- **Whole farm management:** Strategic whole system and business decision making, integrating enterprises and people.

Low rainfall growers already implement a range of soil health and diversity practices. When considering a practice change, look for evidence to substantiate soil and plant health benefits. Often long-term adaption is required to achieve economic and environmental sustainability. It doesn't matter whether you regard yourself as being 'regenerative' or not, growers are eager to keep learning about maintaining and building healthy soils and what is achievable in these environments. There are no quick fixes, but accessing region-specific information that addresses lower Mallee rainfall, soil types and seasons, and peer to peer learning, is important to avoid making costly mistakes.

References

Gupta V.V.S.R., Roper M. and Thompson J., 2019, Harnessing the benefits of soil biology in conservation agriculture. In (Eds J Pratley and J Kirkegaard) "Australian Agriculture in 2020: From Conservation to Automation" pp 237-253 (Agronomy Australia and Charles Sturt University: Wagga Wagga.

Farrell M., Vadakattu G. and Macdonald L., 2021, Addressing the rundown of nitrogen and soil organic carbon. GRDC Update Paper, Adelaide.

Luo Z., Wang E., and Jianxin Sun O., 2010, *Soil carbon change and its responses to agricultural practices in Australian agro-ecosystems: A review and synthesis*. Geoderma, 155(3-4), 211-223.

Robertson M., *et al*., 2022, What can science offer the proponents of regenerative agriculture practices. ECOS. 22: 1-5.

Acknowledgements

This project was supported by the Murraylands and Riverland Landscape Board with funding from the Australian Government's Future Drought Fund, and is a collaboration with CSIRO, BCG and Mallee Sustainable Farming.

Managing standing crops for production, livestock, nutrition and soil cover

Alison Frischke
Birchip Cropping Group (BCG)

Location
Nullawil, VIC
Ferrier Family
Rainfall
Av. Annual: 352 mm (Nov-Oct)
Av. GSR: 236 mm
2022 Total: 497 mm (Nov-Oct)
2022 GSR: 384 mm, decile 10
Paddock history
2021: Lentils
Soil type
Sandy clay
Soil test
pH: 0-10 cm: 8.6, 10-100 cm: 8.9-9.8 Deep N (0-100 cm): 80 kg N/ha
Plot size
10 m x 6 rows
Demo design
Unreplicated
Yield limiting factors
Winter moisture stress

Key messages

- **Standing cereal crops produce large volumes of feed, changing in feed value as they mature and set grain.**
- **Growing lambs grazing standing crops need a protein supplement, supplied either by legume grain, hay, or undersown medic or other legume pasture.**
- **Standing crop residues can be managed over summer to provide more groundcover than other pasture paddocks.**

Why do the demonstration?

The aim was to demonstrate the production of a range of cereal varieties and new medic releases, their grazing value, and the effect of sowing rate and fertiliser for growing standing crops.

A 'standing crop' is a cereal crop that has been held as a fodder bank for grazing later in the year once it has become reproductive, from late stem elongation and into grain fill. It can be used for high quality feed to lamb and wean lambs onto, and to finish lambs between three and six months of age. The standing crop can be a cereal, or a combination of a cereal with a legume or grain supplement which delivers higher protein for growing lambs.

The practice is low cost and low risk. The standing crop is sown and grown as a crop would be for harvest, i.e. locally adapted varieties are sown on time with adequate fertiliser and weed management to maximise dry matter production, as opposed to just 'banging something in' with little or no management. The crop is assessed in late winter or early spring for its best end-use opportunity. Responsive decisions are made to graze, cut for hay or harvest the crop, based on lamb and grain commodity prices, and seasonal conditions or events such as heat stress or frost that might cause a grain crop to fail.

Grazing of senesced pastures and stubble residues during dry months will eventually expose soil to the elements, increasing the risk of erosion from summer storm events. Because a full standing crop offers greater biomass, and grain in the head can meet the higher nutritional demands of lamb production (with a protein supplement), lambs will reach sale weight faster and can be removed from the property sooner. This relieves stocking rate pressure over summer months, preserving groundcover levels and reducing the risk of overgrazing and exposing soils.

How was it done?

Single plots of barley, oats, triticale, ryecorn and medic varieties were sown as a demonstration at Nullawil in the southern Mallee of Victoria. The demonstration was sown on 25 May 2022 with knife points + splitter boot (70 mm split) and press wheels at 30 cm row spacing.

All treatments received Granulock® Supreme Z + Flutriafol (400 ml/100 kg) @ 60 kg/ha at sowing.

The trial was managed as per best practice for herbicides, insecticides and fungicides, and harvested on 9 December 2022.

Assessments included peak biomass and grain yield. Feed tests were conducted on biomass samples and grain protein measured in grain.

What happened?

Measured in March, plant available water was 91 mm and soil N to 1 m was 80 kg N/ha.

The 2022 growing season at Nullawil began after 39 mm rain in the second half of April, although little rain fell in the three weeks before sowing. Trials established evenly, but became moisture limited on the clay soil during winter, stressing leaf tips. For four months, rainfall was recorded on three out of every four days, but there were only eight rain events that exceeded 4 mm. From 8 September, conditions turned around, becoming very wet. Crops recovered well with the spring rain and the growing season improved to a decile 10.

Biomass value

Peak biomass sampled on 17 October as cereal crops finished flowering/early grain fill, measured 7.0 – 11.7 t/ha (Table 1). Single plots of oat varieties essentially grew 10 t/ha biomass, barley 8 t/ha, and triticale and ryecorn 9 t/ha.

Forage varieties Overland and Marleigh oats, and long season Forester oats were still testing >12% for protein, as did forage barley Kraken and grain types Spartacus CL, Commodus and Maximus.

Many varieties of oats and barley were still testing >8 MJ ME/kg DM after flowering - useful levels of energy for maintenance of dry ewes but not for production feeding.

However, acid detergent fibre (ADF) and neutral detergent fibre (NDF) levels were increasing, affecting how much a sheep could consume at this point. High quality hay targets are ADF <30-32 percent and NDF <55 percent. Again, fibre was useful for maintenance feeding but not production.

Grain value

By December, grain was mature and offering 2.5-5 t/ha for forage oats and 4.3-5.5 t/ha for grain type oats, and 3.4 t/ha for forage barley and 5.0-6.4 t/ha for grain type barleys.

Feed tests hadn't been done on the grain at the time of writing, but BCG lab NIR grain protein measured 8.7-11.2 percent in oats and 9.2-13.1 percent in barley. Bilby and Kingbale oats, and most barley varieties measured >10 percent protein.

Table 1. Cereal variety feed value as growing crop or grain, Nullawil 2022.

Crop	End Use	Variety	Sowing rate (kg/ha)	17 October Biomass (t/ha)	Crude Protein (%)	ME (MJ/kg)	ADF (%)	NDF (%)	Grain Yield (t/ha)	Grain protein (%)
Oats	Hay/Grazing	Overland	80	11.1	16.4	10.7	32.4	59.6	3.8	9.3
	Grazing	Marleigh	80	10.0	13.5	9.8	35.7	66.4	4.6	8.7
	Grain	Bilby	80	11.7	9.0	7.6	42.4	70.8	5.1	11.2
	Hay	Forester	80	10.2	12.7	8.7	40.8	67.6	2.5	9.6
	Hay/Grain	Yallara	80	10.3	9.2	8.2	39.9	64.2	4.4	8.8
	Hay/Grazing	Wintaroo @ 60 kg/ha	60	11.0	9.3	7.7	43.4	73.8	4.8	9.6
		Wintaroo @ 80 kg/ha	80	11.2	9.4	7.6	43.3	71.3	4.3	9.1
	Hay	Kingbale	80	11.1	9.1	7.3	43.8	71.3	5.0	10.4
	Milling	Bannister	80	10.9	8.7	9.1	33.9	60.1	5.5	7.8
	Hay/Feed grain	Mulgara	80	9.9	10.2	7.9	41.7	71.5	4.3	9.1
Barley	Grazing	Kraken	50	7.1	13.6	8.9	36.4	61.1	4.1	11.3
		Moby	50	7.6	10.7	8.3	37.5	61.3	3.4	13.1
	Grain	Planet	50	8.2	10.5	9.1	33.6	57.9	6.4	9.2
		Spartacus CL	50	7.0	13.5	9.1	31.7	54.3	5.0	11.8
		Beast	50	7.6	8.6	8.9	33.8	56.8	5.4	10.6
		Compass	50	9.4	11.3	9.0	33.6	59.1	6.4	11.2
		Commodus CL	50	9.2	13.2	9.2	32.8	55.8	5.5	10.7
		Maximus CL	50	8.1	14.9	9.2	31.9	55.6	6.0	11.4
Triticale	Hay/Grazing	Kokoda	80	8.8	9.9	7.9	43.6	75.3	6.9	8.5
Ryecorn	Grazing	Vampire	60	9.3	9.1	6.9	46.3	77.8	4.3	8.9

Sowing rate effect

Wintaroo was sown at two sowing rates to see if there was an effect on biomass or grain production and quality. In terms of biomass, the oats were able to compensate for lower plant densities (as seen in the oaten hay trials at the same site) and had similar quality (Table 1).

Grain yield and grain protein were higher for the lower sowing rate of 60 kg/ha but caution must be taken as plots were not replicated.

Fertiliser effect

The last run of plots sown repeated the same varieties as the previous run, but with no fertiliser. There appears to be a strong fertiliser response to biomass production and protein, and to grain yield and grain protein (Table 2).

Potential to undersow with medic

As standing crops mature through head emergence and through early grain fill, protein dips and is not enough to support lactating ewes or growing lambs. To meet the protein shortfall, a highly digestible legume can be undersown with the cereal crop. Medic, clover, vetch, lucerne or serradella are suitable for satisfying that role, depending on soil type.

Single plots of pure medic varieties were sown to see how the new medic varieties Seraph, Emperor and Penfield performed against older varieties Parragio and Parabinga.

By 17 October, biomass cuts measured large amounts of feed, highest for new release varieties Emperor and Penfield with plots yielding towards 6 t/ha, and early Seraph and older variety Parabinga towards 5 t/ha (Table 3).

Feed tests for medic still showed high quality at this time of year, while other cereals were beginning grain fill. Crude protein was very high around 20 percent, ME about 10 MJ ME/kg DM and fibre levels were of good quality for forage (Table 3).

The establishing medic also responded to fertiliser at sowing, producing 0.5 t/ha more biomass and similar quality than the unfertilised plot, by 17 October (Table 4).

Table 2. Yallara and Mulgara response to applied fertiliser at sowing, Nullawil 2022.

Crop	Fertiliser	17 October Biomass (t/ha)	Crude Protein (%)	ME (MJ/kg)	ADF (%)	NDF (%)	Grain Yield (t/ha)	Grain protein (%)
Yallara oats	+	10.3	9.2	8.2	39.9	64.2	4.4	8.8
	-	7.8	6.5	8.7	34.0	54.3	3.4	8.0
Mulgara oats	+	9.9	10.2	7.9	41.7	71.5	4.3	9.1
	-	7.0	6.9	8.4	36.4	61.5	2.9	8.5
Beast barley	+	7.6	8.6	8.9	33.8	56.8	5.4	10.6
	-	4.9	8.0	8.8	32.5	51.7	4.6	10.2
Maximus barley	+	8.1	14.9	9.2	31.9	55.6	6.0	11.4
	-	5.9	8.9	8.6	33.5	53.9	4.7	10.2

Table 3. Cereal variety feed value as growing crop or grain, Nullawil 2022.

