



Eyre Peninsula Farming Systems Summary 2023

SARDI - Minnipa Agricultural Centre



Government
of South Australia

Department of Primary
Industries and Regions

SARDI



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Eyre Peninsula Farming Systems Summary 2023

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SARDI Foreword

On behalf of the South Australian Research and Development Institute (SARDI), the research division of the Department of Primary Industries and Regions (PIRSA), I am pleased to present the 2023 Eyre Peninsula Farming Systems Summary. The publication proudly provides a record of the recent research, development and extension activities carried out at the Minnipa Agricultural Centre (MAC). It provides a resource for Eyre Peninsula (EP) growers, advisors and other primary industry stakeholders in the region to guide on farm decisions into the future.

The research documented in the summary is a result of a shared effort from researchers and investors. I thank the contributions from the MAC staff, PIRSA-SARDI, the Grains Research and Development Corporation (GRDC), the South Australian Grains Industry Trust (SAGIT), Ag Innovation & Research Eyre Peninsula (AIR EP), Buckleboo Farm Improvement Group (BFIG), the Australian Government (National Landcare Program, Rural R&D for Profit, Soil CRC, Future Drought Fund and SA Drought Hub), NSW Department of Primary Industries (NSW DPI), Department of Primary Industries and Regional Development (DPIRD), The University of Adelaide, the University of South Australia, Landscape Board, CSIRO and plant breeders. Thank you to SAGIT for their investment and ongoing support toward the printing of the EP Farming Systems Summary.

The recent release of the Primary Industries Scorecard data for 2022/2023 has confirmed a record grain harvest of 12.8 M tonnes in 2023 across South Australia, an increase of 51% from 2021/2022. This represents a total field crop revenue of \$7.76 billion, driven primarily by favourable seasonal conditions and strong global commodity prices for grain. EP grain growers provide a significant contribution to the broader SA grain sector, and are in many ways leading the path through innovation in farming practices, and the adoption of new technology on farm to improve farm profitability.

Once again, the MAC team worked hard to plan and deliver a successful MAC field day event, held on the 13 September 2023. The event continues to grow, with 149 stakeholders from the region attending, including growers, consultants, researchers, and industry representatives from across the EP and beyond. I would like to thank all of the MAC team for hosting such a successful event, and all of those in the community who contributed to the success of the day.

In 2023, SARDI was proud to release its refreshed Strategic Plan. The 2023-2028 Plan sets out the key priority areas for SARDI, so that we can continue to deliver applied and relevant outcomes to our primary industries sectors. The plan addresses the contemporary challenges we are all facing in agriculture in the foreseeable future and identifies some of the priority areas that we will focus both our financial investment and the time of our immensely valuable staff cohort over the next 5 years. The plan is available via the PIRSA website.

In August and September 2023, SARDI, AIR EP and the EP Landscape Board, implemented a broad consultation and strategic planning exercise, to set out a vision for farming in 2050 for EP. Consisting of five key elements (governance, social, profitability, productivity, and environment), the vision 2050 plan provides a valuable framework to prioritise and undertake innovative RD&E that is both relevant to EP, and aligns with the big challenges and opportunities of the future, of which there are many.

I look forward to working with the MAC team and harnessing the support of our EP partners, to ensure that 2024 is a success, and that MAC builds on the opportunity ahead to be innovative and provide independent and relevant information to growers in the region.

Dr Tim Sutton
Research Director, Crop Science



SAGIT Foreword

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.

EP grain growers continue to demonstrate their resilience and adaptability. They are to be congratulated for achieving outstanding productivity from the 2023 harvest, despite an incredibly dry late winter and spring with damaging frosts.

Practical solutions to mitigate the impact of frost remains a high priority for SAGIT. We understand how challenging the weather can be at times, but we also know that through dedicated investment in research and development, advances in grain production can continue to be made.

In terms of projects with on-the-ground activity on EP, SAGIT is funding several initiatives. This includes research on Group A resistant barley grass, led by Amanda Cook, SARDI, the Minnipa Agricultural Centre and The University of Adelaide.

A two-year project on crown rot will build on knowledge gained from prior research conducted on the upper EP using trials and complementary grower-sown demonstrations. The aims of the project, led by AIREP and Marg Evans, are to reduce yield losses associated with crown rot and increase the amount and consistency of grain for export.

SAGIT is proud to support career pathways for agricultural graduates, with two internship programs currently funded on the EP. In particular, we have been impressed by 2023 intern Elijah Luo's enthusiasm and his lentil varieties and disease control project, which he presented to fellow researchers at the 2023 SAGIT Annual Update. We look forward to working with the South Australian Drought Hub and EPAG Research to support the 2024 intern.

SA's Lead Ag Teacher, Sue Pratt, whose pilot year has been funded by SAGIT, has been instrumental in supporting EP schools with their agriculture programs. Of note, Karcultaby Area School will have its first SACE agriculture students in 2024; Miltaburra Area School is reintroducing agriculture into its curriculum; and Navigator College in Port Lincoln is also looking to build an agricultural program. Helping students understand the opportunities available in agriculture ensures the long-term sustainability of the industry.

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

SAGIT, 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.

We are also pleased to have the support of EP farmers on the SAGIT board. As a former SAGIT trustee, EP farmer Bryan Smith was a diligent and enthusiastic supporter of innovation in EP RD&E and farming systems. We are pleased to have recently welcomed Andrew Polkinghorne to SAGIT as a trustee, and we are sure his local insights will prove invaluable for supporting EP research into the future.

As Max Young retires from the Board in April 2024, SAGIT is keen to hear from SA grain growers or people with corporate governance experience who may be interested in joining the Trust, so please get in contact if you think this is something for you.

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 2024.

Dr Andrew Barr
Chair



GRDC Foreword

The 2023 season was mixed bag across Eyre Peninsula (EP), with below average winter rain and a dry hot spring in the north, but good rainfall and growing conditions in lower EP. It was certainly warm for the Minnipa Ag Centre Field Day when I was there in September. There were some impressive cereal and canola yields in lower EP, while many crops in the dry areas were assisted by subsoil moisture conserved from summer rain. Useful rain during the 2023/24 summer will again help crops in the coming season, if summer weeds are controlled.

Overall, crops performed surprisingly well in 2023, which is a testament to the industry's research, development and extension over the past two or three decades that resulted in improvements in genetics and crop management. The area of lentil production continued to expand, and new growers in low rainfall zones were generally pleased with yields and profits, helped out by some strong pricing.

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. There's little doubt that GRDC's investments across diverse areas (e.g. pre-breeding, crop protection, soils, nutrition, agronomy and ag tech) have made a significant contribution to the industry's success. In the 2023/24 financial year, GRDC is on track to invest a record amount in research and development across the country, thanks to some favourable crop yield and prices in recent years.

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. In addition, GRDC's National Grower Network meetings and local partners such as Ag Innovation, SARDI Minnipa Agricultural Centre and Research EP (AIR EP) and also contribute input to ensure research is relevant to the EP. Keep an eye out for NGN forums planned for March 20-22 down at various locations down the west coast of EP - we would love to hear from you about the issues and opportunities that you believe GRDC should be investing in.

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. During 2023 several new GRDC investments were instigated that will be of interest to EP growers.

Impact of stripper front and straw length on harvest efficiency, summer weed control, soil moisture retention and pest populations in the Upper Eyre Peninsula, is led by SARDI and is designed to evaluate the potential benefits and challenges of stripper front use in a disc system. Specifically, it will measure the impact of stubble height on harvest efficiency, efficacy of summer weed control, soil moisture retention/fallow efficiency and its resultant impact on yield and pest populations including weeds, snails, insects and mice.

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 SARDI, 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.

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 2024 nvt.grdc.com.au/harvest-reports/south.

While the highly successful **Sandy Soils** project concluded in 2023, we hope to shortly announce a new investment which will continue to help growers identify and overcome constraints to crop growth on sandy soils, including those of the EP.

Enterprise choice and sequence strategies that drive sustainable and profitable southern Australian farming systems is being led by The University of Adelaide. By employing a farming systems approach, the implications of strategic options and tactical in-season decisions will be evaluated over five years or more. This includes a new long-term trial site at Edillilie and delivered by AIR EP & EPAG Research and is an important example of medium rainfall environments across southern Australia.

Riskwise is a national investment led by CSIRO which kicked off last year. It is seeking to better understand and improve the risk-reward outcomes for Australian grain growers by supporting grower on-farm decision-making. As part of investment, AIR EP and EPAG Research are examining fertiliser nitrogen decisions through field trials and paddock benchmarking.

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. We've also had co-investment with SAGIT on white grain disorder, in addition to frost, vetch and soil microbiology.

We've recently signed agreements for another five years of **GRDC Farm Business Updates** and are in negotiations for another five years of **GRDC Grains Research Updates**. These popular flagship extension projects are a key mechanism to raise awareness of practices and technology amongst adviser and growers to improve crop production, profit and farm resilience and viability.

If you want any additional information about any GRDC investments reported here (or others not included here) I'd encourage you to follow up directly with the relevant lead researchers, or there are details on the GRDC investment listing on our website (grdc.com.au/grdc-investments).

Should you wish to raise and discuss ideas with GRDC staff, please contact the GRDC Southern Office via email: southern@grdc.com.au.

Stephen Loss



Senior Regional Manager
GRDC Adelaide

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Minnipa Agricultural Centre update

Nicole Baty
SARDI

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

We would like to thank project funders and collaborators the Grains Research and Development Corporation (GRDC), the South Australian Grains Industry Trust (SAGIT), Ag Innovation & Research Eyre Peninsula (AIR EP), Buckleboo Farm Improvement Group (BFIG), the Australian Government (National Landcare Program, Rural R&D for Profit, Soil CRC, Future Drought Fund and SA Drought Hub), NSW Department of Primary Industries (NSW DPI), Department of Primary Industries and Regional Development (DPIRD), The University of Adelaide, the University of South Australia, Landscape Board, CSIRO and plant breeders 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

Zhaohan (Elijah) Luo joined the MAC Agronomy team in early 2023 as the SAGIT funded AIR EP Intern. Elijah has recently completed his 12-month internship and will be continuing as a Research Officer at MAC. Farzad Aslani was the Soil Research Officer delivering the FDF Sandy and Saline Soils projects for six months. We welcomed Kym Zeppel back to the Agronomy team as a Senior Technical Officer, and Cate Scholz and Matthew Guerin as casual field assistants.

In April, Fiona Tomney transitioned from her joint Research Officer and SA Drought Hub Node Coordinator role for the Minnipa Node to a full time Node Coordinator of both the Minnipa and Port Augusta Nodes. In September we also said goodbye to Zakirra Simpson who was a part of the MAC Farm team since 2021.

In 2023, the Haldrup plot harvester underwent major upgrades to its system to streamline the MAC harvesting process. This included installation of Mirus software and a new weighing system.

New Projects

The GRDC funded two new projects in 2023, which were designed based on grower priorities from the GRDC National Grower Network (NGN) meeting

held at MAC on 1 August, 2022. 'NGN-Lentil check discussion groups to maximise profitability of lentil production in the Upper Eyre Peninsula' (UOA2303-007RTX) involves herbicide research trials at Minnipa and Mudamuckla and Lentil Check Grower Group meetings were held at 4 locations across the Upper Eyre Peninsula at two critical decision-making times. This project and the Lentil Check Grower Group meetings will continue in 2024. The 'NGN - Impact of stripper front and straw length on harvest efficiency, summer weed control, soil moisture retention and pest populations in the Upper Eyre Peninsula' (UOA2303-013RTX) project started. The first year of trials were set up at Minnipa and Cleve post-harvest 2023 and will continue for the 2024 and 2025 growing seasons.

Visitors

MAC held numerous successful extension activities in 2023, including the SARDI EP Farmer Meetings, Lentil Check Grower Group meetings and the Annual MAC Field Day which were all very well supported by growers and industry. A range of events which were held or attended by MAC staff, with details is listed in Table 2.

During the year SARDI MAC researchers presented research projects and outcomes at the SAGIT Annual Update and SARDI Crop Sciences Research Forum. The SAGIT Board visited MAC and a number of project trial sites on their EP tour in late August. This was a valuable exercise to showcase current research in our farming systems and to experience first-hand some of the issues and opportunities for the region. GRDC members also attended the MAC Field Day on 13 September, with over 140 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. We are grateful for the strong farmer involvement and support and will continue to ensure our research is aligned to on ground priority needs. SARDI staff across the state will continue to work closely with primary producers to develop relevant research programs and ensure excellence in our program delivery, industry and regional engagement. We look forward to seeing you throughout 2024 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 2023

Amanda Cook	MAC Senior Research Scientist (Agronomy)	Zakirra Simpson	Agricultural Officer (MAC Farm)
John Kelsh	MAC Farm Manager	Leala Hoffmann	Administration Officer
Jessica Gunn	Research Officer (Livestock)	Fiona Tomney	Node Coordinator for the SA Drought Hub (Minnipa & Port Augusta)
Farzad Aslani	Research Officer (Soils)		
Zhaohan (Elijah) Luo	EP Grains Applied Research Intern	A/Prof Rhiannon Schilling	Program Leader of Agronomy & Deputy Director of SA Drought Hub
Nicole Baty	Project Management Support Officer (Agronomy)		
Kym Zeppel	AgTech Extension Officer/ Senior Agricultural Officer (Agronomy)	Dr Nigel Wilhelm	Senior Research Scientist (Agronomy)
Wade Shepperd	Senior Agricultural Officer (MAC Farm)	Brian Dzoma	Research Officer (Soils)
Ian Richter	Senior Agricultural Officer (Agronomy)	Katrina Brands	Casual Field Assistant
		Rebecca Tomney	Casual Field Assistant
Craig Standley	Senior Agricultural Officer (Agronomy)	Kysen Shepperd	Casual Field Assistant
		Adele Shepperd	Casual Field Assistant
Marina Mudge	Senior Agricultural Officer (NVT)	Cate Scholz	Casual Field Assistant
		Matthew Guerin	Casual Field Assistant

Table 1. Research projects delivered by SARDI Minnipa Agricultural Centre in 2023.

Project name	Funder	Summary
Effective control of brome grass in the southern and western cropping zones	GRDC (UOA2303-006RTX)	GRDC University of Adelaide brome grass 4-year cropping × weed management trial. End: March 2028
Integrated management strategies for Net Form Net Blotch in low, medium, and high rainfall zones	GRDC (DAQ2304-008RTX)	This investment will develop and deliver cost effective IDM strategies for NFNB across all rainfall zones of the Northern and Southern regions by: - Determining the impact of NFNB by measuring the yield and quality loss incurred in response to the different IDM strategies. - Investigating the decline of NFNB inoculum levels of stubble over time and in different growing environments. - Developing integrated disease management strategies and determine the cost benefit for implementing IDM strategies in each rainfall zone. - Developing and delivery of an extension strategy to drive grower adoption. End: May 2027
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
NGN - Impact of stripper front and straw length on harvest efficiency, summer weed control, soil moisture retention and pest populations in the Upper Eyre Peninsula	GRDC (UOA2303-013RTX)	This investment is designed to evaluate the potential benefits and challenges of stripper front use in a disc system in the Upper Eyre Peninsula, specifically the impact of stubble height on harvest efficiency efficacy of summer weed control, soil moisture retention/fallow efficiency and its resultant impact on yield and pest populations including weeds, snails, insects and mice. End: April 2026
NGN - Lentil check discussion groups to maximise profitability of lentil production in the Upper Eyre Peninsula	GRDC (UOA2303-007RTX)	This project aims to deliver four peer to peer learning groups to assist agronomic decision making around lentil production on the Upper Eyre Peninsula. In addition to the facilitated peer to peer learning groups, one herbicide matrix trial at each of two sites to evaluate the efficacy and profitability of both current and newly available herbicide technologies to drive discussion with the groups. Trials will be within close proximity to two of the peer groups with other groups leveraging existing GRDC and industry trial activities. End: March 2025

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	Australian Government's 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: December 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	Soil CRC	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
Best practice for early sowing opportunities	SA Drought Hub, Australian Government's Future Drought Fund (AIR EP)	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? End: June 2024

Retaining soil water in farming systems using strip/disc machinery	SA Drought Hub, Australian Government's Future Drought Fund (AIR EP)	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? End: June 2024
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 (AIR EP)	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 & compacted layers that prevent root growth & access to moisture & 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. End: June 2024
Building resilience to drought with landscape scale remediation of saline land	Australian Government's Future Drought Fund (AIR EP)	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. End: June 2024
Developing robust ground cover to enable resilience in low rainfall mixed farms - Seed priming	Australian Government's Future Drought Fund (AIR EP)	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. End: June 2024
National Variety Trials	GRDC	Yield performance of cereal & break crop varieties at various locations across upper EP.
Crop Improvement Trials	Various	Various trials including; AGT - CoAXium Barley matrix demonstration.