Medic Variety	Sowing rate (kg/ha)	17 October Biomass (t/ha)	Crude Protein (%)	ME (MJ/kg)	ADF (%)	NDF (%)
Parragio	10	2.7	21.1	10.8	29.9	36.3
Parabinga	10	4.9	18.8	9.3	38.8	47.3
Seraph	10	4.7	22.7	10.4	32.4	38.4
Emperor	10	6.0	20.5	10.2	31.9	38.1
Penfield	10	5.6	19.4	9.7	34.4	41.0

Table 4. Penfield medic response to applied fertiliser at sowing, Nullawil 2022.

Crop	Fertiliser	17 October Biomass (t/ha)	Crude Protein (%)	ME (MJ/kg)	ADF (%)	NDF (%)
Penfield medic	+	5.6	19.4	9.7	34.4	41.0
	-	5.1	22.0	10.6	31.7	37.9

Standing crop purpose	Suitable variety characters
Winter grazing	Good early vigour and early maturing, eg. Moby barley
Spring/summer grazing	Longer season varieties, eg. Overland oats, Forester barley
Finishing lambs	Higher grain protein, eg. barley varieties
Problem grasses	Choose herbicide tolerance for grassy weed control, eg. CL varieties

Groundcover

Groundcover from the different cereal crops and pastures in all plots was 100 percent in October, covering plots with varying amounts of biomass and composition of plant material. Breakdown rates of crop and pasture residues are enhanced by nitrogen content, and contact with the soil, so cereal residues generally take longer to break down than legume residues. Depending on when and how standing crops are grazed, the volumes of biomass show great potential for providing greater groundcover over summer months, when other pastures have senesced or have been chemically fallowed.

What does this mean?

The demonstration supports previous work showing several oat and barley varieties, both forage and grain types, can provide useful feed for supporting livestock at different times of the year.

Best varieties are those the growers already have on hand or they should choose one that is fit for purpose.

Feed tests will measure exactly how much biomass, protein, energy, NDF and digestibility the crops are providing at the time, but in general:

- Young cereal crops at GS30 have about 1.5 t/ha biomass, and high protein (20-30 percent), energy (12-14 MJ/kg), lower NDF (35-45 percent) and high digestibility (>80 percent)
- By flowering at GS65, crop biomass can range from 4-12 t/ha, but quality falls to maintenance levels (hay quality) with lower protein (8-9.5 percent) and energy (8-9.5 MJ/kg), higher NDF (55-70 percent) and lower digestibility (50-60 percent).
- Once the grains have set, feed values rise again. The best feed value resides in the grain component, and to a lesser extent in leaves and fine chaff. Grains have very good protein (11-15 percent) and energy (12-14 MJ/kg), low NDF (10-30 percent) and high digestibility (70-95 percent). Fibre will be consumed in chaff and leaves as sheep eat the crop, so fibre needs will be met.

During the spring period when crops flower and enter grain fill, quality falls and limits how much livestock can consume. During this time supplementing with another source of protein and energy may be needed to meet any nutritional shortfalls. The crop will have enough nutrition to support dry ewes, but it can't support the needs of growing lambs.

If livestock has already been on a large paddock for some time, they may have grazed parts of the paddock more intensively than others. Crops growing back on these patches will have fresher, more nutritious feed, and the supplement may not be needed yet, but it depends on the size of the areas and number of stock on the paddock.

Once grain has matured, lambs will grow successfully again, particularly on a diet supplemented with undersown legume pasture, a legume grain feeder or access to an adjacent paddock with legume stubble to top up their high protein and energy needs.

Steps for managing sheep on standing crops and onto grain, and how to manage a standing crop paddock in a rotation, are outlined in the 'Value of standing crops for lamb production and soil protection article' in the 2019 EPFS Summary.

According to the results shown, growers may consider setting up a standing cereal crop that allows flexible options for its use across the growing season which includes supporting livestock production with the right management, providing groundcover into the summer months and protecting soils and supporting soil health.

References

Frischke A., Clarke G. and Jolly S., 2020, EPFS Summary 2019, 'Value of standing crops for lamb production and soil protection' p. 234-238.

Acknowledgements

This project is funded by the Australian Government's National Landcare Program and delivered by BCG and MacKillop Farm Management Group. Special thanks to Millie Moore of S & W Seed Company and Craig Altmann of AGF Seeds for providing seed for the trial.

Section Editor:
Brian Dzoma
SARDI

Section
7

Disease

Effect of deep ripping and fungicide application on rhizoctonia

Amanda Cook[1,2], Nigel Wilhelm[1,2], Daniel Hubreli[3], Karyn Reeves[3], Brian Dzoma[1], Ian Richter[1] and Craig Standley[1]
[1]SARDI; [2]University of Adelaide; [3]DPIRD, Western Australia.

Location
Poochera
Gosling Family
Rainfall
Av. Annual: 326 mm
Av. GSR: 247 mm
2022 Total: 550 mm
2022 GSR: 300 mm
Paddock history
2022: Volunteer pasture
2021: Barley
2020: Wheat
Soil type
Grey highly calcareous sandy loam
Soil test
Very high pH and carbonate, poor P reserves
Plot size
30 m x 2 m x 4 reps
Trial design
RCBD with 4 replicates
Yield limiting factors
Nutrition, hostile subsoil, rhizoctonia

Key messages

- **Despite no reduction in rhizoctonia disease at eight weeks, the application of Uniform® fungicide at seeding increased barley grain yield by 0.26 t/ha, possibly due to lower foliar disease or by protecting the crown roots from rhizoctonia later in the season.**
- **There was a yield improvement of 1 t/ha in barley due to 2020 deep rip plus biochar enriched with nutrients, and deep rip with animal manure.**

Why do the trial?

Rhizoctonia (*Rhizoctonia solani*) remains a significant constraint to barley and wheat production in the low and medium rainfall zones of the Southern and Western regions, especially on calcareous soils of upper Eyre Peninsula (EP). The disease is estimated to be costing Australian growers $78M annually (Murray and Brennan, 2009).

There are currently no resistant commercial cereal cultivars to rhizoctonia. In the absence of resistant cultivars, rhizoctonia can be reliably managed by crop rotations and fungicide applications. Previous GRDC investments evaluated the efficacy of fungicide control of rhizoctonia, which resulted in the registration of in-furrow and seed-dressing fungicides. However, in the low rainfall zone, economic or practical reasons limit the use of fungicide applications, and the unique characteristics of calcareous soils render many of the options less effective. Fungicides are effective in most regions but they are an additional cost with variable results so in-furrow fungicide application has not been widely adopted by growers on upper EP.

The aims of this project were to examine innovative management strategies for rhizoctonia control in low and medium rainfall zones, by exploring new actives (chemicals and biologicals) that can reduce rhizoctonia infection, applied either pre-sowing or in-crop, and investigating the potential of different practices (plant fumigants, soil amelioration and deeper sowing with long coleoptile varieties) to reduce the impact of rhizoctonia. The Poochera demonstration trial initiated in 2020 with soil management strategies was used to investigate the effects of soil amelioration and fungicide application at seeding on rhizoctonia.

How was it done?

The Calcareous Soils project "Producing more profitable crops on highly calcareous soils by improving early vigour and overcoming soil constraints" was funded for three years by the CRC for High Performance Soils with support by the GRDC. In 2020, a three-year rotational trial on the Gosling family farm at Poochera was initiated and included treatments which showcased some of the major issues facing cropping on highly calcareous sands of the upper EP.

Seven treatments were applied in 2020 to plots 30 m long by 2 seeding passes (4 m) wide in a randomised complete block design. The treatments were:

- Control - typical management strategy for the district
- Anti-rhizoctonia - high rates of MAP and SOA, fungicides (Vibrance® and Uniform®) and trace elements at seeding
- Fertiliser toxicity - high rate of DAP with the seed
- Deep ripping + inclusion plates (IP) (Deep Rip)
- Deep rip + IP with animal manure (Deep Rip AM)
- Deep rip + IP with biochar enriched with nutrients (Deep Rip Biochar).

Deep ripping treatments were imposed to 40 cm pre-sowing in early May 2020 using a Yeoman's plough on 64 cm spacings with inclusion plates. The animal manure (Neutrog pellets at 10 t/ha) and nutrient enriched biochar (at 1.5 t/ha) were applied in bands on the soil surface to align with the ripper tines to aid incorporation in the following ripping pass.

The basal fertiliser package was 25 kg DAP/ha with the seed and 50 kg DAP/ha plus 36 kg urea/ha banded under the seed rows for all treatments except Anti-rhizoctonia and Fertiliser toxicity.

The fertiliser toxicity treatment received a package of fertilisers at seeding to reduce germination and establishment; 75 kg DAP/ha plus 36 kg urea/ha with the seed.

The anti-rhizoctonia treatment received 45 kg MAP/ha plus 4 kg SOA/ha with the seed and 68 kg MAP/ha plus 137 kg SOA/ha banded under the seed rows. Seed was treated with Vibrance® at 360 mL/100 kg seed and Uniform® was added to the trace element mix banded 3 cm under the seed rows at 300 mL/ha.

In 2020, the trial was treated with knockdown and soil-active herbicides immediately prior to seeding and subsequent weeds controlled with an Intervix® application mid-season. Spartacus CL barley was seeded in all plots at 60 kg/ha with a DBS seeder using ribbon seeding boots on 19 May 2020. All plots received banded liquid trace elements at seeding of 2 kg Zn, 3 kg Mn and 1 kg Cu/ha as sulphates, except for the anti-rhizoctonia treatment which received a double rate.

In 2021, the trial was sown to Scepter wheat @ 60 kg/ha with 50 kg/ha DAP as a basal on 5 June.

In 2022, the fungicide Uniform® (active ingredients, azoxystrobin & mefenoxam) was applied to one of the seeding passes in each plot. Uniform® was applied at 400 mL/ha with 85 L/ha of water as a split application (on top of the seed rows and banded under the seed rows).

The trial was treated with a knockdown and soil-active herbicides immediately prior to seeding and subsequent weeds controlled with Intervix® mid-season. The trial was sown with a DBS seeder using ribbon seeding boots on 13 May 2022 into good moisture conditions with DAP @ 50 kg/ha and Maximus CL barley @ 60 kg/ha to all plots.

Crop establishment, crop growth and grain yield were monitored during the season. At eight weeks plant roots were scored for seminal rhizoctonia infection, crown root infection and general root health. Rhizoctonia infection was assessed using a standard rhizoctonia root score (0-10) of seminal and crown roots developed by the project team with SAGI-West in project DJP1907-002RMX.

Data from quantitative assessments were analysed using an ANOVA split-plot model with three replicates sown in a single range using GENSTAT. The main plots were the seven 2020 treatments, and the sub-plots were the two 2022 fungicide treatments.

What happened?

The 2022 season was very good with stored soil moisture due to February rains and early seeding at the end of April. Minnipa (35 km from the trial site) had a decile 9 growing season with stored subsoil moisture from summer rains in late 2021 and February 2022.

There were no differences in crop establishment between treatments in 2022 with an average establishment of 89 plants/m^2.

There was no effect of Uniform® fungicide application on early plant dry matter compared to the control.

Treatments imposed in 2020 continued to impact on crop growth in 2022. The mean of the deep ripping with Deep AM, and Deep ripping with Deep biochar increased early and late dry matter compared to district practice (control) (Figure 1). While there was no difference in early or late dry matter of barley in the deep rip, anti-rhizoctonia treatment or fertiliser toxicity compared to the control (Figure 1).

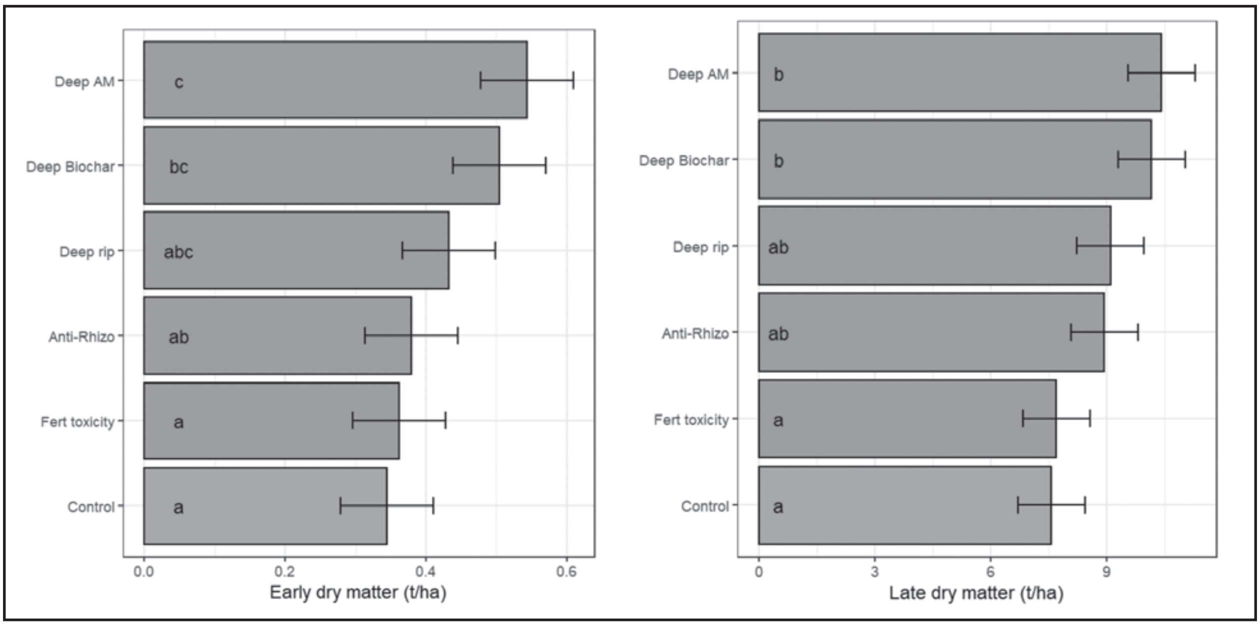


Figure 1. Mean early and late dry matter of barley (t/ha) in the Poochera rhizoctonia management trial, 2022. Bars in each graph are the treatment LSD (P = 0.05).

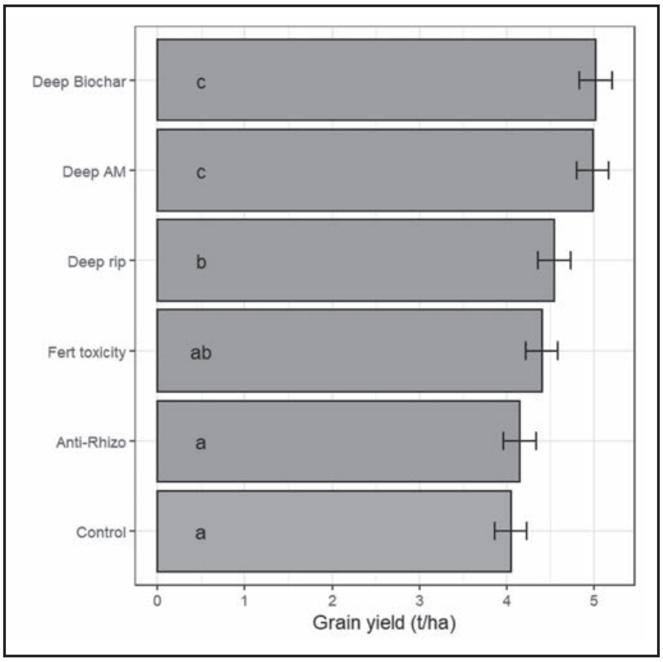


Figure 2. Grain yield of barley (t/ha) in the Poochera Rhizoctonia management trial 2022. Bars are the treatment LSD (P = 0.05).

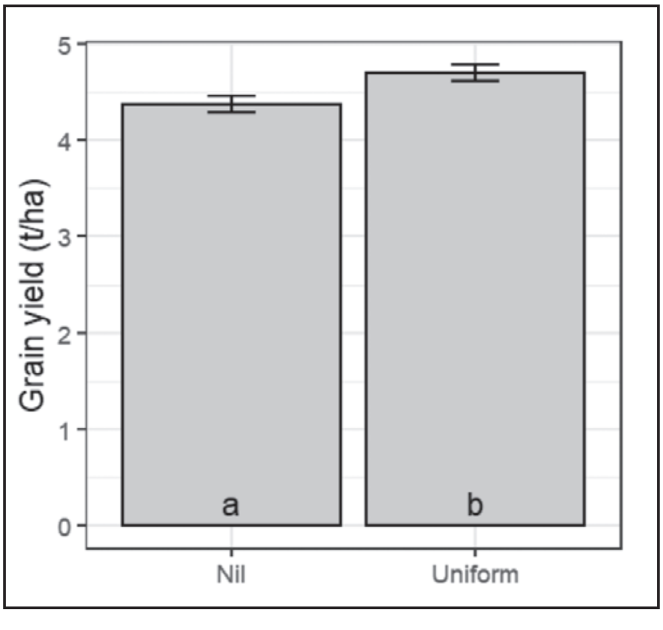


Figure 3. Grain yield of barley (t/ha) in the Poochera Rhizoctonia management trial 2022. Bars are the treatment LSD (P = 0.05).

Disease

There were no differences in rhizoctonia infection eight weeks after seeding despite crop growth appearing different between treatments (data not shown). However, Deep Biochar and Deep AM had lower visual rhizoctonia disease scores compared to the Control at the time of root sampling (data not shown).

Grain yield followed a similar trend to plant growth during the season with Deep Biochar and Deep AM yielding 1 t/ha better than the control and deep rip alone having higher yields than the control (Figure 2).

The application of Uniform® fungicide in furrow at seeding in a split fluid application increased grain yield by 0.26 t/ha compared to the Nil (control) (Figure 3) but did not change disease ratings (data not shown).

What does this mean?

For the third season the management treatments of Deep rip plus biochar enriched with nutrients (Deep Biochar), and Deep rip AM with animal manure pellets imposed at the beginning of 2020 performed better than the district practice control. The yield improvement was 1 t/ha in barley in the 2022 season in an above average rainfall season.

There were no differences due to the 2020 management treatments or fungicide application for rhizoctonia root infection of the seminal roots, the number of crown roots and crown root infection or general root health. Despite no differences being detected with root scoring, the use of Uniform® fungicide applied as a liquid stream with a split application increased grain yield by 0.26 t/ha in 2022. Previous studies on fungicides for rhizoctonia control show yield variation between seasons which may depend on spring rainfall (McKay, A., *et al*.). The benefit of the fungicide may have been a reduction in foliar leaf disease or the protection of the crown roots in the season; later than the eight weeks when roots were sampled. This would need to be confirmed in future trials to assess the level of foliar disease. The 2022 season was in a Decile 9 rainfall year with cool mild grain filling conditions and Uniform® showed a benefit of fungicide application which has not always been detected in previous upper EP research with earlier and drier finishes to the seasons.

Using break crops in the rotation such as canola or legumes and eliminating grass weeds to lower rhizoctonia inoculum levels before a cereal crop are still good management options.

The 'Epidemiology and management of rhizoctonia in low and medium rainfall zones' research has two more seasons with a new trial to examine innovative management strategies for rhizoctonia such as deep ripping and the use of long coleoptile varieties to be established in 2023. The research project also aims to better understand the seasonal triggers driving increased disease expression of rhizoctonia and a better understanding of the spatial variability (within and between paddocks). This research will be undertaken by CSIRO at Buckleboo in 2023.

Acknowledgements

This research was funded by GRDC Epidemiology and management of Rhizoctonia in low and medium rainfall zones (DAW2206-006RTX). The Calcareous Soils project "Producing more profitable crops on highly calcareous soils by improving early vigour and overcoming soil constraints" was funded by the CRC for High Performance Soils with support by GRDC. Thank you to the Gosling family for having the field trials on their property. Thank you to Katrina Brands and Rebbecca Tomney for field work and processing samples and Karyn Reeves for undertaking the statistical analysis.

Managing crown rot on upper Eyre Peninsula - a joint learning experience

Dr Margaret Evans
Evans Consulting

Location
Buckleboo
Tim Larwood
Rainfall
Av. Annual: 297 mm
Av. GSR: 195 mm
2022 Total: 492 mm
2022 GSR: 350 mm
Yield
Potential: potential yield calculator - 5.12 t/ha (good finish); 2.56 t/ha (poor finish)
Actual: 2.66 - 4.14 t/ha (W);
3.52 - 5.12 t/ha (B)
Paddock history
2021: Wheat
2020: Vetch
2019: Oats
Soil type
Red calcareous sandy loam
Soil test
PredictaB® analysis showed inoculum of the following stem-base/root diseases was present at the site: high risk - crown rot; low/medium risk - take-all; low risk - rhizoctonia and *Pratylenchus neglectus*
Plot size
12 m x 2 m x 4 reps
Trial design
Blocked split-plot
Yield limiting factors
Nil

Location
Mitchellville
Ty Kaden
AIR EP and Franklin Harbour Agricultural Bureau
Rainfall
Av. Annual: 282 mm
Av. GSR: 190 mm
2022 Total: 411 mm
2022 GSR: 215 mm
Yield
Potential: potential yield calculator - 3.06 t/ha (good finish); 1.53 t/ha (poor finish)
Actual: 1.90 - 3.12 t/ha (W);
3.73 - 4.36 t/ha (B)

Key messages

- **Crown rot expression was low in trials on upper Eyre Peninsula and in the Upper North as there was no stress that limited water availability for grain filling.**
- **Only yield data are available at this time - when crown rot severity data are available and statistical analyses are complete, more extensive interpretation of results will be possible.**
- **There were no obvious effects of varietal resistance or maturity on responses to Victrato® fungicide seed dressing (due for commercial release in Australia in 2024).**
- **Despite limited crown rot expression, some small yield responses were seen to Victrato®. These responses were consistent with the lower end of responses seen for bread wheat and barley at medium and high rainfall sites in South Australia in previous years, where crown rot expression was significant.**
- **Further research is planned to better understand crop responses to Victrato® in low rainfall and to determine whether those responses influence carryover of crown rot inoculum.**

Why do the trial?

The aims of this series of trials included assessing the effects of varietal resistance and maturity on crown rot expression and the efficacy of the fungicide seed treatment Victrato® for managing crown rot in low rainfall environments such as the upper Eyre Peninsula (UEP). Findings from other trials, demonstrations and capacity building activities will be presented in future EPFS Summary articles.

Victrato® (with Tymirium® chemistry, planned to be available commercially in Australia in 2024) is a seed applied fungicide with potential to reduce yield losses due to crown rot. This product has been shown to improve cereal yields in medium and high rainfall areas in the presence of crown rot. Information on the efficacy of this product for low rainfall areas is limited, but preliminary data from the upper North (one trial in each of 2020 and 2021) indicate responses are likely to be more variable than those seen in medium and high rainfall areas.