Complete project delivery		
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. End: June 2023
Mixed Annual Legume Pastures	NLP 4-BA9KBX5	This project will demonstrate the capacity of mixed legume pastures to increase soil cover and reduce wind erosion whilst extending the growing season for farmers on the upper Eyre Peninsula. The aim is to grow pasture species that will extend the available feed on offer beyond that currently offered by the commonly grown medics (<i>Medicago</i> spp.) End: June 2023
Improving production on sandy soils in low and medium rainfall areas	GRDC CSP00203	There are opportunities to increase production on deep sands by developing cost effective techniques to diagnose and overcome the primary constraints to poor crop water-use or by reducing the impact of constraints with modified practices. Commonly recognised constraints that limit root growth and water extraction on sands include compaction (high penetration resistance), poor nutrient supply and low levels of biological cycling and poor crop establishment. The project has set up trials at Murlong and Brooker to investigate both low cost modified agronomy (e.g. use of wetters) and high cost interventions (e.g. spading incorporation of OM). End: March 2023
More profitable crops on highly calcareous soils by improving early vigour and overcoming soil constraints.	Soil CRC: 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. End: March 2023

Table 2. Minnipa Agricultural Centre events in 2023.

Event	Topic	Attendance
GRDC Update Adelaide 7- 8 February	MAC staff attended the GRDC Update.	Amanda Cook, Nicole Baty, Fiona Tomney, Elijah Luo, Farzad Aslani, Marina Mudge, Craig Standley, Ian Richter, John Kelsh, Zakirra Simpson and Wade Shepperd.
2023 EP SARDI Harvest Report Farmer meetings Minnipa, Wirrulla, Ceduna, Kimba, Port Kenny, Lock, Rudall and Cowell. 20 February - 9 March	Presenters (in person/pre-recorded): Herbicide Resistant Barley Grass, Seed Priming, Rhizoctonia - Amanda Cook Calcareous soils - Brian Dzoma Mixed annual legume pasture species, SA Drought Hub Strip and Disc and Early Seeding - Fiona Tomney Sandy Soils and Saline Soils - Brett Masters / Amanda Cook AgTech - Kym Zeppel Soil Microbes - Farzad Aslani GRDC Potassium nutrient response - Dr Nigel Wilhelm	146 growers and industry representatives attended.
Resilient EP RIG Final Project Meeting 28 - 29 March Port Lincoln	Amanda Cook and Nicole Baty joined monthly on-line research meetings.	AIR EP, Regional Innovators Group (RIG), SARDI, EPAG, CSIRO.
Eyre Peninsula Farming Systems Summary March-April	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.
GRDC Lentil Check Discussion Groups Kimba, Lock, Mudamuckla and Minnipa. 12-13 April	Facilitated by Bates Agricultural Consulting along with local agronomists/consultants and SARDI staff, four lentil check groups met to discuss lentil herbicide safety, nutrition, inoculation, paddock preparation, seed quality, etc.	52 growers, 7 industry representatives and Bates Agricultural Consulting, West Coast Ag, Nutrien Ag, James Cant, Amanda Cook, Navneet Aggarwal, Nicole Baty, Elijah Luo and SARDI MAC technical staff.
Low Rainfall RD&E Committee Meeting Minnipa Agricultural Centre 30 June	Low Rainfall RD&E Committee representatives held the June meeting at MAC and visited the Seed Priming research trials at Gareth Scholz's.	Low Rainfall RD&E Committee and SARDI staff.
SAGIT Annual Update 5 July	MAC staff attended the SAGIT Research Update. Amanda Cook presented on Improving the Early Management of Dry Sown Cereal Crops Early and Elijah Luo presented on Fungicides application on lentils.	Amanda Cook and Elijah Luo.
GRDC Lentil Check Discussion Groups Kimba, Lock, Mudamuckla and Minnipa. 19 - 20 July	Facilitated by Bates Consulting along with local agronomists/consultants and SARDI staff delivered four lentil check groups to discuss herbicide damage, fungal diseases - how, when and where to spot them, preventative fungicide application timing, weed control evaluation, salvage option, nodulation assessment etc.	50 growers, 3 industry representatives and Bates Agricultural Consulting, West Coast Ag, Nutrien Ag, James Cant, Navneet Aggarwal, Nicole Baty, Elijah Luo and SARDI MAC technical staff.
SAGIT Board Tour 31 August	The SAGIT Trustee Board visited project trial sites at Mount Cooper, Mount Damper and Minnipa Agricultural Centre. This was a valuable exercise to gain insight into our local farming systems and experience first-hand some of the issues and opportunities for the region. Current research projects at MAC were presented by Amanda Cook and Elijah Luo.	3 SAGIT Board members and SARDI staff.

Eyre Peninsula - Planning Sustainable Growth Vision 2050 12 September	A facilitated workshop by Tony Frost; Strategy Road was attended by SARDI staff. Farming and agricultural research stakeholders were consulted for their views on farming on the EP in 2050. Their perspectives were sought to help shape a draft picture of the features, drivers and enablers of a strong, sustainable farming industry on the Eyre Peninsula well into the future. This consultation work, driven and supported by AIR EP, SARDI and Eyre Peninsula Landscape Board, has been undertaken, primarily to ensure that Research, Development and Extension priorities and investments on the Eyre Peninsula are being selected to support the realisation of a desirable future for the region and industry	Amanda Cook, Hannah Brown, Rhiannon Schilling, Tim Sutton and PIRSA staff.
MAC Field Day Minnipa Agricultural Centre 13 September	MAC Farm Update - John Kelsh Grain Marketing Update - Richie Mould (Market Check) Soil Carbon in South Australian Agricultural Soils - Dr Amanda Schapel Saline Soils and Mallee Seeps - Dr Chris McDonough AgTech - Dr Robyn Terry Cereal Diseases and GRDC Net Blotch - Dr Tara Garrard NVT Variety Trials - Brianna Guidera and plant breeders Predicting nitrogen cycling and losses in Australian cropping systems - Dr Nigel Wilhelm Seed Priming, GRDC Rhizoctonia, SA Drought Hub Strip and Disc and SA Drought Hub Early Sowing - Amanda Cook Virtual Fencing: Research developments in Sheep - Megan Willis The latest information on e-livestock technologies - Jess Gunn SA Drought Hub - Fiona Tomney Time specific mouse management strategies and the impact of background food - Dr Steve Henry Microbial Indicators - Dr Mick Rose (video presentation) GPSA Fire Safety Code - Shane Gale AGT Demo - Brad Koster and Nick Wells-Smith Vetch, what's next - Stuart Nagel AIR EP Update - Naomi Scholz Lentil Variety Trial - Elijah Luo NVT Peas and Canola - Brianna Guidera and plant breeders Broadleaf weed control and crop safety in lentils across different soil types in South Australia - Dr Navneet Aggarwal Calcareous soils project highlights - Brian Dzoma	149 growers, plant breeders and industry representatives.
Sticky Beak Days - Upper Eyre Peninsula August to October	A series of 15 grower crop walks organised by local Agriculture Bureau Groups across the Eyre Peninsula.	Over 300 people: mostly growers
SARDI Crop Science Research Forum 4 October	MAC research staff attended the SARDI Crop Science Research Forum in Adelaide. Elijah Luo presented SAGIT-AIR EP Internship research - Fungicide application on Lentils. Amanda Cook presented research findings from SAGIT project Herbicide resistant barley grass.	Amanda Cook and Elijah Luo.
Low Rainfall RD&E Committee Meeting Wudinna 12 December	Low Rainfall RD&E Committee representatives held the December meeting at Wudinna.	Low Rainfall RD&E Committee and SARDI Staff.

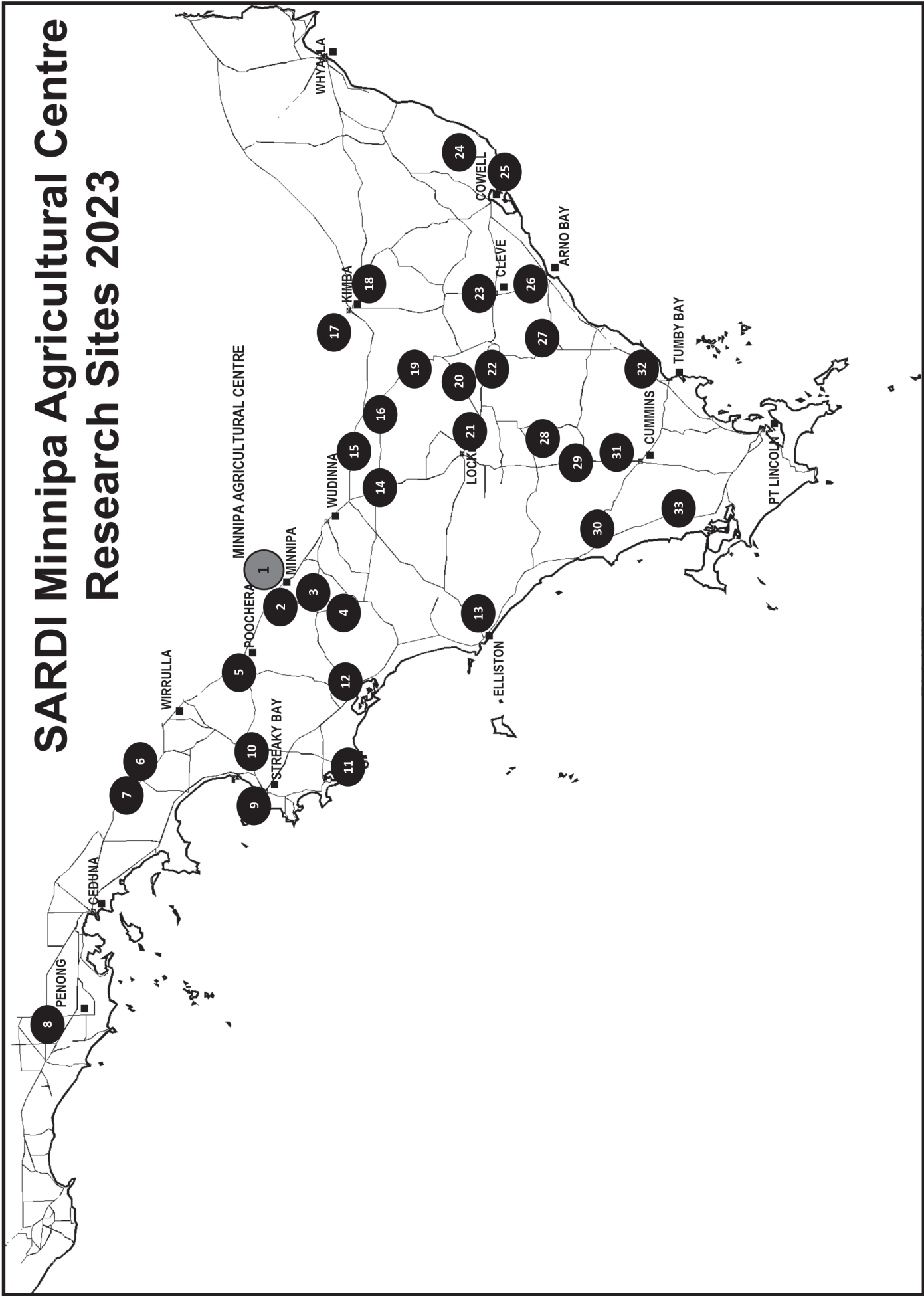
DATES TO REMEMBER

MAC Annual Field Day: Wednesday 11 September 2024



SARDI Minnipa Agricultural Centre

Research Sites 2023



Eyre Peninsula agricultural research sites 2023 map references.

Map reference	Location	Trials	Host farm / business
1	Minnipa	NVT wheat and early wheat, barley, field peas, and IT and TT canola. Vetch breeding. Herbicides in lentils. Lentil variety trial. AGT CoAXium barley matrix demo. Calcareous soils. AgTech demonstrations. Saline soils. Rhizoctonia management.	SARDI Minnipa Agricultural Centre
2	Minnipa	Seed Priming, Strip and Disc	Gareth Scholz
2	Minnipa	Strip and Disc	Clint Oswald
2	Minnipa	Sandy Soils	Wes Daniell
2	Minnipa	Saline Soils	Matthew Cook
3	Minnipa	Saline Soils	Bruce Heddle
4	Mount Damper	Fungicides in lentils	AJ (Ashley) Michael
4	Mount Damper	Sandy Soils	Nigel Oswald
5	Poochera	Calcareous Soils, Rhizoctonia management	Shard Gosling
6	Nunjikompita	NVT wheat and oats	Craig Rule
7	Mudamuckla	Herbicides in lentils	Peter Kuhlmann
8	Penong	NVT wheat, SARDI wheat and barley, Early Sowing, Saline Soils	Cade Drummond
8	Penong	Saline Soils	Lynton Murray
9	Streaky Bay	Saline Soils	Simon Paterson
9	Streaky Bay	Sandy Soils	Dion Williams
9	Streaky Bay	Net blotch	Nigel Brace
10	Piednippie	NVT wheat and barley	Jock Hollitt
10	Piednippie	Rhizoctonia management	Dion Gilmore
11	Baird Bay	Brome grass	John Freeman
12	Port Kenny	Calcareous Soils, Rhizoctonia management	Simon Guerin
12	Calca	Barley grass	Craig Kelsh
12	Mount Cooper	Fungicides in lentils	Angus Gunn
13	Elliston	NVT barley	Nigel May
14	Warrambo	Rhizoctonia management	Jeremy Wagner
14	Warrambo	NVT wheat	Kane Murphy
15	Kyancutta	Sandy Soils	Brett O'Brien
16	Cootra East	Saline Soils	Thomas Schmucker
17	Buckleboo	Saline Soils	Tristan Baldock
17	Buckleboo	Strip and Disc	Vandeleur Family
18	Kimba	NVT wheat	Trevor Cliff
19	Darke Peak	NVT barley	Brendan Kenny
20	Kielpa	Sandy Soils	Mark Dolling
21	Lock	NVT canola	Dylon Kay
22	Rudall	Sandy Soils	Ben Ranford

22	Rudall	NVT wheat	Matt Dunn
22	Rudall	NVT field pea	Basil Heath
23	Cleve	Strip and Disc	Paul Bammann
24	Mitchellville	NVT wheat	Kaden Family
25	Cowell	Early Sowing	Kaden Family
26	Arno Bay	Sandy Soils	Ranford Family
27	Wharminda	NVT barley	Tim Ottens
28	Ungarra	NVT lupins	Anthony Fatchen
28	Yeelanna	NVT field peas, faba beans, lentils	Chad Glover
29	Yeelanna	NVT canola	Peter and Steve Glover
30	Mount Hope	NVT canola	Jules Doudle
31	Cummins	NVT wheat and barley	Stuart Modra
32	Tumby Bay	Saline Soils	McCallum Family
33	Wanilla	NVT wheat and barley	Graham Charlton

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Agricultural Innovation & Research Eyre Peninsula update 2023

Bill Long and Naomi Scholz

Agricultural Innovation & Research Eyre Peninsula (AIR EP)

Vision

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

EP Ag Vision 2050

The AIR EP Board and SARDI were proud to reveal the “EP Ag Vision 2050” roadmap in 2023. Following an extensive consultation and planning process, the strategic plan provides an industry-first 25-year research, development and extension vision for the region. In addition to aligning with AIR EP’s existing vision and purpose, the roadmap aims to propel agriculture and our local communities into a strong and sustainable future.