The decision to target the UEP, specifically the areas of Cowell and Kimba, for research and capacity building around crown rot management was based on the results of a survey undertaken by AIR EP in 2021. AIR EP has undertaken project management and activity co-ordination and, together with the involvement of the Buckleboo Farm Improvement Group and the Franklin Harbour Agricultural Bureau in planning and implementing trials, this has contributed to ensuring the research is relevant to UEP farming systems.

Paddock history
2021: Wheat
2020: Vetch
2019: Oats
Soil type
Sandy loam over carbonate layer
Soil test
PredictaB® analysis showed inoculum of the following stem-base/root diseases was present at the site: high risk - crown rot; low/medium risk - take-all; low risk - rhizoctonia and *Pratylenchus neglectus*
Plot size
12 m x 2 m x 4 reps
Trial design
Blocked split-plot
Yield limiting factors
Nil

Location
Booleroo Centre
Matt Nottle
Upper North Farming System
Rainfall
Av. Annual: 391 mm
Av. GSR: 276 mm
2022 Total: 410 mm
2022 GSR: 244 mm
Yield
Potential: potential yield calculator - 2.41 t/ha (good finish); 1.20 t/ha (poor finish)
Actual: 1.66 - 2.39 t/ha (W); 3.10 - 3.28 t/ha (B)
Paddock history
2021: Wheat
2020: Canola
Soil type
Duplex
Soil test
PredictaB® analysis showed inoculum of the following stem-base/root diseases was present at the site: high risk - crown rot; low/medium risk - take-all and common root rot; low risk - rhizoctonia, *Pratylenchus neglectus* and *P. thornei.*
Plot size
12 m x 2 m x 4 reps
Trial design
Blocked split-plot
Yield limiting factors
Very late sown due to poor early season rainfall and this reduced yields.

How was it done?

Field trials were established in paddocks with a high risk of crown rot at Buckleboo (9 May 2022), Mitchellville (9 May 2022) and Booleroo Centre (21 June 2022). Statistical advice and trial designs were provided by Sharon Nielsen (SN Stats), who will undertake statistical analyses (including meta-analysis) once all data from the trials are available.

Five bread wheat varieties and one barley variety suited to UEP were sown at all sites with and without seed-applied Victrato® fungicide. Entries included a range of maturities (which can influence responses to crown rot) and different crown rot resistance ratings (S = susceptible; MSS = moderately susceptible to susceptible).

Bread wheat varieties were Emu Rock (very quick to quick maturing; MSS), LRPB Anvil (quick to mid maturing; MSS), Vixen (quick maturing; S), Calibre (quick to mid maturing), Razor (quick to mid maturing; IMI tolerant; S), and Scepter (mid maturing; S). Commodus barley (quick to mid maturing) was included as barley may "escape" yield losses due to crown rot because of its very early maturity.

The same seed sources were used for all trials and Victrato® fungicide was supplied by Syngenta Australia and applied to seed by Lyndon May. Total solution rate was 600 mL/100 kg of seed.

At this time, only grain yield data are available - 2022 harvest dates were 17 December Buckleboo and Mitchellville, 18 December Booleroo Centre. No statistical analyses have been undertaken. Once the data set is complete (plant density, whitehead expression, browning on main stem bases, grain quality) and results from statistical analyses are available, further EPFS articles will include that information.

What happened?

Mild conditions during flowering and grain filling meant white heads due to crown rot did not express as there was limited moisture stress on plants. Stem browning symptoms due to crown rot developed at all sites. All trials were weed free and not adversely affected by leaf diseases, insect pests or frosts.

At Booleroo Centre the start to the season was late so the trial was late-sown, which affected plant growth and yields. At Buckleboo plant growth and yields benefited from good sub-soil moisture due to high summer rainfall and good early growing season rainfall.

Average yields of varieties (Table 1) reflect seasonal conditions at the sites, being lowest at Booleroo Centre and highest at Buckleboo. Commodus barley, as would be expected, had the highest yields at all sites (Table 1). There was no obvious influence of varietal maturity or resistance to crown rot on yield.

There were some yield improvements in the Victrato® treated plots (Table 2), but also a number of negative yield responses. Yield improvements were most consistent at Mitchellville (Table 2), where preliminary stem browning assessment suggests greater expression of crown rot symptoms than at the other sites.

The most consistent yield improvements (average and range) were seen for Calibre and Razor (Table 2). There was no obvious influence of varietal resistance or maturity on responses to Victrato® treatment.

Table 1. Preliminary information[1] on effects of varietal resistance[2] and maturity[3] on yields (t/ha - average, range in brackets) of bread wheat and barley in the presence of crown rot at Buckleboo, Mitchellville and Booleroo Centre in 2022.

	Calibre	Scepter	Razor	Vixen	Emu Rock	Anvil	Commodus
CR Resistance	?	S	S	S	MSS	?MSS	"Escape"
Maturity	Q-M	M	Q-M	Q	VQ-Q	Q(-M)	Q-M
Buckleboo	3.4 (2.7-3.7)	4.1 (3.6-4.8)	3.7 (3.2-4.1)	4.1 (3.6-4.7)	3.6 (3.2-3.8)	2.7 (2.3-2.9)	4.3 (3.5-5.1)
Mitchellville	2.9 (2.8-3.1)	2.8 (2.6-3.1)	2.4 (2.3-2.5)	3.1 (2.8-3.4)	2.7 (2.6-2.8)	1.9 (1.5-2.2)	4.1 (3.7-4.4)
Booleroo Centre	2.4 (2.1-2.9)	2.3 (2.1-2.7)	2.2 (2-2.6)	1.8 (1.4-2.2)	1.7 (1.5-2.0)	1.7 (1.5-1.9)	3.2 (3.0-3.3)

[1] Interpretation of these data will be improved once crown rot severity information for main stems is available.
[2] ?=unknown, S=susceptible, MSS=moderately susceptible to susceptible.
[3] ?=unknown, Q=quick maturing, M=mid maturing, VQ=very quick maturing.

Table 2. Preliminary information[1] on yield improvements (average %, range in brackets) due to Victrato® seed treatment in cereals with different crown rot resistances[2] at Buckleboo, Mitchellville and Booleroo Centre in 2022.

	Calibre	Scepter	Razor	Vixen	Emu Rock	Anvil	Commodus
CR Resistance	?	S	S	S	MSS	?MSS	"Escape"
Buckleboo	11 (2-20)	-9 (-24-4)	4 (-1-8)	8 (2-19)	0 (-8-12)	5 (-13-13)	12 (0-30)
Mitchellville	6 (-1-15)	2 (-3-9)	10 (0-21)	10 (6-15)	6 (5-8)	7 (-2-25)	7 (-2-16)
Booleroo Centre	9 (1-22)	4 (-5-10)	1 (-6-7)	-1 (-12-13)	6 (-1-20)	6 (-1-15)	0 (-10-14)

[1]Interpretation of these data will be improved once crown rot severity information for main stems is available.
[2]?=unknown, S=susceptible, MSS=moderately susceptible to susceptible.

What does this mean?

Mild seasonal conditions and good moisture availability during grain filling meant crown rot pressure on yield was limited, although some stem browning expression occurred at all sites. This meant responses to Victrato® were lower than, but still consistent with, responses seen in replicated trials in medium rainfall areas of South Australia in 2020 and 2021.

The variability amongst replicates of a given variety in response to Victrato® is likely to have been influenced by normal spatial variability in yield as crown rot expression was so low. Statistical analysis of yield and crown rot severity data may clarify the roles played by spatial variability and Victrato® effects, as will results from the trials planned for 2023.

To determine whether there is a reduction in inoculum carryover after Victrato® was applied in 2022, crown rot inoculum will be quantified pre-sowing in 2023 using PredictaB® analysis of soil samples. If inoculum carryover is reduced, this will influence when and how Victrato® is used to manage crown rot on the UEP and in other low rainfall environments.

Acknowledgements

Thanks to the growers and their families who hosted trials, as well as to AIR EP and the farmer groups that provided support for the project. Thanks to SAGIT for funding the project "AEP-1022-R Managing crown rot on Upper Eyre Peninsula - a joint learning experience" for the period 2022-2024. Thanks to Elders Limited for funding the Booleroo Centre trial. Also to Lyndon May (Elders) for organising and helping sample the Booleroo Centre trial, treating seed for all trials and assisting with sampling and to the other Elders staff who assisted with sampling. Thanks also to EPAG Research and AgXtra for managing trials and to EPAG Research staff for sampling and processing samples from the UEP sites. Thanks to Syngenta Australia for providing Victrato® fungicide and for technical assistance.

White grain in the 2022 wheat harvest

Dr Margaret Evans[1] and Dr Tara Garrard[2,3]
[1]Evans Consulting; [2]SARDI; [3]University of Adelaide

Key messages

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

Background

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

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

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

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

What happened in 2022?

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

Viterra responded to the situation by creating a segregation for the 2022/23 harvest to allow receivals with higher levels of white grain. At receivals, white grain falls into the defect category WGD/HS as per the Grain Trade Australia standards and normally levels of 1% or higher are cause for rejection.

However, the 2022/23 grade of SWGD (stockfeed white grain disorder) allows up to 20% WGD/ HS defect. This segregation was open at the Port Pirie site with a lower price point than feed grade (FED1), sitting more than $170/t below H1 grain (as at 27/01/23).

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

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

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

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

So what can we do?

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

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

Anecdotal evidence from affected growers and advisors suggests:

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

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

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

Acknowledgements

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

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

Disease

Fungicide resistant wheat powdery mildew - update on management and resistance testing

Sam Trengove[1], Stuart Sherriff[1], Jordan Bruce[1], Fran Lopez Ruiz[2], Kejal Dodhia[2], Nick Poole[3] and Ben Morris[3]
[1]Trengove Consulting; [2]Centre for Crop and Disease Management, Curtin University, Perth; [3]FAR Australia

Take home messages

- **Varietal resistance can play an important role in managing wheat powdery mildew. The variety Grenade CL Plus[A] (MS) had less powdery mildew infection in the untreated than Chief CL Plus[A] and Scepter[A] (SVS) treated with a two-spray fungicide strategy. However, Scepter was the highest yielding variety regardless.**
- **The application of group 11 QoI fungicides increased the frequency of resistance mutation G143A at the QoI target at three trial sites where resistance was present at low levels initially.**
- **Multiple diseases were present at trial sites this season. Fungicides providing broad-spectrum disease control, particularly for stripe rust, were the highest yielding treatments.**
- **A permit has been issued for the use of Legend® and other registered quinoxyfen (250 g/L) products for control of powdery mildew in wheat. Legend provided good control of WPM at Bute in 2022.**
- **WPM head infection reduced yield at Port Neill when severity exceeded 40% head infection.**

Background

Wheat powdery mildew (WPM) was widespread across south-eastern Australia in the 2022 season, occurring in most wheat growing regions, expanding its area of incidence compared with historical occurrence. There are a range of interacting factors that have caused this, including the predominance of SVS varieties grown in most regions over a long period of time, early crop establishment in many regions in 2022, conducive environmental conditions for developing large crop canopies and for disease development and inoculum source carrying over from previous seasons. Difficulty achieving high levels of disease control with what were considered robust and well-timed fungicides were reported in many regions. Increasing prevalence of resistance and reduced sensitivity to group 11 QoI and group 3 DMI fungicides has been implicated in these control failures. Following recent SAGIT project (TC120) findings, investment by GRDC (TRE2204-001RTX) is seeking to quantify the extent of resistance development across the regions and identify management strategies for WPM given resistance development.

Method

Small plot trials were established at four locations in 2022, at Port Neill, Bute and Malinong, SA and Katamatite, Vic. In a range of WPM resistance populations, these trials investigated post emergent fungicide efficacy, pre-emergent fungicide efficacy, fungicide timing and varietal resistance interactions. Season 2022 was conducive for development of a range of diseases, including Septoria, stripe rust and leaf rust. Three of the four locations were impacted by moderate to high levels of stripe rust, assessments endeavoured to account for these and quantify their impacts in addition to WPM. Assessments included disease incidence and severity, grain yield and grain quality. WPM samples were collected in a Nucleic Acid Preservation (NAP) buffer solution to assess change in resistance frequencies of mutations G143A at CytB, that indicate resistance to QoI, and Y136F at Cyp51 that is associated to other mutations conferring reduced sensitivity to DMI fungicides.

Variety trial: located at Bute, SA. Six varieties including Chief CL (SVS), Scepter (SVS), Mace (MSS), Grenade CL Plus (MS), Calibre (S) and Brumby (R). Four fungicide strategies were applied to Chief CL, Scepter, Mace and Grenade CL Plus, they were:

- Nil = no fungicide applied.
- Strategy 1 = Amistar Xtra @ 400 mL GS39.
- Strategy 2 = Epoxiconazole125 @ 500 mL/ha GS31 fb Amistar Xtra @ 400 mL/ha GS39.
- Complete = complete control of powdery mildew.

Fungicide efficacy trials: four product trials were implemented as small plot randomised complete block designs with 3 or 4 replicates. Trials were located at Bute, Port Neill, Malinong and Katamatite. Bute and Port Neill trials will be discussed in this paper, Bute treatments are shown in table 3. Product rates at Bute were the high label rate, unless specified otherwise in Table 3. The Port Neill trial was assessing fungicide performance at head emergence timing. The trial site was located within a farmer sown crop that was boom sprayed with Prothio T 420 fungicide at 300 ml/ha on 16 August when the crop was at GS33-39.

A field survey was conducted with triplicate samples of WPM collected in NAP buffer solution from 145 commercial paddocks in late September and early October for assessing the resistance frequency status of mutations G143A at CytB and Y136F at Cyp51 in regions across SA and Vic, including the Eyre Peninsula, SA Mallee and Upper SE of SA. These add to the database of 51 paddocks sampled from the Yorke Peninsula and Mid North SA in 2021 and 22 paddocks sampled from NE Vic and southern NSW in 2020. The results are not available at the time of writing the paper.

Table 1. site details for fungicide efficacy trials at Bute and Port Neill.

Site	Variety	Date of trial treatments	Growth stage	Number of Treatments	Replicates
Bute	Chief CL Plus	16/08/22 12/9/22	GS31 GS39	21	4
Port Neill	Vixen	5/09/2022	GS55	18	3

Results and discussion

Varietal resistance to wheat powdery mildew

The benefit of varietal resistance in limiting WPM build up is clear in untreated plots, where WPM pustule number typically follow the variety resistance rating (Figure 1). This is consistent with findings in both 2020 and 2021 (Trengove *et al*. 2021, Trengove *et al*. 2022). In the Bute region, Calibre has performed better than its S rating in both 2022 and 2021 (Trengove *et al*. 2022), being more closely aligned with Mace (MSS) and Grenade CL Plus (MS) in those seasons, respectively. WPM is a highly variable pathogen, and this deviation from expected performance based on resistance rating may reflect the local pathotype that is present. Brumby all but eliminated WPM development, highlighting its R status. Brumby's high level of resistance is derived from a major gene and supported by alternate minor genes that confer a lower level of resistance. Due to the high genetic variability in WPM, pathotypes may already exist that can overcome this major gene resistance and have virulence on this variety, where virulence will then depend on the performance of the minor genes. This was observed in a small isolated hot spot in Brumby in 2021 in a WPM variety trial at Bute, SA (Trengove *et al*. 2022). Therefore, Brumby is expected to provide excellent resistance when first grown in a region. However, there is a risk it will be overcome by more virulent pathotypes if they are selected across a wide area on a repeated basis. The timeframe over which this may occur will depend on the frequency and regional extent of virulent pathotypes in the WPM population, and the area of varietal selection. This makes rotating varieties an important strategy in managing WPM.

In a SVS variety like Chief CL a robust fungicide program like strategy 2 was required to reduce WPM levels significantly, but still had more WPM than Grenade CL (MS) with no fungicide treatment. Untreated plots were severely affected by stripe rust and leaf rust late in the season, being the main influence on yield in those plots (data not shown). With the nil plots excluded due to stripe rust, within variety, there was no grain yield difference between fungicide programs, except for the variety Chief CL (Figure 2). WPM continued to develop late in the season in Chief CL resulting in a 0.67 t/ha difference between Strategy 2 and complete WPM control. Responses of similar magnitude were recorded in SVS varieties in 2020 and 2021 to WPM control (Trengove *et al*. 2021, Trengove *et al*. 2022).

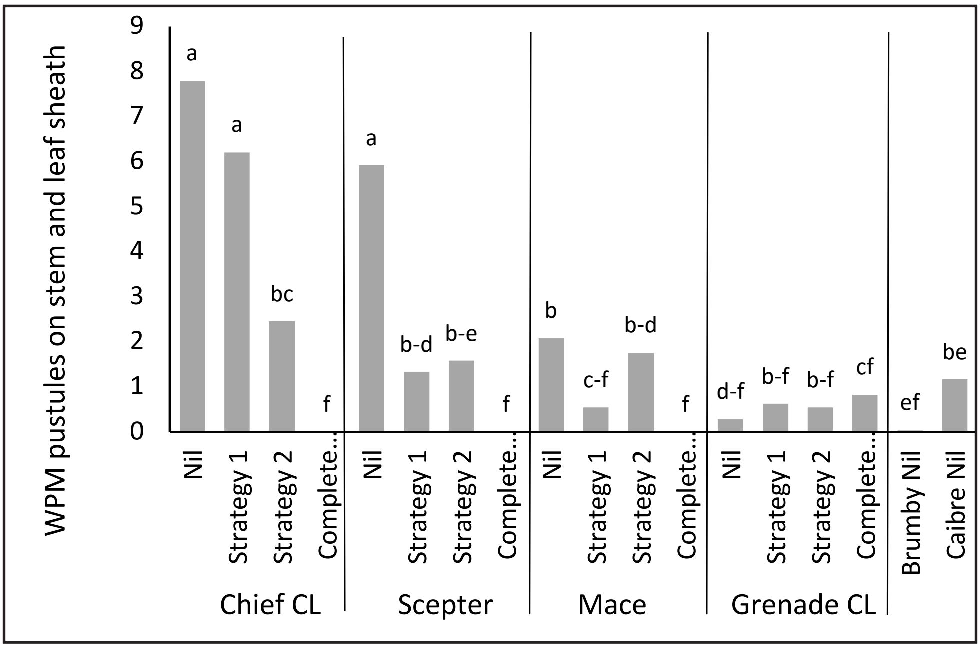


Figure 1. Variety by fungicide trial at Bute 2022. WPM pustules on the stem and leaf sheath assessed 27/9/2022 (P = <0.001).

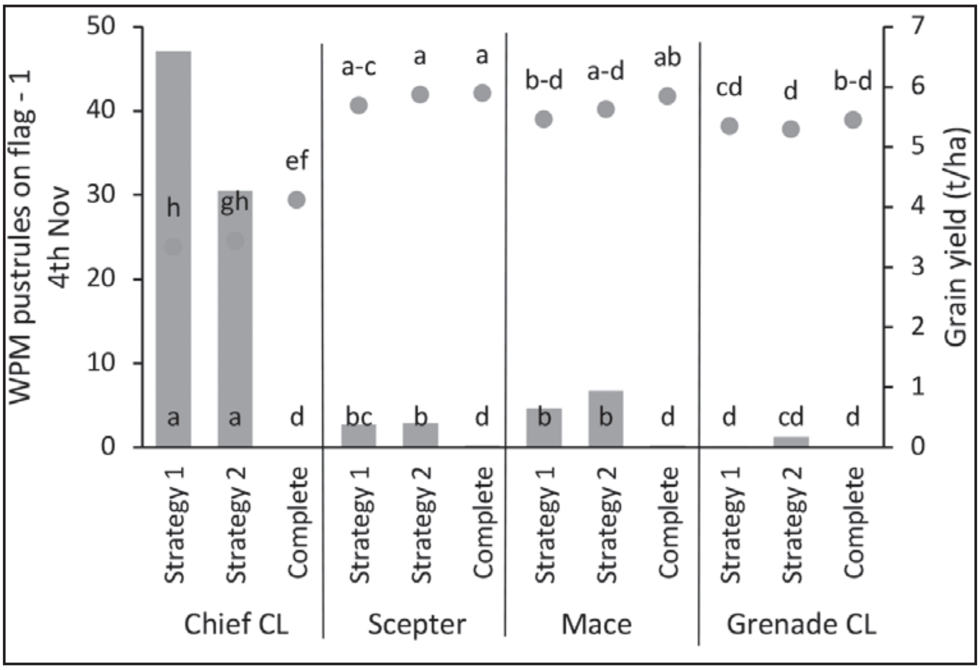


Figure 2. Variety by fungicide trial at Bute 2022. WPM pustules on the Flag minus 1, assessed 4/11/2022 (P = <0.001) and final grain yield (P = <0.001).

Wheat powdery mildew fungicide resistance and post-emergent fungicide performance

Mutation frequency for Y136F at Cyp51 was high at all trial sites averaging over 99%, regardless of treatment. This indicates that the gateway mutation associated with reduced sensitivity to group 3 fungicides is saturated at all trial site locations likely due to the strong selection pressure that wheat powdery mildew populations are under because of the reliance on DMI fungicides. Trial sites at Bute in 2020 and 2021 had 70% and 87% frequency of Y136F mutation and are consistent with survey data indicating this reached saturation in a relatively short time period.

Mutation frequency for G143A at CytB that confers resistance to group 11 QoI fungicides ranged from 1.2-24% across sites in the untreated control (Table 2). There is a trend for treatments containing the group 11 fungicide azoxystrobin to increase this frequency across the sites. This is expected, where the continual use of group 11 QoI fungicides maintains selection pressure on the population. This is consistent with 2021 results from Bute where treatments including azoxystrobin increased mutation frequency from 19 to 48.5% (Trengove *et al*. 2022).

Table 2. Fungicide treatment effect in four product efficacy trials on frequency of G143A mutation at CytB, conferring resistance to group 11 QoI fungicides. Letters denote treatments that are significantly different.