Supported the EP Landscape Board, the roadmap identified five critical elements, being Governance, Social, Profitability, Productivity and the Environment. As one of the State’s largest agricultural regions, the benefit of this long-term vision ensures RD&E priorities and investments into the Eyre Peninsula are recognised, consolidated, and prioritised to navigate future challenges and opportunities that may lie ahead.

With the roadmap now developed, AIR EP have established a working group to identify further actions and opportunities to progress the vision in 2024. This initiative is a primary example of how professional, farming systems groups like AIR EP are well positioned to drive change in our region not only for growers, but for the broader community.

Key activities

AIR EP hosted, delivered and supported a range of RD&E activities across the region in 2023. More than 27 RD&E projects were delivered to the region, ranging in value from \$750 to larger multi-year projects to the value of \$3.2million. Some of the AIR EP events delivered included:

- Mallee seeps advisor workshop held at Darke Peak, 15 February
- AIR EP Lower EP Ag Expo was held in Cummins on 16 February, featuring an extensive range of topics including nitrogen management, lentil damage, long coleoptile wheat varieties, timing of sowing, trace elements in pulses, frost and powdery mildew, and fungicide applications.
- Sandy soil amelioration demonstration held on farm at Kielpa on 24 March

- Acid Soil Forums held in Cleve on 27 March and Yallunda Flat on 28 March, with an additional webinar hosted on 20 June
- AIR EP and SA Drought Hub hosted the Preparing your livestock enterprise for dry times workshop in Wudinna on 8 June
- Regenerative Agriculture workshop held in Cleve on 15 June
- Upper and Lower EP Member Days with a ‘back to basics on crop nutrition’ were held at both Wudinna and Wangary 5 - 6 July
- iFarmwell delivered the Work-Life balance for Farming Families workshop in Minnipa on 4 August
- Sandy Soils Masterclasses held at Mt Damper, Ungarra and Cummins from 5 - 7 September
- AIR EP Lower EP Crop Walk provided a research update to participants at Cummins on 14 September
- Pulse and Frost Field Day at Tooligie Hill on 21 September
- Optimising Plant Health by Harriet Mella virtual information sessions were available online from 18 October - 8 November, with additional workshops held in Ungarra, Minnipa and Cleve from 4 - 8 December

Structure

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

Board Members: Bill Long (Chair), Greg Scholz, Ken Webber, Matthew Cook (LR RD&E rep), Greg Arthur, Mark Stanley (special skills), Daniel Adams (MR RD&E rep), Mary Rowe. In 2023, we farewelled Andrew Polkinghorne, who had resided on the Board since it’s inauguration. We wish Andrew all the best with his Churchill Fellowship and role as SAGIT Trustee. Mary Rowe was formally elected to the Board in December 2023. Mary has extensive experience in the livestock sector working as the Senior Professional Sales Representative for Zoetis and managing her sheep property with her family near Elliston.

Low Rainfall RD&E Committee Members: Symon Allen (Chair), Andy Bates, Rhiannon Schilling, Amanda Cook, Daniel Bergmann, Matthew Cook, Rhys Tomney, Andrew Ware, Leigh Scholz, Kevin Dart, Chris Lymn, Bruce Heddle, Jarrad Schiller (2023).

Medium Rainfall RD&E Committee Members: Daniel Adams (Chair), David Davenport, Dustin Parker, Billy Pedler, George Pedler, Jacob Giles, Denis Pedler, Lochie Siegert, Brett Masters, Daniel Puckridge, Andrew Ware, Nick Gale (2023).

Staff: Executive Officer - Naomi Scholz, Finance Officer - Alanna Barns, Regional Agricultural Landcare Facilitator - Amy Wright, Project Officer - Rebekah Fatchen. After 3 years of hosting the Sustainable Agriculture Officer position with the EP Landscape

Board, we bid a fond farewell to Josh Telfer. Josh has been a valued member of the AIR EP team, and we wish him all the best in his new role with PIRSA. In December, we appointed Rowena Norris to the recently created position of Operations Manager. Rowena has previously worked in communication and industry development roles in the grains and horticulture sectors, and resides on her family farm located near Cowell.

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.

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Eyre Peninsula seasonal summary 2023

Joshua Telfer
SARDI

Key messages

- **Stored soil moisture helped finish crops in a dry year**
- **Mice and multiple frost events proved challenging**
- **All regions came under moisture stress in Spring. However, parts of western and north western EP were on decile 1 making 2023 an increasingly challenging season.**

Autumn

After an above-average year in 2022, a particularly moist spring and good summer rainfall events, many growers started 2023 spraying summer weeds to retain soil moisture for the upcoming season. Rainfall events in mid-April resulted in an early seeding, but with only small follow up rainfall events until late June - early July. Seeding progressed well, with most growers able to sow in a timely manner and reasonable establishment was generally achieved. With the decile 9 growing season in 2022 resulting in grain losses at harvest and high stubble loads, mice were an issue in most regions effecting pastures as well as grain crops with baiting occurring at seeding.

Winter

Good conditions prevailed for seeding and early crop establishment despite below-average rainfall for most areas through July and into August. Up to the end of June, there was around 4-7 decile rainfall across most of EP (Figure 1). There were urea shortages due to tight local supplies as growers tried to position their crops for good yield potential following a large removal of nutrients in 2022. However, growers were also cautious about over-ordering due to early poor seasonal forecasts and recent erratic movements in fertiliser prices. While this eventually got resolved, some crops ended up with less urea fertiliser than ideal. The lentil crop on EP in 2023 continued to expand, particularly in Upper and Eastern EP. Similarly, the planting of canola hectares was up on the 5-year average after good experiences in 2022 and moderate stored soil moisture.

Spring

The spring in 2023 was characterised by dry conditions in September, October and November, with warmer than average temperatures in September. Some areas benefited from residual moisture from 2022 (Figure 2). However, October and November were cooler in many areas, with a lot of overcast days, which slowed

maturity, particularly in the cooler and southern parts of EP. This didn't seem like a particular problem at the time as harvest approached, as it moderated the use of the stored soil moisture.

With further decreasing livestock prices and relatively high feed grain prices, the continued decline of livestock prices and the forecast of a drier summer period led many livestock producers to reduce stock numbers.

Growers in the Far West faced the most extreme moisture pressure in 2023 (Figure 2), while the eastern coastal areas received enough rainfall for some good grain fill. Unfortunately, frost damage in central, eastern, and south-eastern parts of EP affected crop yields, particularly wheat though all other crops as well, with significant frost events in August and September impacting large areas that would have otherwise had economic yields of 2.5-5 t/ha while offering limited opportunities for cutting for hay.

Harvest

Following a moisture-challenged growing season, especially in spring, harvest dates of 2023 crops varied across the EP, ranging from mid-October (upper EP) to mid-January (parts of lower EP). The area of GM Canola continues to expand on EP as growers take advantage of the combination of better yield genetics, herbicide resistance and anti-shattering traits, with many canola crops on lower EP more frequently yielding greater than 2-3 t/ha. There was good canola production on Eastern Eyre, though generally not at the same levels as 2022.

Pulse crops such as lentils and faba beans continued to increase in popularity on EP, with continued bulk shipments from Port Lincoln. Rain during harvest (December), along with a lack of warm drying weather caused some grain quality issues, with reports of mould in canola and weather damage in wheat across EP, although the price spread for these issues was only moderate. There were challenges in getting crops to dry sufficiently for harvest, especially on lower EP, including crops like canola, and further inland from the coast than usual. Due to most of EP receiving 25-100 mm of rain through the December-January period, most growers had to engage in summer weed control directly after harvest. While this incurred an economic costs, it has also presented an opportunity to enter the 2023 season with elevated soil moisture levels, which was crucial for crops in 2022 with the dry spring.

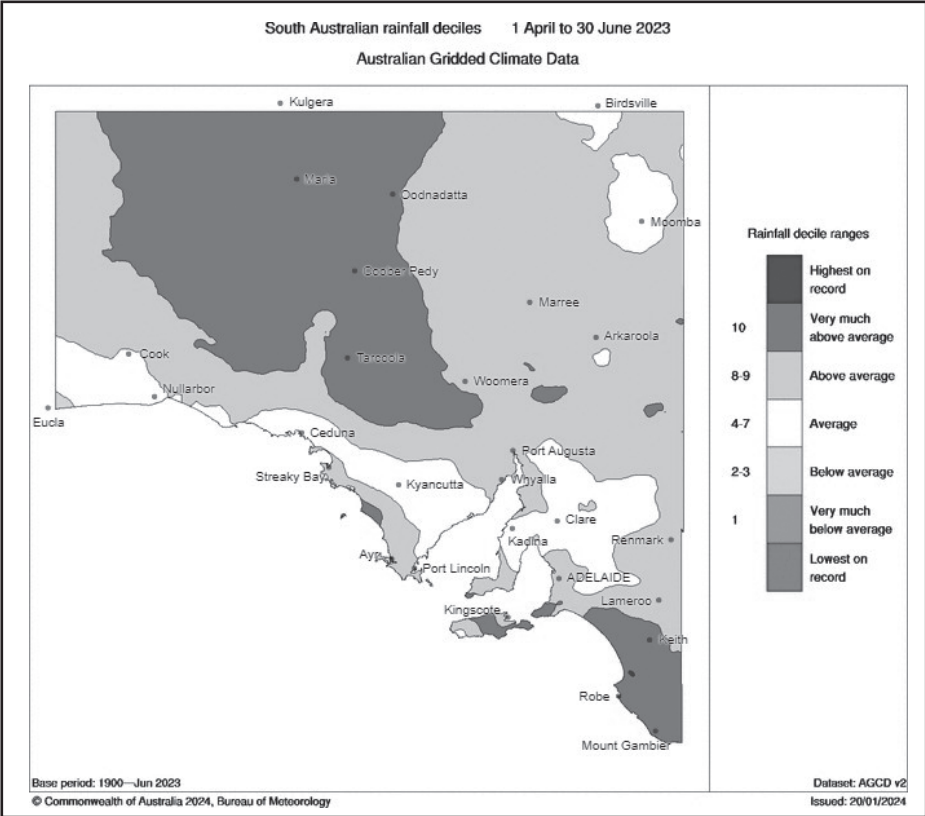


Figure 1. Rainfall deciles for SA in the Crop establishment window (1 April-30 June 2023).

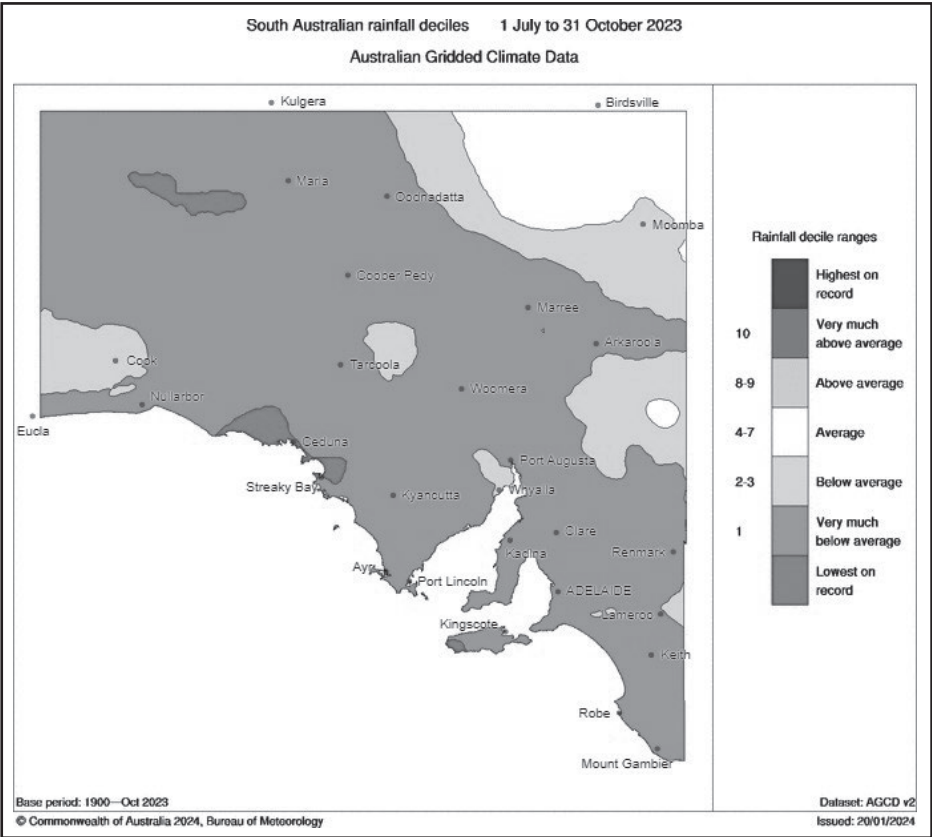


Figure 2. July-October rainfall deciles on EP 2023.



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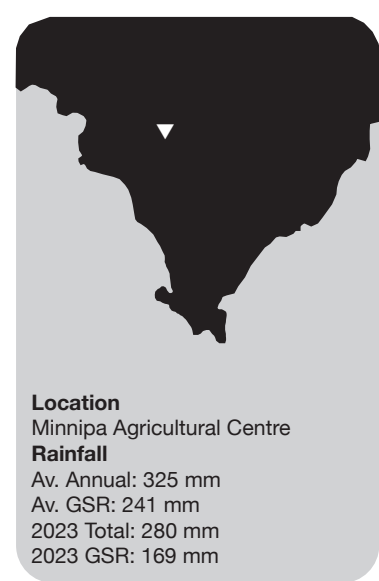


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MAC Farm Report 2023

John Kelsh
SARDI



Key outcomes

- **Stored soil moisture and favorable conditions leading into seeding meant yield potential was high.**
- **Yield potential was reduced by a dry latter half of winter and spring.**

Background

The performance of the Minnipa Agricultural Centre (MAC) farm is a core component in the delivery and extension of relevant research & development projects in 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 demonstrate best-practice farming on Eyre Peninsula.

What happened?

Weather

Following the exceptional year in 2022, the outlook for the 2023 season was initially positive. A significant amount of stored soil moisture was retained over summer, and a few good rain

events in autumn and early winter had our yield potential again in the high range. Sowing progressed normally, until the 17 May, where we paused due to a lack of moisture, and subsequently finished off with some barley at the end of May.

The high yield potential was evident early in the season with some paddocks looking similar, or marginally better than the year prior. The rainfall pattern was following a decile 5 year's trajectory until the middle of July. By 9 July we had already received 70% of our growing season rainfall, and by the beginning of harvest our GSR was at a decile 1 level. Our two biggest rainfall events in 2023 occurred in December, and together represented 26% of our annual rainfall. This highlights the significance of retaining stored soil moisture over summer, by controlling summer weeds, in our farming system.

Cropping

Our seeding program commenced with damp soils shortly after ANZAC day, sowing a paddock of early sheep feed (triticale) before sowing canola and then wheat varieties. We paused sowing due to drying conditions and ended up sowing two paddocks of barley at the end of May to complete the bulk of seeding. Tomahawk CL was sown extremely late (13 June) due to seed availability constraints. Granulock Z was sown below the seed, with the canola paddocks having 60 L/ha UAN applications. Both fertiliser and seeding rates are in Table 2.

The distribution of our arable areas was as follows:

- 34% Wheat - 368 ha (Scepter, Hammer CL, Calibre, Valiant CL, Catapult, Anvil CL, Tomahawk CL)
- 11% Barley - 116 ha (Commodus CL, Maximus CL, Cyclops)
- 15% Peas - 161 ha (PBA Butler)
- 9% Canola - 96 ha (Trident, Renegade, Bandit)
- 4% Triticale - 39 ha (Razoo)
- 3% Oats - 31 ha (Archer)
- 24% Pasture - 255 ha (regenerated medic)

The long season wheats performed surprisingly well, both Valiant and Catapult out-yielding a nearby Calibre paddock. Yields were a little below average across the board with the field peas and canola taking the dry spring conditions particularly hard. Being a team-member (and truck) down for harvest was challenging, with contractors playing an important role in delivering grain to the silo system.

Grain quality was good with most deliveries achieving H2 pay grade. An issue with mould in canola saw half the canola downgraded to CANX. In total we delivered ~800 tonnes of grain in 2023.

Livestock

Another successful year for the MAC Merino flock with 410 ewes joined and 661 foetus' scanned (161%) resulting in 517 lambs marked (126%), full details in Table 1. This year the MAC team adopted genomic testing, in lieu of manual observations, to determine lineage. The work involved in this project has been significant as it required the whole flock to be sampled.

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; 425 flock ewes, 242 ewe lambs and 8 rams.

Acknowledgements

SARDI Research Support staff: Wade Shepperd, Zakirra Simpson and Leala Hoffmann

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

	Ewes joined	Lambs scanned	Lambs marked	Scanning %	Marking %	Survival at marking %
2013	350	534	448	153	128	84
2014	349	442	386	127	111	87
2015	424	555	437	131	103	79
2016	422	532	502	126	119	94
2017	366	428	361	117	99	84
2018	335	434	294	130	88	68
2019	342	486	434	142	127	89
2020	367	543	464	148	126	85
2021	398	625	485	157	122	78
2022	366	620	519	169	142	84
2023	410	661	517	161	126	78
Av.	375	533	441	142	117	83

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

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Table 2. Cropping results summary table for the 2023 season, Minnipa Agricultural Centre.

Paddock	Rotation 19-20-21-22-23	Crop	Variety	Sown	Area (ha)	Seed Rate (kg/ha)	Fert Rate (kg/ Ha	UAN Rate (L/ha)	Harvested	Yield (t/ha)
AP MAC	L-W-B-P-W	Wheat	Calibre	11-May	37.3	70	50	-	15-Nov	1.9
AP Town	C-W-W-P-W	Wheat	Scepter	05-May	17.0	65	50	-	12-Nov	1.5
Minnipa Hill	W-W-M-W-P	Field Peas	PBA Butler	16-May	38.1	110	30	-	-	-
North 1	W-M-W-M-C	Canola	Bandit TT	28-Apr	64.6	4.0	50	60	25-Oct	0.48
			Renegade TT	28-Apr		4.0	50	60	26-Oct	0.49
			Trident TT	29-Apr		3.0	50	60	27-Oct	0.80
			Trident TT (F2)	30-Apr		4.0	50	60	27-Oct	0.50
North 2	W-B-M-W-B	Barley	Maximus CL	29-May	43.8	70	30	-	20-Nov	0.8
North 3	B-W-P-W-B	Barley	Commodus CL	30-May	48.9	70	30	-	21-Nov	0.8
			Maximus CL	30-May		70	30	-	21-Nov	1.0
North 4	W-B-M-W-P	Field Peas	PBA Butler	17-May	53.6	110	30	-	23-Oct	0.3
North 5 N	M-W-M-W-O	Oats	Archer	19-May	30.9	60	30	-	19-Nov	0.6
North 5 S	M-W-M-M-C	Canola	Trident TT	01-May	31.4	3	50	60	27-Oct	0.7
North 7	B-M-W-M-W	Wheat	Calibre	10-May	52.6	65	50	-	28-Oct	1.5
North 10	B-V-W-B-B	Wheat	Hammer CL	13-Jun	26.0	65	50	-	18-Nov	0.8
			Tomahawk CL	13-Jun	14.4	65	50	-	18-Nov	0.9
North 12	W-B-P-W-B	Barley	Cyclops	18-May	23.0	130	50	-	Cut for hay	
South 1	W-M-W-M-W	Wheat	Calibre	12-May	41.2	65	50	-	30-Oct	1.8
South 2	B-P-W-M-W	Wheat	Valiant CL	02-May	37.5	65	50	-	02-Nov	1.9
			Catapult	02-May		65	50	-	02-Nov	1.9
South 3	B-C-W-B-P	Field Peas	PBA Butler	14-May	69.5	110	30	-	19-Oct	1.2
South 4	W-B-O-W-T	Triticale	Razoo	28-Apr	39.3	70	30	-	Grazed	
South 5	W-B-C-P-W	Wheat	Calibre	10-May	31.3	65	50	-	29-Oct	1.7
South 6	C-W-M-W-W	Wheat	Anvil CL	10-May	38.2	65	50	-	11-Nov	1.0
South 7	W-B-M-W-W	Wheat	Hammer CL	09-May	41.0	65	50	-	12-Nov	1.2
South 8	M-W-M-C-W	Wheat	Valiant CL	03-May	46.3	70	70	-	02-Nov	1.2

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

PIRSA AgTech Program on the Eyre Peninsula

Joshua Grist
PIRSA

Key messages

- The AgTech Program aims to advance profitability and sustainability in the agriculture industry by supporting primary producers to adopt fit-for-purpose and cost-effective technologies.
- There are four AgTech Demonstration Farms across the state - Struan/Kybybolite, Loxton, Nuriootpa and Minnipa. A Kangaroo Island Demonstration program is also in place, supporting AgTech integration on KI producer farms, funded through the Australian Government's Regional Recovery Partnerships program.
- All Demonstration Farms are open to primary producers and other interested parties to facilitate an understanding of AgTech solutions being demonstrated, and access assistance from the AgTech Extension Officers.
- The AgTech Growth Fund has provided grants across two rounds of funding to sixteen innovative SA agribusinesses for projects to accelerate the development of technologies. Further information and case studies for first round projects can be found at <https://www.pir.sa.gov.au/research/agtech/agtech-growth-fund>

Background

There is a vast number of technologies on the market, and PIRSA is helping primary producers to make more informed decisions about which AgTech solutions are right for them. The PIRSA AgTech Demonstration Farms help by demonstrating the benefits of various technologies for producers to make informed AgTech adoption decisions.

Demonstrated technologies

Various AgTech suppliers have provided their products for the AgTech Demonstration Farms. Farmers and advisers can see these products on-farm. The products currently being demonstrated at the Minnipa AgTech Demonstration Farm are:

Remote water monitoring solutions

Remote water monitoring gives you insights into the status of your water infrastructure right to your mobile phone or other device. It provides alerts for

issues including leaks and 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, in turn 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, satellite or 4G connectivity.
- Remote Tank Level monitor by Farm Tasker. Battery powered with 10+ year battery life, 4G or LoRaWAN connectivity.
- Remote water pressure monitor by Farm Tasker. Battery powered with 10+ year battery life, 4G or LoRaWAN connectivity.
- Remote meter reader by Farm Tasker. Battery powered with 10+ year battery life, 4G or LoRaWAN connectivity.

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 stock nutritional deficiencies, improving health and production. This system ensures that all stock receive an accurate dose of the supplement in their drinking water, reducing or eliminating the need for lick blocks and the issue of stock not accessing it, 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 may identify a leak in your water supply. DIT AgTech also supplies an anti-methanogenic supplement for livestock.

Cordless shearing handpiece and foot parer - Mobishear

Australian designed cordless battery-operated shearing handpiece and foot parer for easy use in the paddock.

Farm visitor and safety management software - Onside

Farm communication and visitor software for streamlining visitor management, assigning tasks and reporting risks, and digital record keeping for safety compliance purposes.

Farm data management software - Agworld

Provides a single point of data collection for planting, harvesting and general farm activities. Also enables easy data access and communications with your agronomist.

A further range of technologies suitable for broadacre cropping, sheep and cattle production are demonstrated on the Struan AgTech Demonstration Farm. If you are interested in this tech, you can see virtual tours of the farms and access more information on the AgTech page of the PIRSA website pir.sa.gov.au/research/agtech

AgTech Producer Groups

In December 2023, PIRSA launched AgTech Producer Groups to support producers in AgTech implementation. Groups will meet regularly and will be led by a facilitator to create a plan tailored to the members' existing knowledge, skills and areas of interest. Individuals can register their interest with a local group directly or contact the AgTech team to identify a group. www.pir.sa.gov.au/research/agtech/producer_groups

Acknowledgements

Dr Robyn Terry, AgTech Program Manager, Major Programs and Regions PIRSA.



NEW LongReach Matador
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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 m² (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)

Yield Approximations

Wheat 1 t = 12 bags	1 t/ha = 5 bags/acre
Barley 1 t = 15 bags	1 t/ha = 6.1 bags/acre
Oats 1 t = 18 bags	1 t/ha = 7.3 bags/acre

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

1 bag/acre = 0.2 t/ha
1 bag/acre = 0.16 t/ha
1 bag/acre = 0.135 t/ha

Soil Carbon in South Australian Agricultural Soils

Amanda Schapel
SARDI

Key messages

- Soil organic carbon (OC) is critical for soil health, function and resilience.
- Soil OC is strongly influenced by soil texture, climate (rainfall and temperature) and management practices that affect the input and output of organic matter (OM) into the system.
- Benchmarks determined for South Australian agricultural districts provide a guide to understanding if you can improve OC in your soil.

What is soil organic carbon?

Soil organic carbon is the carbon found in soil resulting from organic matter and includes all living and dead organic material, such as plants, soil organisms and animal

materials. It does not include fresh or undecomposed plant material greater than 2 mm in size or inorganic ‘carbonate’ matter.

Organic matter is primarily made up of carbon (58%), with the remaining mass consisting of other nutrients such as nitrogen, phosphorus and sulfur.

Why is it important?

Soil organic matter has an essential role in soil health, function and resilience. It is a source and store of plant nutrients, important for stabilising soil structure; aggregating soil particles; increasing water infiltration and overall water holding capacity; improving cation exchange and buffering capacity. It is also essential for providing a food source for a range of soil

organisms, stimulating their activity so they can cycle nutrients, suppress pests and pathogens, and convert active soil organic carbon to a stabilised form.

OM can be added to or lost from soil. Management practices can;

- optimise inputs into soil by growing more biomass (roots and shoots), providing a continuous “in situ” source of organic matter, and adding OM from elsewhere (eg manures).
- decrease losses of soil OC from the soil by maximising stabilisation with clay, within aggregates or in chemical complexes, improving soil surface cover and minimising erosion.

Changes to management practices can have multiple benefits and affect the function of the soil.

Table 1. Summary of ways to improve soil function.

OPTIMISE SOIL OM INPUTS	MINIMISE SOIL OC LOSS
Add more OM	Decrease OC loss
Grow more shoots Retain more biomass Grow more roots and exudates Grow more soil organisms Add OM from elsewhere	Maintain OM inputs Minimise soil erosion Minimise CO ₂ loss from decomposition of OM Maximise stabilisation of OC Maximise production of Mineral associated OC (MAOC)
Adjust Management	Adjust Management
Address soil limitations to production where possible Optimise nutrition Grow green plants for longer Optimise plant diversity Consider growing perennial instead of annual plants Encourage root growth Minimise bare ground	Provide OM inputs to maintain or improve OC Minimise bare ground Minimise soil disturbance Maximise soil particle surface area for capture and stabilisation of HOC Find ways to optimise decomposition conditions to reduce release of CO ₂

How much OC stays in the soil?

Key factors affecting the total amount of OC in the soil are soil type, climate, management and soil biota.

All soils have a finite capacity to store OC. Sandy soils have a lower potential to store OC than loamy soils due to their lesser clay contents. Clay particles and aggregates can shield organic matter from breakdown by microbes, slowing the loss of OC through decomposition.

However, a soil's potential to store OC based on its clay content is rarely achieved because climate and management practices also influence supply of OC to the soil. In dryland systems, rainfall has the greatest influence on plant production and input of OC to soil. Soils in areas of high rainfall tend to have greater OC storage than their counterparts in lower rainfall regions simply due to the amount of above and below ground biomass that can be grown. In irrigated systems, strategic application of water can increase the biomass grown and hence OC inputs into the soil.

Management influences the type and amount of organic material produced - crop selection, provision of nutrients and soil amendments, residue management, tillage practices and pest management strongly influence soil OC content. Losses of OC can occur from topsoil erosion and removal of plant and animal products.

How to build soil OC

Plants and soil biota are the key. The amount of OC inputs needs to be greater than losses from decomposition and erosion.

There is a fine balance between increased OC inputs and decomposition by soil biota. Management practices that grow

the greatest amounts of carbon inputs and maximise retention of plant residues, places OC deeper in soils, enhances soil aggregation and reduces soil erosion, will ultimately result in an increase in OC.

OC concentrations will vary as inputs and outputs change over time. When plant production slows or stops, so do carbon inputs but decomposition continues as soil biota consume carbon to satisfy their energy requirements and hence soil OC declines. Microbial activity and hence decomposition is affected by moisture, air flow and temperature. Moist, hot and well aerated soils favour decomposition of organic matter. Conversely, wet and cold soils with poor air flow reduce microbial activity and decomposition.

The greatest decomposition of OC usually occurs in the surface 10 cm of soil due to presence of microbes, adequate moisture, nutrients and good aeration. Subsoils have high potential for stabilisation of OC due to less favourable conditions for microbial activity and often more reactive mineral surfaces that can protect OC from decomposition.

Opportunities to increase soil OC

The potential for storing more carbon depends on

- the soil's measured (base) level of OC
- soil type (texture) determines the amount of soil OC that can be protected and stored long term
- climate and management practices that affect the amount of organic matter that can be grown and put into the soil

Any organic carbon that is surplus to the protective capacity of the soil type remains susceptible to decomposition from microbes.

The rate of breakdown will depend on the form of organic matter, soil type (clay percentage and mineralogy) and climatic factors.

Ultimately, the opportunity to increase soil OC depends on the

- ability to grow or supply sufficient biomass or organic matter and maintain these inputs
- ability of the soil to stabilise OC (clay, aggregates)
- capacity of the soil to store more OC
- capacity to convert OC to more stable fractions

Things to consider

It is not always possible in an agricultural system to maximise plant growth and return all of the material to the soil. A considerable amount of biomass is removed in hay production, feed for animals; tillage is occasionally required to overcome a limitation such as compaction or to incorporate clay or amendments, burning can be required to manage pests, diseases and high stubble loads.