Treatment	Bute	Katamatite	Malinong	Port Neill
Nil	1.2 c	24 c	4.2	2.0 b
Epoxiconazole (3)	4.9 b	38 bc	6.8	2.2 b
Azoxystrobin (11)	9.2 a	45 bc	10.6	4.1 a
Tazer Xpert (3 + 11)	5.8 ab	70 ab	12.3	1.6 b
Tebuconazole (3)		53 ab		
Veritas (3 + 11)		79 a		
Prothioconazole (3)	2.4 bc			
Maxentis (3 + 11)	5.3 b			
Aviator Xpro (3 + 7)	3.1 bc			
LSD (P = 0.05)	*0.002*	*0.022*	*0.107*	*0.011*

WPM control at Bute was poor with single active DMI products being no better than the untreated (Table 3). Dual active DMI Prosaro® provided some control. Azoxystrobin reduced WPM infection, both standalone and in the dual active group 3 and 11 mixtures. Given low levels of QoI resistance at the site this is not unexpected, however is not likely to be a long-term solution given ongoing selection for resistant individuals (Table 2). Aviator Xpro® is a DMI plus SDHI mix but is no better than the standalone prothioconazole DMI component (Proviso® 250EC), which is consistent with previous results. Telbek® Adavelt® is a new group 21 fungicide and provided useful WPM control at this site.

Legend® fungicide and other registered products with quinoxyfen (250 g/L) have been issued Permit 93197 for use in wheat for the control of powdery mildew at use rates of 200-300 mL/ha. The permit is in place for 18 months. Critical use comments from the label include:

- Apply at the first signs of infection as a protectant treatment only.
- Monitor crops regularly from early tillering and apply at or before GS31.
- Monitor if conditions favour disease development and reapply from 21 to 28 days after the first application and no later than GS39.
- Apply foliar application by ground boom.
- Use higher rates where conditions favour disease development.
- Use a spray volume of 50-100 L/ha.
- DO NOT apply more than 2 applications per crop.
- DO NOT apply less than 21 days after the initial treatment.
- DO NOT apply after the growth stage GS39.
- Apply quinoxyfen in accordance with the current CropLife Fungicide Resistance Management Strategy.

These comments will need to be factored in when planning to use Legend for WPM control.

Legend® provided high levels of WPM control at Bute in 2022 (Table 3), and this result is consistent with trial results in 2020 and 2021. Several experimental products tested also provided high levels of control. It is important to note that diseases do not occur in isolation though, and broad-spectrum fungicides were required to control all diseases present at the site including stripe rust, Septoria tritici, Wirrega blotch and WPM. Stripe rust infection and its control was the biggest determinant of grain yield and products that controlled stripe rust were the highest yielding, where the untreated control yielded 20% of the best treatments. Legend® and the experimental products provided no stripe rust control and were only marginally better than untreated control for grain yield. Mildew specific fungicides such as Legend® will need to be applied with an appropriate mix partner to provide broad spectrum disease control.

When QoI group 11 fungicides are rendered ineffective due to resistance, and control from SDHI group 7 fungicides is typically low, the DMI group 3 fungicides have been the remaining fungicidal control option, albeit at reduced levels due to reduced sensitivity. A trial at Bute investigated the effect of applying DMI actives at full label rates, standalone or in two-way and three-way mixes, to try and optimise control. Active ingredients included tebuconazole, epoxiconazole and prothioconazole. Results indicate that increasing the load of DMI by applying active ingredients in combination provided better control than applying the actives as standalone treatments (Figure 3).

Table 3. Fungicide effect on wheat powdery mildew, Wirrega blotch & Septoria tritici, stripe rust and grain yield in Chief CL wheat at Bute, SA, 2022.

Product	WPM canopy score 28 Sept	[a]WPM pustules/ stem 28 Sept	[b]Blotch Score 28 Sept	Rust canopy score 16 Oct	Rust canopy score 4 Nov	Grain yield (t/ha)
Nil	3.0 a	1.0 a	37 bc	9.3 a	9.9 a	0.66 j
Tebuconazole430	2.8 a	0.8 a-d	18 f-h	1.5 h	4.1 h	2.69 d-f
Opus® 250 mL/ha (GS39 only)	2.6 ab	0.9 ab	33 b-e	1.5 h	4.0 hi	2.53 d-g
Opus® 500 mL/ha	2.6 ab	0.9 a-c	16 gh	0.5 i	2.6 jk	2.85 b-d
Propiconazole	2.4 a-c	0.8 a-c	20 d-h	3.0 fg	6.9 f	2.53 d-g
Proviso® 250EC	2.3 a-d	0.8 3	18 e-h	5.5 c	8.4 cd	2.36 fg
Prosaro®	2.1 a-d	0.6 c-f	21 d-h	1.0 hi	3.3 i-k	3.07 a-c
[c]Mirador® 625 (azoxystrobin)	2.3 a-d	0.6 c-f	12 h	2.8 g	5.4 g	2.57 d-g
Veritas Opti®	1.8 b-e	0.5 d-g	24 c-h	1.0 hi	3.4 h-j	2.67 d-g
Amistar Xtra®	1.5 c-e	0.5 d-g	20 d-h	1.5 h	3.9 hi	3.23 a
Tazer Xpert®	1.4 d-f	0.4 f-h	12 h	1.3 hi	2.6 k	3.19 ab
Maxentis®	1.6 c-e	0.4 f-i	31 b-g	4.0 de	6.9 f	2.74 c-e
Aviator Xpro®	1.8 b-e	0.7 b-e	10 h	4.8 cd	7.1 ef	2.41 e-g
Telbek® Adavelt®	1.1 ef	0.4 f-h	20 d-h	6.5 b	8.9 bc	1.65 h
[d]Legend®	0.5 fg	0.0 j	34 b-d	9.0 a	9.9 a	1.04 i
Telbek® Adavelt® + TC EXP 01	0.1 g	0.1 h-j	32 b-f	6.8 b	9.2 a-c	1.54 h
Telbek® Adavelt® + TC EXP 01 + Proviso® 250EC	0.0 g	0.1 ij	29 b-g	4.8 cd	7.7 de	2.31 g
TC EXP 01	0.0 g	0.5 efg	32 b-f	9.0 a	9.9 a	0.98 ij
TC EXP 02	0.5 fg	0.3 f-i	40 ab	6.8 b	9.1 bc	1.57 h
TC EXP 04	0.0 g	0.2 g-j	54 a	9.0 a	9.6 ab	1.06 j
Probability	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
LSD (P = 0.05)	*0.875*	*0.3*	*15*	*0.9*	*0.8*	*0.36*

[a] data has been transformed to log10(1 + pustule count).
[b] blotch score is the leaf area percent of the flag minus 1, 2 and 3 affected by necrosis caused by Wirrega blotch and Septoria tritici combined.
[c] Mirador® 625 is registered in wheat only when mixed with a DMI mix partner. It has been applied standalone in this trial for research and demonstration purposes.
[d] Legend is available for use under PER93917.

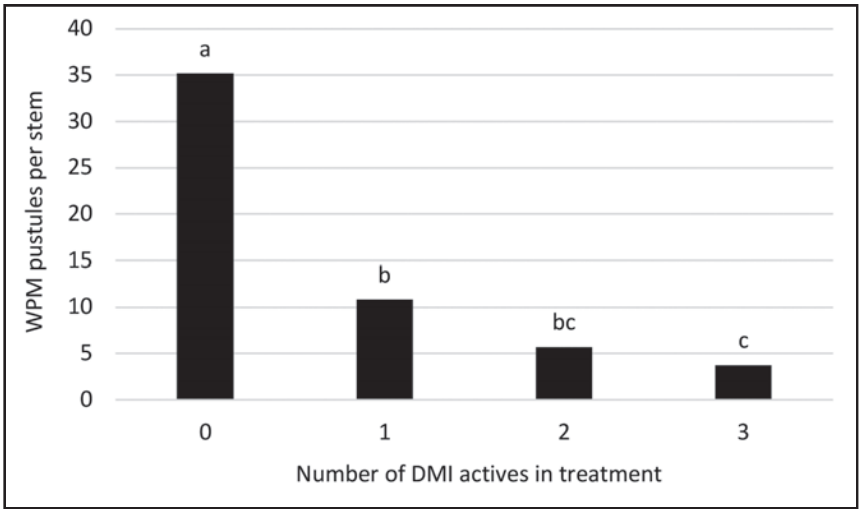


Figure 3. Total WPM pustule number assessed on the Flag minus 1, 2 and 3 and the lower stem on 29/9/2022 for Chief CL treated with group 3 DMI fungicide combinations.

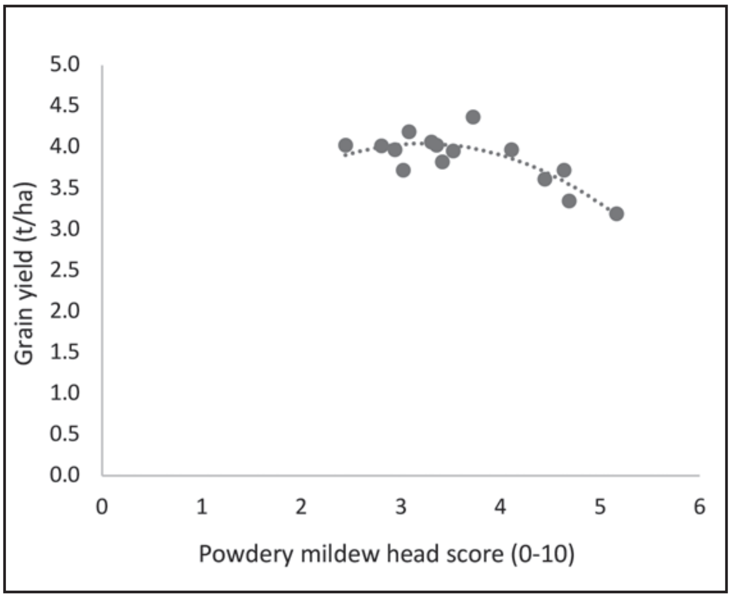


Figure 4. WPM head score in Vixen wheat at Port Neill on Nov 3rd and grain yield response (Y = -0.232x2 + 1.494x +1.637, R2 = 0.689).

Fungicide applied at head emergence at Port Neill resulted in different levels of WPM head infection, with treatment scores ranging from 2.4 to 5.2 in the untreated (Figure 4). The relationship between WPM head infection and grain yield indicates when the head score was less than 4 there was little difference in grain yield but declined when the head score exceeded 4, where the untreated control yielded 3.2 t/ha. A head score of 4 indicates approx. 40% of the head has mildew growth.

References

Trengove, S., Sherriff, S., Bruce, J. Lopez Ruiz, F. (2021). Management of powdery mildew on fungicide resistant wheat, 2021 GRDC Adelaide Grains Research Update.

Trengove, S., Sherriff, S., Bruce, J., Lopez Ruiz, F and Dodhia, K. (2022). Fungicide resistant wheat powdery mildew - management and resistance testing, 2022 GRDC Online Grains Research Update

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 author would like to thank them for their continued support. PER93917 is a result of SAGIT and GRDC investments, field studies and regulatory, and the support of Grain Producers Australia (GPA) as the permit holder. The input during this project from Tara Garrard is gratefully acknowledged.

GRDC project code:
TRE2204-001RTX

[A]Varieties displaying this symbol beside them are protected under the Plant Breeders Rights Act 1994

Disease

Section Editor:
Elijah Luo
SARDI

Section 8

Pests

Using zinc phosphide to control wild house mice

Steve Henry[1], Lyn Hinds[1], Wendy Ruscoe[1], Peter Brown[1], Richard Duncan[2], Nikki Van de Weyer[1] and Freya Robinson[1]
[1]CSIRO Health and Biosecurity, Canberra; [2]University of Canberra

Key messages

- **Mice are not as sensitive to zinc phosphide (ZnP) as was first reported in studies in the 1980s.**
- **2 mg of ZnP is required on each grain to deliver a lethal dose to a 15 g mouse.**
- **Grain bait mixed at 50 g ZnP/kg wheat is significantly more effective than bait mixed at the previously registered rate of 25 g ZnP/kg wheat.**
- **Reducing background food could be critical to achieving effective bait uptake.**
- **Timely application of ZnP grain bait at the prescribed rate is vital for reducing the impact that mice have on crops at sowing.**
- **Strategic use of bait is more effective than frequent use of bait.**

Why do the trial?