It can take many years to see management practices causing a consistent, positive change in OC. A change in practice needs to be carefully considered in relation to what is practical, economical and appropriate for the long-term aims of the enterprise as well as the manager's capacity to implement the change well.

The process of working out how long it takes to measure a change in OC and identify the rate of change over long time periods, is still being developed. There is often a sharp increase in OC observed after a few years that can be driven by accumulating particulate OC which is good for soil health but not necessarily for long-term soil OC storage. This initial increase in OC is likely to slow down after several years as the soil biota comes into equilibrium with the changed conditions.

Which soil OC test do I use?

The selection of an analytical method for OC depends on the reason for sampling and the presence or absence of carbonate in the soil.

Most soil samples are analysed for OC using the Walkley-Black (OCwb) test and good standards are available for the typical 0-10 cm agronomic test. It is a good analytical option for calcareous soils as it does not pick up carbonate. However, it does not recover all OC so underestimates total OC value of a soil therefore it is not used for soil carbon accounting.

Total Carbon is measured by catalysed, high temperature combustion commonly referred to as Dumas or Leco C test. However, this method captures the inorganic carbon fraction (charcoal and carbonate) and is unsuitable for many of SA's calcareous soils. Adjustments

are required where biochar has been applied if monitoring for soil carbon accounting.

Total OC is used for soils containing carbonate (identified through fizz test or by MIR). The laboratory uses acid to remove carbonate prior to submitting soil to a high temperature combustion method (eg Leco).

Identification of opportunity to store additional OC

For each agricultural district, benchmarks were determined for the topsoil layer based on OC Walkley and Black method laboratory analysis results.

Steps for determining opportunities to increase OC in a soil:

- compare a paddock's soil analysis OC concentration to the agricultural district benchmarks determined for texture and land use. If the paddock's soil OC value is

below the 40th percentile there is a large opportunity to increase OC storage, a moderate opportunity if between the 40th and 60th percentile and probably modest if above the 60th percentile.

- identify soil constraints limiting productivity and organic matter addition and consider if there are practical and economic means of overcoming these.
- identify and consider management practices that can build and/or minimise loss of OC.

Acknowledgements

This work was a collaboration between the Department for Environment and Water (DEW) and Primary Industries and Regions SA (PIRSA) Sustainable Soils groups and based on the report below.

Schapel A, Herrmann T, Sweeney S and Liddicoat C (2021). Soil Carbon in South Australia: Volume 4 - Benchmarks and Data analysis for the Agricultural Zone 1990-2007. Soil and Land Hub, Adelaide. Soil Carbon in SA Vol 4 - SA Ag Benchmark Analysis 1990-2007 June 2021 Final.pdf (environment.sa.gov.au)



GRDC Nitrogen cycling trial soil pit in MAC S2, 2023.

Agricultural District Benchmarks for Eyre Peninsula
 Benchmark topsoil soil OC (%) values for texture displaying the mean and percentile values for each district compared to the mean for the whole of the SA Agricultural Zone.

Eastern EP 0.016%		Land use cropping 95%, pasture 5%				Annual SOC change		
Texture	Ag Zone Mean	Ag District Benchmarks						
		Count	Mean	25%	40%	50%	60%	75%
Sand	1.12							
Loamy sand	1.42	351	0.72	0.54	0.62	0.67	0.74	0.86
Sandy loam	1.79	429	0.88	0.63	0.77	0.82	0.90	1.07
Loam	1.96	371	1.05	0.80	0.94	1.03	1.13	1.27
Clay loam	1.93	310	1.21	0.91	1.09	1.16	1.24	1.46
Clay	1.66	312	1.04	0.70	0.90	1.00	1.10	1.28
Weighted Mean (all texture)	1.77	1773	0.97	0.71	0.85	0.92	1.01	1.17

Western EP 0.041%		Land use cropping 99%, pasture 1%				Annual SOC change		
Texture	Ag Zone Mean	Ag District Benchmarks						
		Count	Mean	25%	40%	50%	60%	75%
Sand	1.12	6	0.67	0.44	0.55	0.63	0.71	0.82
Loamy sand	1.42	372	1.01	0.67	0.80	0.89	1.06	1.28
Sandy loam	1.79	670	1.10	0.79	0.94	1.01	1.12	1.32
Loam	1.96	347	1.26	0.93	1.04	1.12	1.22	1.49
Clay loam	1.93	169	1.27	0.98	1.16	1.25	1.35	1.51
Clay	1.66	126	0.99	0.80	0.83	0.90	1.00	1.20
Weighted Mean (all texture)	1.77	1690	1.12	0.81	0.94	1.02	1.14	1.35

Lower EP 0.043%		Land use cropping 92%, pasture 6%				Annual SOC change		
Texture	Ag Zone Mean	Ag District Benchmarks						
		Count	Mean	25%	40%	50%	60%	75%
Sand	1.12							
Loamy sand	1.42	432	1.08	0.75	0.88	0.98	1.08	1.28
Sandy loam	1.79	542	1.45	1.06	1.23	1.34	1.46	1.70
Loam	1.96	405	1.68	1.28	1.46	1.57	1.69	1.99
Clay loam	1.93	384	1.62	1.35	1.47	1.56	1.65	1.85
Clay	1.66	259	1.47	1.10	1.30	1.42	1.60	1.80
Weighted Mean (all texture)	1.77	2022	1.46	1.10	1.26	1.36	1.48	1.71

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

Brian Dzoma¹, Nigel Wilhelm¹, Amanda Cook¹, Ian Richter¹ and Craig Standley¹

¹SARDI



Location
Minnipa
Minnipa Agriculture Centre

Rainfall
Av. Annual: 325 mm
Av. GSR: 241 mm
2023 Total: 280 mm
2023 GSR: 169 mm

Paddock History
2021: Wheat
2022: Barley
2023: Pasture

Soil type
Mild calcareous sand

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

Plot size
30 m x 2 m x 4 reps

Trial design
RCBD with 4 replicates

Yield limiting factors
Moisture, hostile subsoil

Location
Poochera - Gosling family

Rainfall
Av. Annual: 326 mm
Av. GSR: 247 mm
2023 Total: 207 mm
2023 GSR: 120 mm

Paddock History
2021: Barley
2022: Wheat
2023: Pasture

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
Moisture, hostile subsoil

Key messages

- Deep ripping as a physical intervention to manage subsoil compaction has not resulted in any significant difference to the control in all three years of these trials.
- Topsoil strategies showed the greatest benefits in productivity in the first 2 years; however, these responses did not carry through into the 3rd year, possibly due to less rainfall during Spring in the 2023 year.
- On very highly calcareous soils, improving the fertility of subsoils has the potential to improve grain yield, but responses only started showing in the third crop after application compared to the control.

Why do the trial?

Highly calcareous soils are common in some areas of south-eastern Australia and challenge crop production with a range of constraints. The challenges limit the effectiveness of improved agronomic practices developed elsewhere. This collaborative project, which started in 2020, aimed to identify and overcome calcareous soil constraints in order to lift crop production on these difficult soils. Replicated field trials were conducted on the upper Eyre Peninsula from 2021 to 2023 to investigate impacts of subsoil and topsoil amelioration strategies. This article summarises results of topsoil and subsoil strategies from the third crop grown on these trials in 2023. For details of trial set up

and past results, see the 2021 and 2022 EPFS Summary article titled: More profitable crops on highly calcareous soils by improving early vigour and overcoming soil constraints.

How was it done?

Six replicated field trials were established in 2021 at Poochera, Port Kenny and Minnipa and were re-seeded in May 2023 with GIA Kastar field peas @ 100 kg/ha with 60 kg/ha of MAP. This variety is tolerant to imidazolinone herbicides but does not have improved tolerance to flumetsulam (Broadstrike®) or residual sulfonylurea herbicides. Fresh carbon-coated mineral (CCM) @ 500 kg/ha was applied in topsoil trials as the only new treatment for 2023. The rest of the treatments were the same as in previous years. For more treatment details, see article in EPFS Summary 2022 titled: More profitable crops on highly calcareous soils by improving early vigour and overcoming soil constraints.

Measurements taken included crop establishment, flowering biomass, shoot nutrients at flowering, grain yield and soil penetration resistance of selected subsoil treatments. Statistical analysis of data was performed using standard ANOVA models in R.

Location
Port Kenny - Simon Guerin

Rainfall
Av. Annual: 349 mm
Av. GSR: 270 mm
2023 Total: 248 mm
2023 GSR: 171 mm

Paddock History
2021: Barley
2022: Pasture
2023: Wheat

Soil type
Grey very 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
Moisture, hostile subsoil

and subsoil strategies at any site. Mean plant population was 46 plants/m² (Poochera), 43 plants/m² (Port Kenny) and 39 plants/m² at Minnipa.

Shoot biomass at flowering was not improved by subsoil strategies and trial site averages ranged from 2.1 t/ha (Port Kenny), 1.3 t/ha (Poochera) and 0.9 t/ha (Minnipa). At Minnipa and Poochera, none of the topsoil strategies improved biomass at flowering, however, at Port Kenny in 2023 applied CCM @ 500 kg/ha improved flowering biomass by 15% when compared to ‘typical practice’ (2.45 t/ha).

Shoot nutrient analysis

After assessing flowering biomass, samples were sent to APAL for shoot nutrient analysis. Table 1

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

Subsoil

Shoot concentration of P at Minnipa and Port Kenny was not different from the control, however, at Poochera shoot P was significantly higher with CCM (0.22%) than typical practice (0.18%). Neutrog in the subsoil resulted in higher concentration of zinc in the plants at all 3 sites. Shoot zinc concentration with Neutrog was 17.5 mg/kg (Minnipa), 41.3 mg/kg (Poochera) and 25.1 mg/kg (Port Kenny). Shoot nitrogen (%) and manganese (mg/kg) was not affected by amendments and deep ripping at all 3 sites.

What happened?

Crop establishment was not affected by any of the topsoil

Table 1. Average nutrient concentrations across all treatments in flowering DM at Minnipa, Poochera and Port Kenny in 2023 and the significance of treatment differences.

SUBSOIL	Minnipa		Poochera		Port Kenny	
	<i>p-value</i>	mean	<i>p-value</i>	mean	<i>p-value</i>	mean
Nitrogen %	<i>ns</i>	2.45	<i>ns</i>	2.34	<i>ns</i>	2.65
Phosphorus %	<i>ns</i>	0.14	0.003	0.20	<i>ns</i>	0.22
Potassium %	<i>ns</i>	2.03	<0.001	2.16	0.005	2.21
Sulfur %	<i>ns</i>	0.12	0.001	0.19	<i>ns</i>	0.19
Copper (mg/kg)	<i>ns</i>	3.77	<i>ns</i>	6.13	0.05	3.33
Zinc (mg/kg)	0.02	14.5	0.007	34.2	<0.001	10.4
Manganese (mg/kg)	<i>ns</i>	29.4	<i>ns</i>	30.2	<i>ns</i>	20.8
TOPSOIL	Minnipa		Poochera		Port Kenny	
	<i>p-value</i>	mean	<i>p-value</i>	mean	<i>p-value</i>	mean
Nitrogen %	<i>ns</i>	2.44	<i>ns</i>	2.11	<i>ns</i>	2.24
Phosphorus %	<i>ns</i>	0.13	<i>ns</i>	0.18	<i>ns</i>	0.19
Potassium %	<i>ns</i>	2.03	0.01	2.06	<i>ns</i>	2.23
Sulfur %	0.006	0.13	0.004	0.17	<i>ns</i>	0.17
Copper (mg/kg)	<i>ns</i>	4.56	0.01	5.33	<0.001	3.83
Zinc (mg/kg)	<0.001	15.6	<i>ns</i>	27.4	<0.001	15.1
Manganese (mg/kg)	<i>ns</i>	29.9	<i>ns</i>	23.4	<i>ns</i>	19.3

Topsoil

Though adequate in controls, the combination strategy (fungicide + N + P + TEs) resulted in higher concentration of zinc in the plants at Minnipa (24.5 mg/kg) and Port Kenny (18.5 mg/kg). Shoot nitrogen (%), phosphorus (%) and manganese (%) were not affected by topsoil strategies at all 3 sites.

Grain yield

In 2023, a lack of moisture during late spring resulted in an early finish and generally very poor yields. Pod filling was poor at Minnipa and Poochera. The Minnipa site was not harvested, Poochera was harvested on 19 October, and Port Kenny on 18 October. Site mean for grain yield

was 0.2 t/ha at Poochera and 1.1 t/ha at Port Kenny. Topsoil strategies did not improve grain yield at the 2 harvested sites. In the subsoil trial, deep ripping alone did not improve grain yield at both sites, however, all ripping with amendments improved grain yield at Port Kenny. Typical practice was 0.87 t/ha, and the two highest yielding treatments were deep ripping with inclusion plates and Neutrog (1.12 t/ha) and deep ripping with CCM (1.10 t/ha).

Soil strength

Measurements of penetration resistance were carried out using a cone penetrometer in December, after 72 mm of rain (Figure 1). Data from the unripped

controls showed that soil strength is not severe in these soils with penetration resistance ranging between 500 - 2500 kPa. However, there were signs of re-compaction of the ripped treatments because penetration resistance was slightly higher in 2023 than in 2021 initial measurements. For example, in 2021 at 35 cm soil depth, penetration resistance was 524 kPa at Poochera and 964 kPa at Port Kenny, and at the same depths in 2023 it increased to 1216 kPa at Poochera and 1684 kPa at Port Kenny respectively.

2023 Deep rip means that soil penetration resistance measurements were taken in 2023 (after ripping in 2021).

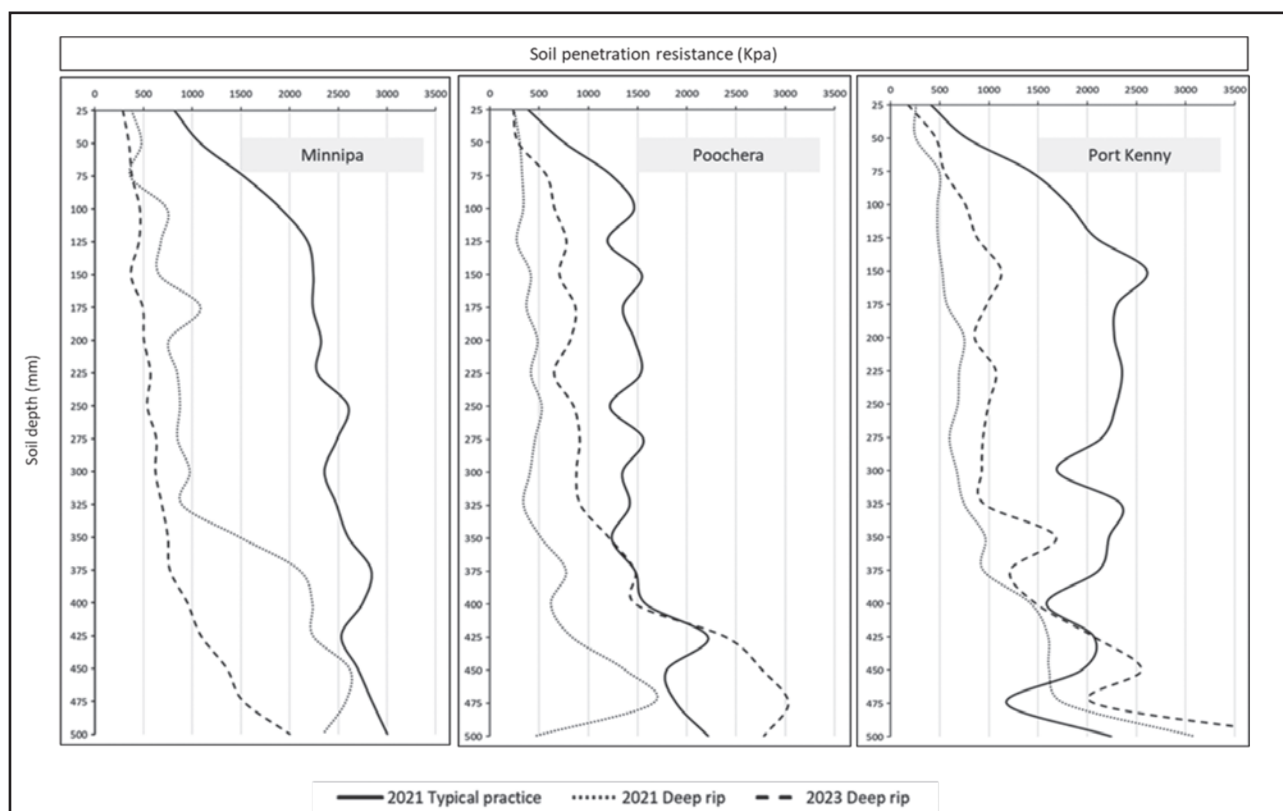


Figure 1. Soil penetration resistance (kPa) in 2021 or 2023 comparing deep ripping with unripped typical practice at Minnipa, Poochera, and Port Kenny.

What does this mean?

Our results have demonstrated that on very highly calcareous soils, while improving the fertility of the subsoil has potential to improve grain yield, the responses can take several years to appear and were quite modest in size compared to their cost. These modest responses might be a result of the poor finish in 2023 and the response of these interventions in the longer term under different growing season conditions is unknown. Deep ripping without amendments as a physical intervention to manage subsoil compaction has not improved grain yields in all three years of running these trials. This indicates that the constraints in these soils are more than just compaction, and therefore managing multiple

constraints would be required to optimise crop production on these challenging soils. Topsoil interventions have showed strong benefits in the first two years of conducting the trials, however, in year 3, under poor growing conditions, they have not shown any residual benefits over and above typical practice.

CCM applied under seed rows resulted in the highest flowering biomass in all three seasons at Port Kenny. Even though it is not commercially available, follow up research is required to assess whether the knowledge gained from this work can be developed into a commercial option. This new research should focus phosphorus supply and uptake in calcareous soils using different formulations (e.g., liquid and pelletised CCM of

different types), and an economic analysis to determine if these strategies can be financially attractive.

Acknowledgements

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Building resilience to drought with landscape scale remediation of saline land

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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.

Background

The Future Drought Fund project ‘Building resilience to drought with landscape scale remediation of saline land’ has 48 demonstration sites across 3 states (SA, NSW & Vic) and every successful management recommendation revolves around achieving a healthy soil environment, and not allowing a saline soil to develop or reform. While some sites have become scalded and highly saline to depth over many years, many other sites range between growing poorly or nothing after hot dry periods, to achieving good pasture/crop growth after critical rainfall periods. The broader project has demonstrated that it is the top 5 cm of soil, critical to achieving seed germination and early plant establishment, which can quickly change from toxic to only mild salinity after good rainfall, but soon revert, particularly on heavier clay soils. The rainfall has dual impacts of leaching some salt to slightly lower layers as well as diluting the salt concentration, allowing a stronger osmotic gradient for plant roots to function well.

The worst scenario for these vulnerable soils, is to have them bare over hot, dry periods (summer and/or droughts) as this greatly increases evaporation and capillary rise of moisture bring salts to the surface layer where they accumulate and concentrate. This is often exacerbated by:

- the lack of growth providing no summer cover,
- sheep grazing and camping on these areas, and
- wind sweeping sandy loam

topsoils down to the harder clay layers beneath.

The key principles of all dry saline land management is to get ground cover, and maintain cover over these soil areas for ideally all of the time. This is not always easy, particularly when large patchy areas are involved, and there still more work needed for efficient, practical options and solutions.

Locally dry saline land is an increasing issue in some parts of Eyre Peninsula, particularly in the drier areas. It is seen more in dry seasons and seems to expand in the area affected over a series of drier years. On Eyre Peninsula this project has focussed mostly on dry saline land demonstrations during 2022 and 2023, although there is one mallee seep site on lower EP. The 2022 and 2023 grower demonstrations compared using various soil amendments such as sand or organic matter, sowing techniques as well as crop tolerances.

Why do the trials?

Across areas of Eyre Peninsula, different regions and districts that suffer from patchy crop establishment and poor growth within paddocks caused by the accumulation of salts in soil layers particularly in heavy textured soil. These are typical and enduring issues particularly in the lower rainfall western regions of Eyre Peninsula. These dry saline zones, historically referred to as ‘magnesia patches,’ have been recorded and persisted for numerous years (Kennewell 1999).

A recent survey conducted among landholders (McDonough and Scholz, 2021) reveals growing concerns about these areas. Both the affected land area and the extent of production losses are reported to have escalated in recent years particularly through the dry period of 2017-2019.

There is evidence from farmers, and researchers that there is some scope to use management intervention to ‘reduce the wicking ability of soil’ and reduce the capillary rise of water that keep the salts at the surface once soil water has evaporated from the surface, which stops delivering the ‘conveyer belt’ action delivering and then concentrating toxic salts into the 0-5 cm zone.

The management interventions may include soil surface additions of sand, straw, chaff or manure. Some farmers who have tried these techniques with sand have found the effect can last over many seasons if enough sand is initially applied. However, available and spreadable sand isn’t available in many areas, and the use of other material like straw, chaff or manure may be an option.

This project in collaboration with landholders across Eyre Peninsula established demonstration sites in 2022 and 2023 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 2023 season with the 2022 reported previously (see EPFS Summary 2022, p. 57).

How was it done?

The 2022 sites at Karcultaby, Minnipa and Buckleboo were sown again by the landholders involved, and the legacy effect of the previous treatments were monitored (see EPFS Summary 2022, p. 57).

Three additional demonstration sites were established with landholders at Minnipa (Heddle) and Koongawa (Schmucker) and Charra (Drummond) which looked at the effect of added chaff, and different rates of sand at the respective sites. The sites Heddle, Schmucker, Baldock, Minnipa MAC and Cook were farmer sown and managed. Drummond’s site was SARDI plot seeder sown as it was located in a pasture paddock.

Following the substantial rain seen in December 2023, an additional treatment site was established on the known dry saline land at Koongawa to investigate the ‘over summer’ effect of sand, straw as well as a different surface cover (2nd hand carpet) on the saline present on the soil surface from the time of application (December 2023) until just prior to seeding (on-going). This will give some insight into the reduction of soil water evaporation, the summer mulching effect compared and the additional positive effect of germination at seeding.

There were also demonstration sites in the project comparing crop species (oats and barley) and variety differences in tolerance to dry saline land at Penong, as well as looking at management options such as on-row versus off-row seeding. Both of these demonstrations were inconclusive given the seasonal conditions (droughted).

Table 1. Summary of dry saline land demonstration sites in 2022 and 2023.

Co-operator/ Location	Demonstration type	Crop type and sowing date	Treatments (approximate rates)
Cook, Karcultaby	Soil ameliorants (Replicated)	2023 Self regenerating medic pasture 2022 Barley (Scope CL)	Control - untreated Soil ameliorants Surface manure @ 8 t/ha Surface sand @ 300 t/ha
Minnipa Ag Centre (MAC)	Soil ameliorants (Replicated)	2023 Barley 2022 Wheat (Scepter)	Control - untreated Soil ameliorants Surface manure @ 8 t/ha Surface sand @ 300 t/ha
Karinya Ag, Buckleboo	Soil ameliorants (Unreplicated due to different salinity zones, but multiple measurements within each treatment)	Wheat Oats (Yallara) and Vetch (Timok)	Control - untreated Soil ameliorants Low-rate sand @ 75 t/ha High-rate sand @ 150 t/ha
Drummond, Charra	Soil ameliorants (Replicated)	Oats (Yallara)	Control - untreated Soil ameliorants Low-rate sand @ 60 t/ha High-rate sand @ 120 t/ha
Schmuckers, Koongawa	Soil ameliorants (Replicated)		Control - untreated Soil ameliorants Low-rate sand High-rate sand
Heddle, Minnipa	Soil ameliorant (Unreplicated but multiple measurements within each treatment)		Control - untreated High chaff rate - 100 kg/ha

What happened?

The six different demonstration sites in 2023 that had either sand, straw, or chaff applied, all showed consistent improvements over the control. While the rates and amounts on the different treatments were not consistent, the overall trend was.

See the different results on the tables and graphs below which relate to different sites. The recording of sand depth in the Drummond site at Charra, allowed direct comparison of sand depth to both biomass and grain yield.

Koongawa (Schmucker)

Schmuckers site at Koongawa had a Nil control, a low and high rate of sand applied. These treatments were replicated three times on the 25 April 2023 just prior to sowing with Scepter wheat on 9 May. While this was a narrow window, there was still some movement of sand across the treatments from the treated plots to the untreated plots. However, in spite of this, there was still enough sand left of the treated plots to show treatment difference. The site received 272 mm annual rainfall with a growing season (April-Oct) rainfall of 145 mm. The site had an average improvement of grain yield with the addition of sand between 0.23 to 0.5 t/ha over the Nil Control treatment (Table 2).

Buckleboo (Baldock)

At Buckleboo, in 2022 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 2022. 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. In 2023 the paddock was sown to wheat. The site received 258 mm annual rainfall with a growing season (April-Oct) rainfall of 109 mm in 2023. In 2023 the addition of sand after 14 months, applied in 2022 resulted in 0.7-1.38 t/ha improvement in grain yield compared to the Nil Control areas (Table 3).

Minnipa (Heddle)

Bruce Heddle used chaff from his chaff cart at harvest to apply chaff amendments to two saline areas in the paddock. The hill area was a lower saline site, and the paddock site was a lower topographical area in the paddock with a highly saline area and longer-term 'magnesia patches' with visible poorer plant growth and establishment. In 2023 the addition of chaff applied in December 2022 resulted in 0.2-1.0 t/ha improvement in grain yield compared to the Nil Control area (Table 4).

Karcultaby (Cook) and Minnipa (MAC)

At Karcultaby and Minnipa the soil ameliorants were surface applied prior to seeding in 2022. The manure was taken from feedlot material. The sand was taken from the closest local source.

The MAC N2 trial was over sown by the MAC Farm team to Maximus barley on 29 May which yielded 0.8 t/ha. The site received 280 mm annual rainfall with a growing season (April-Oct) rainfall of 169 mm in 2023. The amendments resulted in a 0.1-0.2 t/ha yield improvement in the most saline area in the paddock (Table 5).

The Karcultaby site was a self-regenerating medic pasture with self-sown barley. The 2022 soil amelioration treatments applied (EPFS Summary 2022, p. 57) produced 0.9-1.0 t/ha greater dry matter in a self-regenerating medic pasture than the Nil control treatments in 2023 (Figure 1).

Charra (Drummond)

At the Charra site, drift sand was taken from a nearby fence line which was applied to a saline soil at different amounts. Similar to other sites, there was a high 10 t/ha rate and lower 6 t/ha rate applied. On this site, the sand depth was recorded which allowed a line of regression to be fitted (Figure 2). The Charra site received a growing season rainfall of 64 mm which resulted in low yield but there was a biomass and yield benefit to the application of sand at both rates.

Table 2. Wheat Yield (t/ha) in response to amelioration treatments applied at Koongawa in 2023.

Treatment	Mean (t/ha)	Standard Deviation
Sand High	1.38	0.59
Sand Low	0.87	0.47
Control	0.64	0.25

Table 3. Mean Baldock Buckleboo wheat yield (t/ha) 2023.

Treatment - sand rate t/ha	BAY 1: Lower salinity	BAY 2: Western Scald	BAY 3: Lower salinity
Control 0 (better production area)	0.52	0.32	0.40
Sand low - 75 t/ha	1.46	1.55	1.43
Control 1	0.75	0.74	0.73
Sand high - 150 t/ha	2.13	1.80	1.86
Control 2	0.75	0.57	0.67

Table 4. Grain yield (t/ha) at Minnipa (Heddle) of soil amendment of chaff at two different paddock locations compared to Nil treatment in 2023.

Location	Treatment	Grain yield (t/ha)	Standard deviation
Hill (lower salinity)	Chaff	1.70	0.04
	Nil	1.48	0.08
Paddock (high salinity)	Chaff	1.47	0.11
	Nil	0.48	0.18

Table 5. Barley yield (t/ha) at MAC N2 saline area in 2023 with 2022 soil amendment treatments.

Treatment	Mean barley yield (t/ha)	Standard deviation
Nil	0.262	0.07
Manure	0.354	0.09
Sand	0.44	0.09

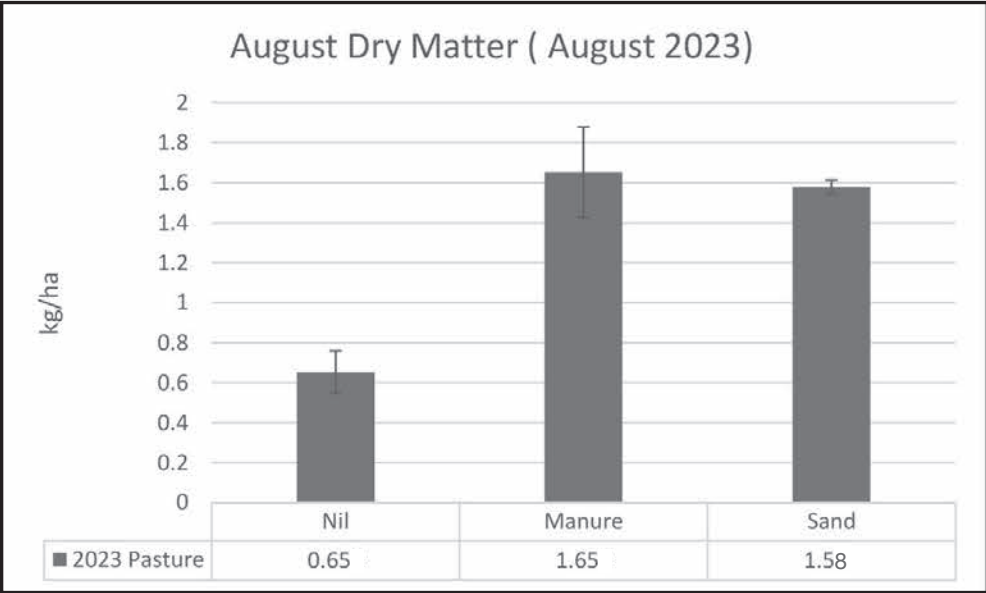


Figure 1. Karcultaby Pasture Dry Matter (kg/ha) mean for three replicates with standard deviation show on the error bars, August 2023.

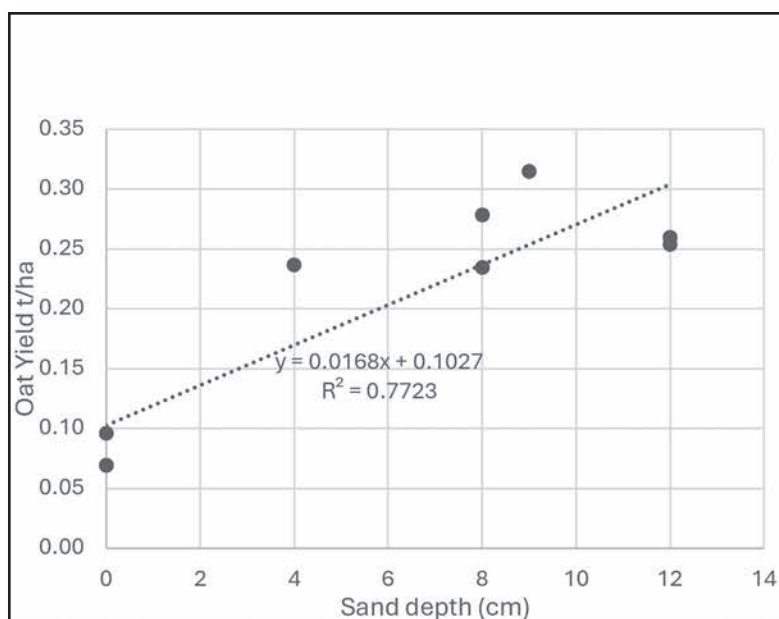


Figure 2. Charra Depth of Sand and Yallara Oat grain yield (t/ha) in 2023.

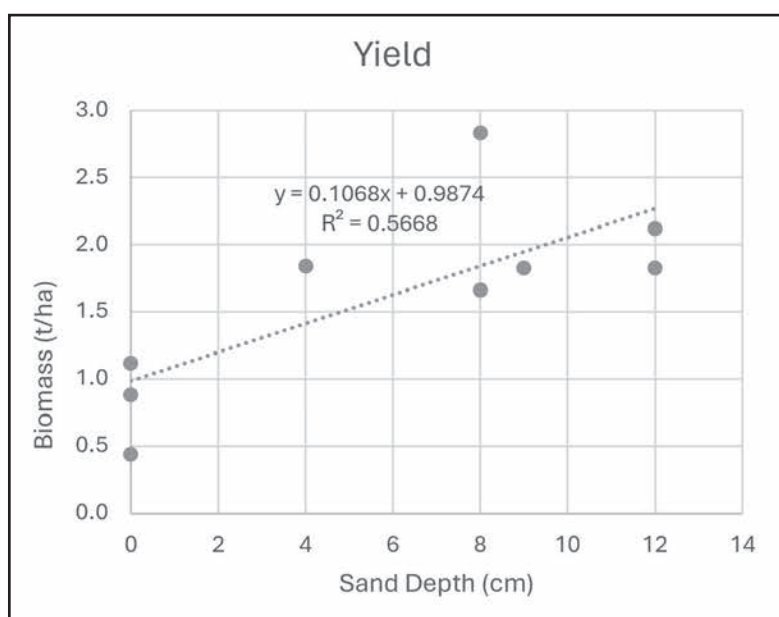


Figure 3. Charra Depth of Sand and Yallara Oat dry matter biomass (t/ha) on 14 September 2023.

What does this mean?

In the saline soil demonstrations undertaken there was a positive response to adding amelioration treatments to saline bare patch soils (dry saline soils or magnesite patches). Each site saw an approximate doubling of the yield in either grain or biomass.

Importantly the three sites initiated in 2022 with soil amendments produced ongoing benefits in 2023. This result implies if the surface cover of soils can be maintained, the effects (both agronomic and economic) can last multiple seasons.

Growers should also be aware of potential biosecurity issues, mainly weeds, with the addition of material including sand, manures/old straw from feedlots, chaff, or hay to paddocks. Extra management may be required to manage these weeds.

The challenges of applying large quantiles of sand, straw, or other materials to larger paddock areas are challenging both on a logistical, engineering and possibly financial level. Technologies and techniques like EM38 and satellite mapping of dry saline patches might be able result in more targeted application

and reduce the area needed to be treated. The ready and economic availability of sand, straw (old hay or other grain waste), manure and chaff will vary greatly based on location and farming system. However, as a principle the results seen here could help justify the treatment of soil particularly when there is a residual effect.

The overall project has produced the following outcomes and recommendations:

1. **Adding soil cover** (hay, straw, manures, chaff cart residues, etc) to the surface greatly decreases evaporation and capillary rise of salts to the surface, reducing/preventing toxic levels forming after summer, which may allow plants to germinate and grow. Affects will last while cover remains, and organic matter can improve topsoil health.
2. **Adding sand to surface** also acts like a mulch cover, decreases evaporation and capillary rise and provides non-toxic seed bed for plants to establish/cover the previous scalds. Soil tests show that the original saline topsoil layer returns to health in a few seasons after around 8 cm of sand is placed on the surface. This seems to indicate a permanent soil fix with sites still growing excellent crop after 10 years, next to bare untreated areas. The long-term benefits often far outweigh the high initial costs of moving sand, and farmers with close sandhills and machinery access have fixed very large areas. While excellent results have been obtained initially from lower and thinner sand applications, there is concern that once the sand remixed with the clay loams below, the increased wicking affect may allow salt to accumulate in surface layers again.

3. **More strategic management around sowing rains.** Historic analysis of numerous sites, along with anecdotal farmer experiences suggests that it is that rains immediately prior to seeding (at least 20 mm) has the greatest impacts on increasing crop/pasture germination. Large summer rains can leach surface salt, but then wick more salts back to the surface with hot periods following. Numerous sites showed improved growth with volunteer pastures, because the seeds germinated with the first big rain, as opposed to spraying areas bare for a period before sowing. While more work is needed in this area, it suggests that being flexible enough to sow these specific areas straight after significant rainfall events, whether very early, or well after the normal cropping program, may better achieve a soil cover that can then be maintained.
4. **Using more salt tolerant crops/pastures.** While not a big focus for the EP sites, for less severe cropping areas, barley or oats appear to be better performers, but will still die out in worst patches. Messina, puccinellia and tall wheat grass (usually targeted for higher rainfall saline zones with shallow water tables) showed some promise at some sites, but suffered badly in drought conditions. Saltbush and bluebush have been used in some severe areas where farmers have gone back to permanent pasture.

5. **Caution must be applied if attempting to ameliorate sodic/saline subsoils.** One site in the Mallee where sand and manure was ripped and then spaded into heavy clay to 25cm resulted in making the problem worse, as too much problem clay was raised to the surface. However, the sand and manure left on the surface at this site proved successful in terms of crop growth. However, another heavy site where deep ripping with active inclusion plates and discs, which mostly only pushed surface material down, has shown some encouraging results of increased growth and root penetration into previously hostile layers. More work is required before any definitive recommendations on this are forthcoming.

The FDF Saline Land Project is in the process of developing a Web based interactive Decision Tree for Dry Saline Land, that will allow farmers assess their own situations, follow the key principles to best improve their situation. It will involve numerous case studies, podcasts and short videos of farmer experiences and demonstration site results that will greatly assist landholders to overcome this growing land degradation issue as well as putting in the context of other forms of salinity see <https://msfp.org.au/mallee-seeps-decision-tree/>

Management options for dry saline soils on upper Yorke Peninsula: the second season

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Location
Tickera, SA
Barker family

Rainfall
Av. Annual: 347 mm
Av. GSR: 252 mm
2023 Total: 389 mm
2023 GSR: 219 mm

Paddock history
2022: Refer to wheat trials
2023: Wheat

Soil type
Moderate to strongly alkaline clay loam

Plot size
10 m x 1.5 m x 4 reps

Trial design
RCBD with 4 replicates

Yield limiting factors
Moisture and salinity

Key messages

- In season one lentil grain yields were generally low (0.16 t/ha - 0.62 t/ha) in the sand, straw and gypsum amelioration trial. The high sand application rate (1300 t/ha) was the only treatment to improve lentil grain yield compared to the control.
- This season larger differences among the sand and straw rates are emerging. Sand rates above 650 t/ha and straw rates above 6.6 t/ha resulted in wheat grain yields of 1.95 t/

ha - 2.42 t/ha compared to the control 0.67 t/ha.

- Wheat yields following various crop type/varieties sown in 2022 to manage salinity ranged from 0.51 - 0.99 t/ha. Wheat yields following canola and field pea were higher compared to wheat following wheat, triticale or barley.
- There was a link between wheat grain yield this season and plant cover from the various crop types/varieties at harvest last year. Crop types which had <40% plant cover at harvest resulted in lower wheat yields the following season.

Why do the trial?

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

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

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

How was it done?

Site selection and rainfall

Two trials were established at Tickera, SA (-33.8466, 137.6844) in 2022 - a soil amelioration trial and a crop type/variety trial. The saline area was selected based on historical crop performance and soil test results (Table 1). The amelioration trial was a randomised complete block design and the crop type/variety trial was a split plot design where crop type (monocot/dicot) was the whole plot and crop type/variety was the sub plot. Both trials had four replicates and the individual treatments are described below.

All plots were scored prior to seeding for stubble cover (barley) to assess the variation in salinity level across the site. Stubble cover was measured visually by scoring each plot from 1 (low stubble cover = more saline) to 5 (high stubble cover = less saline).

Growing season (April - October) rainfall at Tickera was 250 mm in 2022 and 219 mm in 2023. Long-term (1969-2022) average growing season rainfall for Tickera is 252 mm.

Soil properties

Soil samples were collected on 29 April 2022 by sampling the surface 0-10 cm in all five stubble cover scores (Table 1). Deeper cores were sampled in areas with scores 1 and 4 and segmented as follows, 0-10 cm, 10-20 cm, 20-40 cm and 40-60 cm, these were not replicated.

The Tickera site is a moderate to strongly alkaline (pH >8.0) clay loam with salinity issues (Table 1). Salinity was measured using chloride and an electrical conductivity estimated

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

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

Sand, gypsum and straw amelioration trial

Sand and gypsum treatments were spread on the soil surface 3 May 2022. Straw treatments (from baled

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

In the first season, the trial was sown with Hurricane XT lentils on 26 May 2022 at a rate of 50 kg/ha. Fertiliser at seeding was applied as MAP 1%Zn at 60 kg/ha. The trial was sown to Chief CL Plus wheat on 11 May 2023 at a rate of 80 kg/ha. Fertiliser at seeding was applied as MAP 65 kg/ha plus urea 42 kg/ha. The trial was managed with the application of pesticides to ensure a weed, insect and disease-free canopy.

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

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

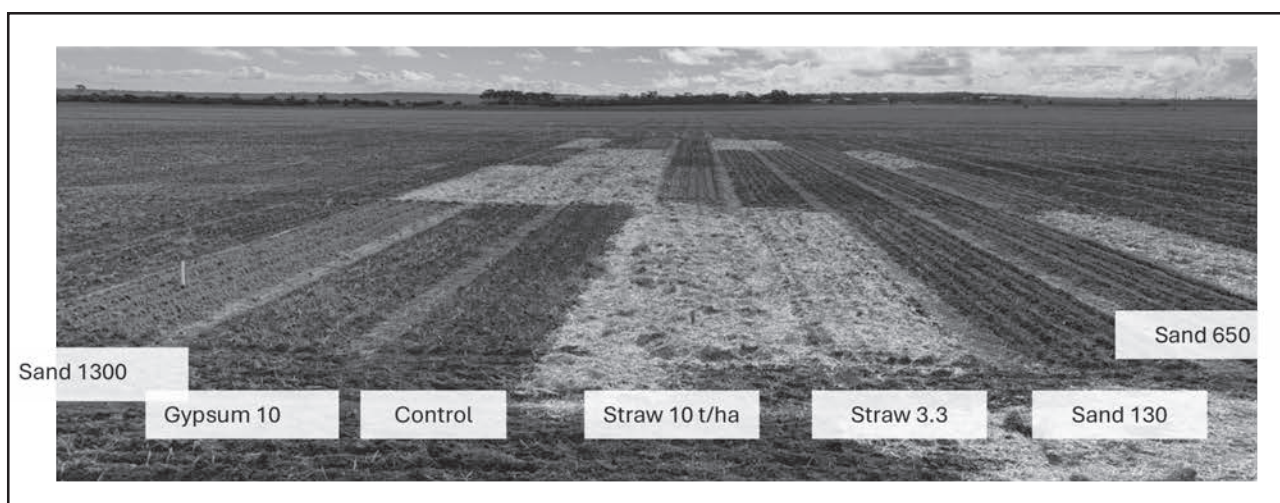


Photo 1. Sand, gypsum and straw amelioration treatments post seeding at salinity management trial Tickera, SA (taken 27 May 2022).

Table 2. Crop types and varieties sown in the first season (2022) of the salinity management trial Tickera, SA.

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

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

Crop type and variety trial

A range of crop types and varieties were selected for the trial based on their expected relative tolerance to soil salinity (Table 2). The crop type/variety treatments were sown in 2022. The residual effects of these treatments were assessed in 2023 with all plots sown to a Chief CL Plus wheat as described above on 11 May.

Crop assessments

The same crop assessments were conducted in both trials in 2023. Plant emergence was scored for each plot on 29 May 2023, ranging from 0% (no plant emergence) - 100% (full plant emergence). A Greenseeker was used to measure NDVI on 29 June and 28 July 2023. Grain harvest was completed on 2 November 2023 using a plot header. Grain quality assessments included protein, test weight and screenings.

Statistical analysis

Analysis of this experiment was conducted using linear mixed models with restricted maximum likelihood using ASReml-R (Butler, 2022) and the R Core Team (2022) package biometryassist (Nielsen *et al.* 2022). Where there is significance evidence from the model that the explanatory variable means differ, Tukey's multiple comparison test was used to determine which of the means are different at a significance level of 5%.

What happened?

Sand, gypsum and straw amelioration trial

In season one lentil grain yields were generally low (0.16 t/ha - 0.62 t/ha) across the trial. The high sand application rate (1300 t/ha) was the only treatment to improve lentil grain yield compared to the control.

This season sand applied at 650 t/ha and 1300 t/ha improved wheat grain yields to 1.97 t/ha and 2.26 t/ha, respectively compared to the control at 0.61 t/ha (Table 2). Both treatments can clearly be identified (high plant cover) in an aerial image of the trial (Photo 2). These results indicate the higher sand rates are providing one or both of the following, a mulching effect disrupting the evaporation from the soil surface retaining more moisture and reducing surface salinity and a layer of soil with lighter texture for crops to establish well and therefore yield significantly more. In general grain quality in the sand treatments was similar compared to the control, meeting H2 receival standard. However, test weight was borderline (minimum for maximum grade >76 kg/hL) for the sand rates and in one case reduced the delivery grade to AUH2. This reflects below average growing season rainfall impacting grain fill

in the sand treatments which had higher yield potential.

A similar result was observed for the straw rates trialled. The 6.6 t/ha and 10 t/ha treatments had high wheat grain yields of 1.95 t/ha and 2.42 t/ha, respectively (Table 2). As for the sand treatments these results suggest the higher rates of straw had a mulching effect and were able to retain more soil moisture (summer and in-season) for the crop by reducing evaporation and surface salinity and improving emergence and yield. Grain quality for these two treatments was lower compared with the sand, gypsum and control. Grain protein was less than 11.5% resulting in a maximum delivery grade of APW1. It is not surprising that nitrogen supply may be lower in these treatments given the large volume of straw applied, where soil microbial biomass ties up nitrogen as the straw decomposes.

The lower rates of straw 3.3 t/ha and sand 130 t/ha produced wheat grain yields that were no different to the control (Table 2).

Gypsum applied at 10 t/ha has not improved grain yield compared to the control in either season. A lack of crop response is not uncommon from many soil amendments in the

first few years after application. The surface-applied gypsum will gradually move through the soil profile with rainfall, but this can take many years. Long-term monitoring of this site will be required to understand the full soil, crop and economic returns from these treatments.

Cumulative grain yield response to the various sand rates applied (Figure 1) shows grain yield stabilises after approximately 650 t/ha. That is, application of sand rates beyond this point did not result in large yield gains. This sand rate is higher compared to 2022 results in isolation, which suggested rates above 200 t/ha were sufficient to achieve high lentil grain yields.

For the straw rates there is a liner response in cumulative grain yield (Figure 1). This suggests the straw rates trialled have not maximised grain yield and further gains may be achieved from rates above 10 t/ha.

As multiple seasons of data and crop types are evaluated a better understanding of optimal sand and straw rates at Tickera will be determined. It is also unknown how long these treatments will have effect on crop growth and production.

Table 2. Lentil and wheat grain yields (t/ha) and wheat grain quality for sand, straw and gypsum treatments at Tickera, SA.

Treatment	2022	2023		
	Lentil grain yield (t/ha)	Wheat grain yield (t/ha)	Protein (%)	Test weight (kg/hL)
Control	0.23 b	0.67 c	11.8 bc	78.1 abc
Gypsum at 10 t/ha	0.16 b	1.26 c	11.8 bc	77.7 bcd
Sand at 130 t/ha	0.25 ab	1.26 bc	11.9 abc	76.3 cde
Sand at 650 t/ha	0.40 ab	1.97 ab	12.1 ab	76.1 de
Sand at 1300 t/ha	0.62 a	2.26 a	12.6 a	75.4 e
Straw at 3.3 t/ha	0.40 ab	1.19 c	11.5 bcd	78.4 ab
Straw at 6.6 t/ha	0.46 ab	1.95 ab	11.3 cd	78.9 ab
Straw at 10 t/ha	0.46 ab	2.42 a	11.0 d	79.8 a
Pr(>F)	0.001	<0.001	0.007	0.001

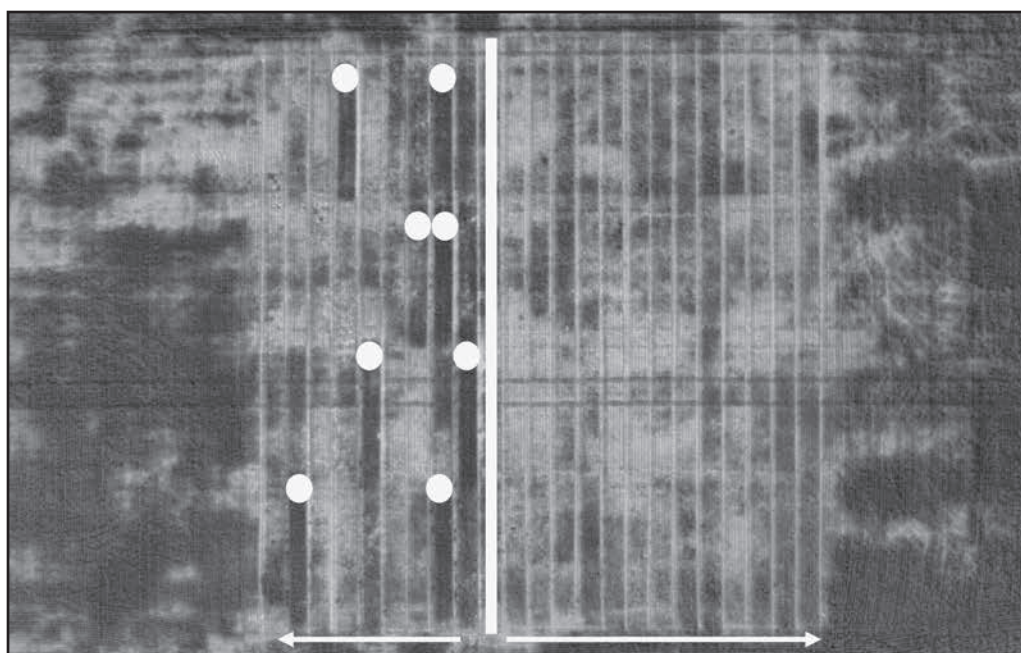


Photo 2. Aerial photo of the salinity management trials at Tickera, SA on July 28, 2023. Line shows the buffer with the sand, gypsum and straw trial on the left and crop type/variety trial on the right. Dots indicate the 650 t/ha and 1300 t/ha sand rate plots applied in 2022.

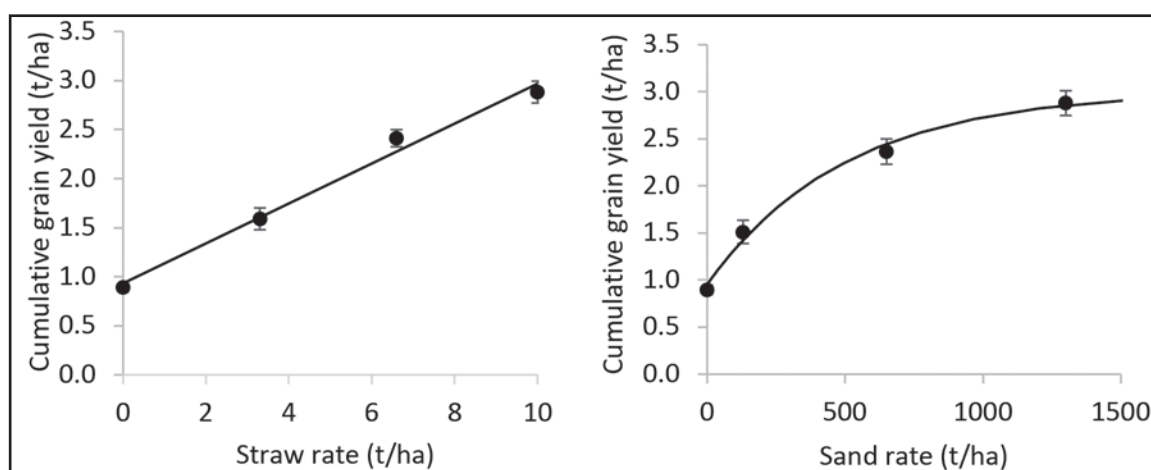


Figure 1. Cumulative (2022 lentil + 2023 wheat) grain yield response in relation to straw (left, $R^2 = 0.988$) and sand (right, $R^2 = 0.978$) rates applied in salinity management trial Tickera, SA.

Crop type and variety trial

Summary of 2022 crop performance

Canola and safflower had the highest crop cover (75% and 83%, respectively) at harvest in 2022. Other treatments with high crop cover at harvest were oats (82%), lentil (57%) and vetch (57%). The lower crop cover in the cereals was attributed to low rainfall from mid-June through July which limited tillering and caused crop damage/death in the more saline patches.

Grain yield was variable across the site, however there were

differences between crop type with oats (0.9 t/ha) being the highest yielding. Barley, peas, and safflower had intermediate performance averaging 0.53 t/ha. Wheat, triticale, lentil and vetch were the lowest yielding. Grain yield of canola was not recorded due to severe bird damage prior to harvest.

Carryover effects in the 2023 wheat crop

Wheat plant emergence scores 18 days after sowing were low and varied between 11 - 44% across the crop types (Table 3). Despite variation in emergence there were only minor differences

among treatments at the end of the season. The high variability in plant emergence is related to the natural variability of soil salinity levels across the trial (Photo 2). In some cases, crop production and stubble cover from 2022 may have also contributed this variation however there was not a strong correlation (Figure 2).

Table 3. Wheat plant establishment, Greenseeker NDVI and grain yield (t/ha) averaged across variety for the crop type and variety salinity management trial Tickera, SA 2023.

2022 Crop	Plant emergence (%) 29 May	NDVI 28 July	Grain yield (t/ha)
Barley	15 bc	0.306 abc	0.64 bc
Oats	44 a	0.391 a	0.91 a
Triticale	11 c	0.303 abc	0.78 abc
Wheat	32 abc	0.299 bc	0.7 abc
Lentil	30 abc	0.375 ab	0.88 ab
Peas	30 abc	0.361 abc	0.66 abc
Vetch	26 abc	0.292 bc	0.6 c
Canola	40 ab	0.352 abc	0.83 abc
Safflower	16 abc	0.285 c	0.58 c
Pr (>F)	0.040	0.022	0.020
LSD (0.05)	27.5	0.089	0.26

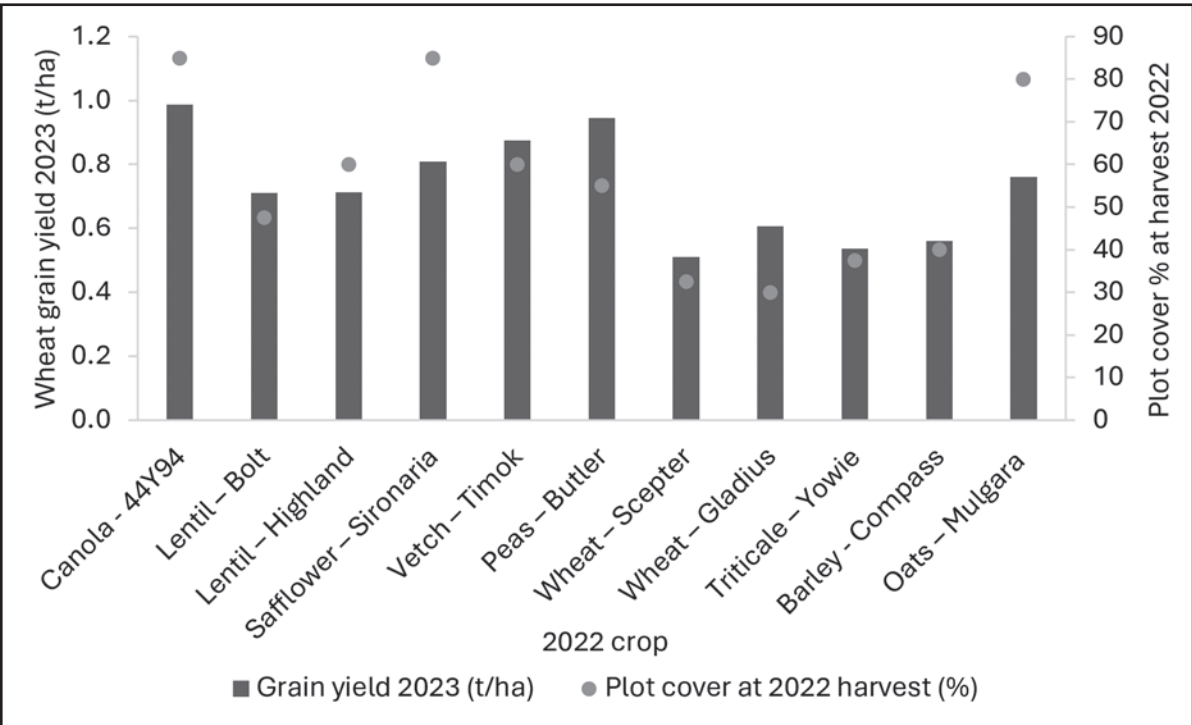


Figure 2. Wheat grain yield for the various crop types/varieties sown in 2022 and their respective plot cover % at harvest for salinity management trial at Tickera, SA.

Grain yields across the trial were similar to the control treatments in the adjacent amelioration trial discussed above. They ranged from 0.51 t/ha - 0.99 t/ha and this highlights that these strategies are relatively ineffective at treating dry saline soils. Despite this, Greenseeker NDVI and grain yield data showed there were minor differences between crop type this season although there was no variety effect (Table 3). Both crop assessments showed wheat following canola and field pea were generally higher compared to wheat following wheat, triticale or barley.

There was a moderate relationship ($R^2=0.62$) between wheat grain yield this season and plant cover from the various crops/varieties at harvest in 2022 (Figure 2). Crop types with more crop cover at harvest had more residue cover over summer, with implications for soil evaporation, salt accumulation, and the establishment and growth of the following crop. In general canola, safflower, oats, and the pulses had moderate to high (>45-70%) plant cover which corresponded to the higher yielding treatments. The plant cover from wheat, triticale and barley in 2022 was low (<40%) and similarly wheat grain yields were lower following these crops.

There were no differences in grain quality among the treatments with all samples meeting H2 receival standard. On average grain protein was 12.1%, test weight 76.7 kg/hL and screenings 4.0% (data not shown).

What does this mean?

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

Crop type and variety selection had minor influence on wheat NDVI and grain yield in season two of the trial. Both crop assessments showed wheat following canola and field pea were generally higher compared to wheat following wheat, triticale or barley. There were few differences among the remaining crop types/varieties. However, there was a moderate relationship between plant cover at harvest in season one and wheat grain yield in 2023. Crop/variety treatments which had higher plant cover at harvest in 2022 generally had higher grain yields compared to those with low (<40%) plant cover.

Acknowledgements

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

Josh Telfer, Brianna Guidera, Brian Hughes and Andrew Harding
SARDI



Location
Brooker
Neil and Leah, Casey and Kathryn Carr

Rainfall
Av. Annual: 398 mm
Av. GSR: 314 mm
2023 Total: 330 mm
2023 GSR: 260 mm
2022 Total: 552 mm
2021 GSR: 364 mm

Paddock history
2023: Bendoc Faba beans
2022: Scope CL barley
2021: Yitpi wheat
2020: Cobra wheat
2019: 44Y90 Canola

Soil type
Shallow sand loamy sand on clay

Soil test
pH, nutrition ect

Plot size
24 m x 4 m x 4 reps

Trial design
Experimental: randomised complete block

Yield limiting factors
Very high ryegrass infestation, moderate nitrogen deficiency throughout winter, temporal waterlogging for extended periods throughout winter.

Key messages

- **In 2023, several lime treatments (3 t/ha and 6 t/ha surface and 6 t/ha incorporated lime) applied in 2020, improved the yield of faba beans by about 1 t/ha compared to untreated controls (20-25% yield increase).**

- **Soil testing undertaken in Autumn highlighted the impact of different liming treatments on pH. Incorporation improved the 5-10 cm pH level when 3t/ha was applied.**
- **Plant analysis indicated lime treatments increased molybdenum above critically low levels and while lime dropped the level of manganese, zinc and copper they were still above deficiency levels.**
- **Financial returns from applying 3 t/ha lime have resulted in \$1000/ha of extra grain at a cost of \$200/ha with several years of benefits to go.**

Why do the trial?

The trial was initiated to address critical issues related to soil acidity on the Eyre Peninsula. Approximately 7% of the agricultural land on the Eyre Peninsula, equivalent to 186,000 ha, is affected with surface soil acidity at depths of at least 0-10 cm (DEW Interim acidity Model, 2023). Soil acidification is increased by high application rates of ammonium-based nitrogen fertilizers and the removal of agricultural products. This is particularly significant on low buffering (sandy) soils within high-production systems.

An additional 19% or 500,000 ha is at risk of becoming acidic over the next 10 to 50 years (DEW, 2023). The consequences of such acidification include the

loss of production, diminished soil biological activity, reduced crop fertiliser use efficiency, and an increase in overall soil acidification levels (Forward and Hughes, 2019). Furthermore, approximately 4% of Eyre Peninsula agricultural land is identified to have acidic subsurface layers, and failure to treat surface soil acidity adequately may result in progressive acidification of subsurface and subsoil layers, leading to pH stratification. This stratification poses a more complex and expensive challenge to address.

Previous experiences from the