The content of this paper relates primarily to the GRDC investment, *Determining the effectiveness of zinc phosphide rodenticide bait in the presence of alternative food supply*. Growers were reporting concerns regarding the effectiveness of commercially prepared zinc phosphide (ZnP) wheat-based baits. In response, we conducted three experiments to examine the efficacy of ZnP bait. The initial experiment (Experiment 1) aims to determine what was driving the reduced efficacy of the bait and sought to test potential new bait substrates that might be more attractive to mice. The second experiment (Experiment 2) aims to re-assess the acute oral toxicity of ZnP for wild house mice. The third experiment (Experiment 3) aims to quantify the efficacy of the higher lethal dose compared to the registered rate in a field trial.

How was it done?

Experiment 1

This experiment consisted of two sub-experiments (Experiment 1a and 1b). Experiment 1a had mice held on a background food type (barley, lentils or wheat) and then offered the choice of an alternative grain type (malt barley, durum wheat or lentils) for five nights to determine their two choice grain preference. Experiment 1b tested the toxic bait take with different background grains by holding mice a background food type (lentils, barley or wheat) then offering mice ZnP baited grain (25 g ZnP/kg grain) for three consecutive nights.

Experiment 2

This experiment re-assessed the acute oral toxicity of ZnP for wild house mice using an oral gavage technique, where known doses of ZnP were delivered directly into the stomachs of mice. The responses of three different groups of mice were assessed and compared: (1) wild mice from an area where ZnP had been spread frequently (exposed), (2) wild mice from an area where ZnP had never been used (naïve), and (3) laboratory mice (Swiss outbred). The proportion of mice that died at each dose was used to calculate a dose response curve for each of the groups of mice (Figure 1) (Hinds *et al*. 2022).

Table 1. Percentage mortality from ZnP bait (25 g ZnP/kg grain) and the average number of toxic grains consumed for each background food type on night one of the study (Henry et al. *2022).*

Background food	n	Mortality (%)	Toxic grains eaten (av.)
Lentils	30	86	7.3 ± 2.5
Barley	30	53	4.5 ± 2.9
Wheat	30	47	2.1 ± 1.6
MN 2021	10	0	90

Experiment 3

This experiment addressed the efficacy of the two different bait types, ZnP25 (25 g ZnP/kg bait, ~1 mg ZnP/grain) applied at 1 kg bait/ha and the new formulation, ZnP50 (50 g ZnP/kg bait, ~2 mg ZnP/grain), applied at 1kg bait/ha. Nine sites were selected on farms in the area surrounding Parkes in central NSW, three un-baited control sites, three sites baited with ZnP25 (25 g ZnP/kg bait), and three sites baited with ZnP50 (50 g ZnP/kg bait). All sites were trapped prior to baiting to establish population sizes and then again after baiting to determine changes in population.

What happened?

Experiment 1

In Experiment 1a, mice displayed a strong preference towards cereal grains, with a slight preference towards malt barley. In Experiment 2b, mice consumed toxic bait grains regardless of bait substrate although background food type had a strong influence on the number of toxic baits consumed. Most of the mice in this experiment consumed what was considered to be a lethal dose; however, the mortality rate was significantly lower than expected (Table 1) (Henry *et al*. 2022). Furthermore, animals that survived after consuming toxic grains didn't consume any more toxic grains for the duration of the study.

Experiment 2

The results from Experiment 2 showed no significant differences in the sensitivity of any of the groups of mice to ZnP, indicating that there has been no selection for tolerant mice in areas where mice had frequent exposure to ZnP. However, there was a significant difference between the previously reported LD50 of 32.68 mg ZnP/kg body weight (Li and Marsh 1988) and our re-calculated LD50 of 72–75 mg ZnP/kg body weight.

Experiment 3

In Experiment 3, baiting with ZnP50 led to a median reduction in mouse numbers of >85%. Modelling showed that under similar circumstances, using the ZnP50 formulation should deliver >80% reduction in population size most (>90%) of the time. In contrast, the current registered bait (ZnP25) achieved approximately 70% reduction in population size, but with more variable results. We would be confident of getting an 80% reduction in population size only 20% of the time if using the currently registered ZnP25 bait under similar field conditions (Figure 2) (Ruscoe *et al*. 2022).

What does this mean?

In Experiment 1, mortality was not as high as expected in mice that consumed toxic grains. The development of aversion was rapid and the duration is unknown. These results indicated that mice are not as sensitive to ZnP as was first reported in studies in the 1980s.

The critical results from Experiment 2 mean that 2 mg of ZnP/grain is needed instead of 1 mg of ZnP/grain to kill a 15 g mouse (Hinds *et al*. 2022).

Data collected and analysed in Experiment 3 suggested that ZnP grain bait mixed at 50 g ZnP/kg wheat is significantly more effective than bait mixed at the previously registered rate of 25 g ZnP/kg wheat as the kill rate of >80% could be achieved 90% of the time for the higher rate compared to the registered rate for which an 80% kill rate would be observed only 20% of the time.

With mice being reported across many areas in the cropping zone, it is critical that farmers and agronomists have a good understanding of mouse activity in stubbles:

1. Focus on areas where there has been significant grain loss (barley stubbles, lodged crops and storm damage).
2. Monitor stubbles for mouse activity using active burrow counts and chew cards.
3. Reduce grain on the ground where possible (graze stubbles, spray out germinations).
4. Bait mice when other food sources are low (such as when the crop is sown and residual food is buried by the seeder).
5. Continue to monitor after baiting to ensure that numbers are reduced.

Lab – Swiss outbred

LD_{50} = 79.18 ± 6.24mg ZnP/kg

Naïve wild mice

LD_{50} = 72.11 ± 9.09mg ZnP/kg

Exposed wild mice

LD_{50} = 75.22 ± 4.39mg ZnP/kg

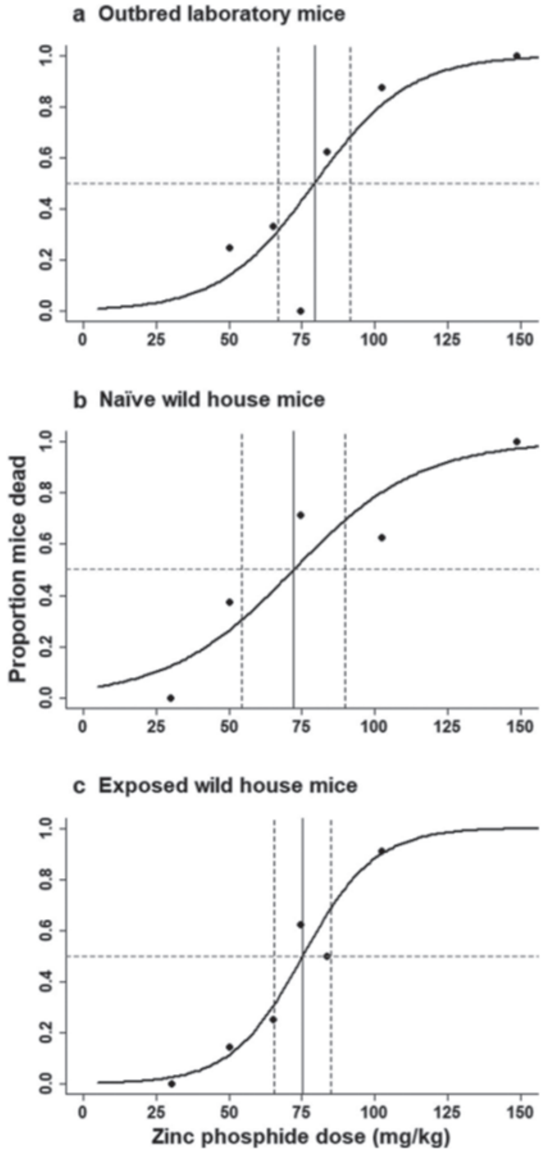


Figure 1. Proportion of mice dying after oral gavage with different ZnP concentrations (mg ZnP/kg body weight). Calculated dose response curves for (a) outbred laboratory mice, (b) naïve wild house mice, and (c) exposed wild house mice. Horizontal dashed line represents 50% mortality; vertical solid line equates to LD50 value; vertical dashed lines represent standard error for the LD50 estimate. N>four animals per test dose, with a mix of males and females (Hinds et al. 2022).

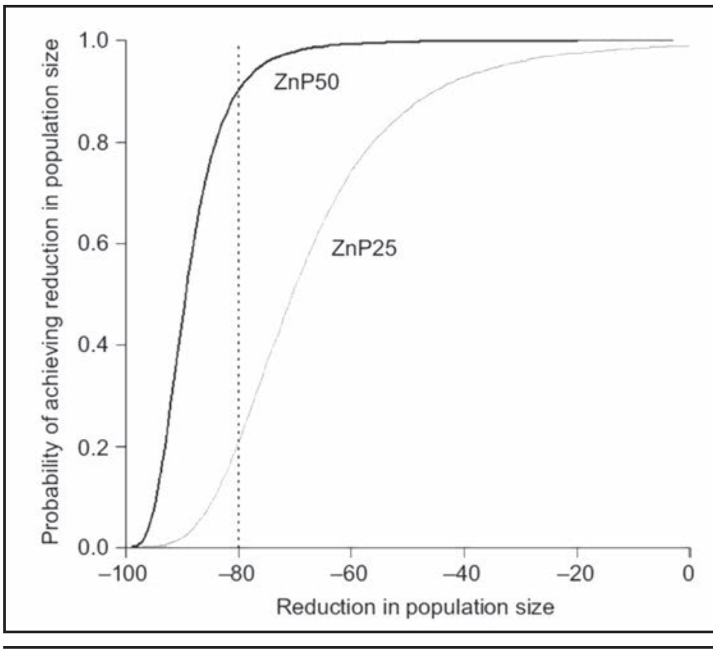


Figure 2. The probability of achieving a certain reduction in population size or better by using the ZnP50 bait (solid black line) and the ZnP25 bait (solid grey line). The dotted vertical line shows that there is a ~90% chance of getting a >80% reduction in population size by using ZnP50, but only a 20% chance of achieving that outcome by using ZnP25 (Ruscoe et al. 2022).

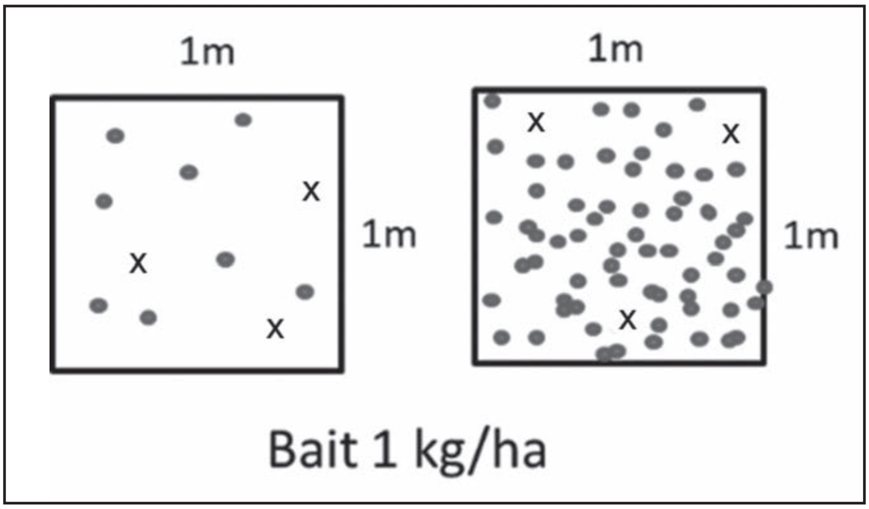


Figure 3. Representation of detectability of toxic grains at different levels of background food. The dots represent grains and crosses represent toxic grains.

These results highlight the benefit of applying 50 g bait and if used in conjunction with the above practices should lead to good results from baiting effort. In addition, more research on how background food influences the uptake of ZnP bait is required as substantial grain loss, pre-and post-harvest is common in zero and no-till cropping systems. In 2022, it was estimated that $300 million worth of grain (GRDC project code GGA2110-001SAX) was left on the ground post-harvest in WA alone and reports of losses of 1 t/ha are not uncommon (pers. comm). Bait spread at 1kg/ha equates to approximately three toxic grains per square metre. If there have been losses of 1 t/ha, equivalent to about 2200 grains per square metre, finding a toxic grain becomes a game of hide and seek for mice (Figure 3). Therefore, understanding the role that background food plays in the uptake of ZnP bait will be critical to achieving effective mouse control.

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.

References

Henry, S., Brown, P. R., Van de Weyer, N., Robinson, F. and Hinds, L. A. (2022). Effects of background food on alternative grain uptake and zinc phosphide efficacy in wild house mice. Pest Management Science 78, 1090-1098. doi: 10.1002/ps.6720.

Hinds, L. A., Henry, S., Van de Weyer, N., Robinson, F., Ruscoe, W. A. and Brown, P. R. (2022). Acute oral toxicity of zinc phosphide: an assessment for wild house mice (Mus musculus). Integrative Zoology 0, 1-13, doi: 10.1111/1749-4877.12666.

Li, J. and Marsh, R. E. (1988). LD50 determination of zinc phosphide toxicity for house mice and albino laboratory mice. Proceedings of the Vertebrate Pest Conference, 13. https://escholarship.org/uc/item/1194x1bk

Ruscoe, W. A., Brown, P. R., Hinds, L. A., Henry, S., Van de Weyer, N., Robinson, F., Oh, K. and Duncan, R. P. (2022). Improved house mouse control in the field with a higher dose zinc phosphide bait. Wildlife Research, doi 10.1071/WR22009.

Trial Information

Location: Experiment 1 and were undertaken in laboratory in Canberra. Experiment 3 was undertaken on farms around Parkes, NSW.

GRDC GRAINS RESEARCH & DEVELOPMENT CORPORATION

CSIRO

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
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

Triazine Tolerant (TT)

Gesaprim 600Sc - registered trademark of Syngenta Group Company
Lexone - registered trademark of Du Pont (Australia) Ltd or its affiliates
Supercharge - registered trademark of Syngenta Group Company

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 Pty Ltd
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
Terbyne Xtreme - registered trademark of Sipcam Australia Pty Ltd
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
Pyrinex Super - registered trademark of ADAMA

Fungicide

Aviator - registered trademark of the Bayer Group
Baytan - registered trademark of the Bayer Group
Cruiser Maxx - registered trademark of a 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
Prosaro - registered trademark of the Bayer Group
Rancona Dimension - registered trademark of UPL
Raxil - registered trademark of the Bayer Group
Stayer - registered trademark of the Bayer Group
Uniform - registered trademark of a Syngenta Group Company
Veritas - registered trademark of ADAMA
Vibrance - registered trademark of a Syngenta Group Company

Acronyms and abbreviations

ADF	Acid Deterent Fibre
AH	Australian Hard
APG	Australian Pastures Genebank
AM fungi	Arbuscular Mycorrhizal Fungi
APW	Australian Premium Wheat
AWW	Ausralian White Wheat
BCG	Birchip Cropping Group
BGA	Bluegreen Aphid
BGM	Botrytis grey mould
BLR	Barley leaf rust
BGA	Bluegreen Aphid
CV	Coefficient of variation
DAP	Di-ammonium Phosphate
DCC	Department of Climate Change
DLPS	Dryland Legume Pasture Systems
DM	Dry Matter
EP	Eyre Peninsula
Ex-GST	Goods and Service Tax exclusive
FHB	Fusarium head blight
GPE	Grain number per ear
GS	Growth Stage
GSR	Growing Season Rainfall
HEI	Plant height at maturity
HI	Harvest index
HS	Head Scab
IBS	Incorporated by sowing
IHM	Indian Hedge Mustard
IMI	imidazolinone
LD50	The dose of a test substance that is lethal for 50% of the animals in the test group
LOD	Lodging
LoRaWAN	Long range wide area network
LSD	Least Significant Difference
MAC	Minnipa Agricultural Centre
MAP	Monoammonium Phosphate
ME	Metabolizable Energy
MJ	Megajoules
MJ ME/kg D	Megajoules of metabolizable energy per kilogram of dry matter
MLA	Meat and Livestock Australia
MR	Moderately Resistant
MR#	Moderately Resistant (Warning more susceptible to alternate pathotypes)
MRMS	Moderately Resistant - Moderately Susceptible
MRMSp	Moderately Resistant - Moderately Susceptible (Provisional rating)
MRP	Moderately Resistant (Provisional rating)
MS	Moderately Susceptible
MSp	Moderately Susceptible (Provisional rating)
MSS	Moderately Susceptible to susceptible
ns	not significant
NAP	Nucleic Acid Preservation
NDF	Neutral detergent fibre
NDVI	Normalised difference vegetation index
NFNB	Net form net blotch
NIR	Near-infrared spectroscopy
NVT	National Variety Trials
OC	Organic Carbon
PIRSA	Primary Industries and Regions South Australia
PM	Powdery Mildew
PSPB	Post-sowing pre-emergent
R/S	Resistant pathotype differences susceptible
RCBD	Randomised Complete Block Design
RF	Rainfall
RMR	Resistant to Moderately Resistant
RMRp	Resistant to Moderately Resistant (Provisional rating)
RP	Relative performance
S	Susceptible
SAA	Spotted alfalfa aphid
SFNB	Spot form net blotch
SU	tolerance of Sulfonylurea
SVS	Susceptible to very susceptible
TBC	To be confirmed
TE	Trace Elements
TGW	Thousand grain weight
TIN	Fertile tillers at harvest
TOS	Time Of Sowing
TW	Test weight
UEP	Upper Eyre Peninsula
WGD	White grain disorder
WUE	Water use efficiency
ZnP	Zinc phosphide

Contact list for authors

Name	Position	Location	Phone Number	E-mail
Aggarwal, Navneet	Research Agronommist	SARDI Clare	0490 380 944	navneet.aggarwal@sa.gov.au
Bruce, Jordan	Agronomist	Trengove Consulting	0408 422 903	jordanpbruce@gmail.com
Cook, Amanda	Research Leader	Minnipa Agricultural Centre SARDI	(08) 8680 6217 0427 270 154	amanda.cook@sa.gov.au
Day, Sarah	Research Officer	SARDI Clare	(08) 8841 2404	sarah.day@sa.gov.au
Desbiolles, Dr Jack	Agricultural Research Engineer	University of South Australia	0419 752 295	jack.desbiolles@unisa.edu.au
Dzoma, Brian	Research Officer	SARDI Waite	0455 071 032	brian.dzoma@sa.gov.au
Edmondson, Colin	Technical Development Manager - SA & VIC	Long Reach Plant Breeders	0428 833 321	cedmondson@longreachpb.com.au
Evans, Dr Margaret		Evans Consulting	0427 604 168	margevans33@gmail.com
Fatchen, Rebekah		EPAG Research		rebekah@epagresearch.com.au
Ferguson, Kaye	Senior Research Officer	SARDI Port Lincoln	0437 297 585	kaye.ferguson@sa.gov.au
Frischke, Alison	Livestock & Farming Systems Officer	BCG	0429 922 787	alison@bcg.org.au
Giles, Jacob	Extension Officer	EPAG Research	0431 110 018	jacob@epagresearch.com.au
Gupta, Dr Vadakattu	Senior Principal Research Scientist Microbial Ecology	CSIRO Agriculture & Food	(08) 8303 8579	gupta.vadakattu@csiro.au
Gontar, Blake	Senior Research Officer	SARDI Waite	(08) 8429 0290 0430 597 811	blake.gontar@sa.gov.au
Henry, Steve	Research Officer	CSIRO	0428 633 844	steve.henry@csiro.au
Keeley, Amy	Senior Research Officer	SARDI Port Lincoln	0401 646 961	amy.keeley@sa.gov.au
Kelsh, John	Farm Manager	SARDI Minnipa Agricultural Centre	(08) 8680 6212	john.kelsh@sa.gov.au
Loss, Dr Stephen	GRDC Senior Regional Manager - South	GRDC, Adelaide	(08) 8198 8400	stephen.loss@grdc.com.au
Masters, Brett	Senior Sustainable Agriculture Consultant	SARDI Port Lincoln	0428 105 184	brett.masters@sa.gov.au
McBeath, Dr Therese	Principal Research Scientist	CSIRO Agriculture & Food Waite Campus	0422 500 449	therese.mcbeath@csiro.au
Meiklejohn, Rhaquelle		EPAG Research		rhaquelle@epagresearch.com.au
Peck, David	Senior Research Officer	SARDI Waite	(08) 8429 0475	david.peck@sa.gov.au
Pham, Ahn	Postdoctoral Research Fellow	University of Adelaide	(08) 8313 6700	ahn.pham@adelaide.edu.au

Name	Position	Location	Phone Number	E-mail
Preston, Dr Christopher	Professor	University of Adelaide	0488 404 120	christopher.preston@adelaide.edu.au
Rose, Mick	Senior Research Scientist, Soils	NSW Department of Primary Industries	0422 522 774	mick.rose@dpi.nsw.gov.au
Schilling, Dr Rhiannon	Program Leader - Agronomy	SARDI, minnipa Agricultural Centre & SARDI Waite	(08) 8429 2926	rhiannon.shilling@sa.gov.au
Scholz, Naomi	Executive Officer	AIR EP	0428 540 670	eo@airep.com.au
Tomney, Fiona	Research Officer / Node Coordinator	SARDI, Minnipa Agricultural Centre / SA Drought Resilience Adoption and Innovation Hub	0459 540 697	fiona.tomney@sa.gov.au
Trengove, Sam	Principal Consultant	Trengove Consulting	0428 262 057	samtrenny34@hotmail.com
Ware, Andrew	Consultant	EPAG Research	0427 884 272	andrew@epagresearch.com.au
Wilhelm, Dr Nigel	Farming System Leader	SARDI, Waite	0407 185 501	nigel.wilhelm@sa.gov.au
Young, Max	Chair	SAGIT	0419 839 008	maxhyoung62@gmail.com
Zeppel, Kym	AgTech Extension Officer	PIRSA, Minnipa Agricultural Centre	(08) 8680 6210	kym.zeppel@sa.gov.au

SAGIT visiting Mount Cooper trial site, 6 September 2022.

NOTES:

NOTES:





Government of South Australia

Department of Primary Industries and Regions

SARDI

SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE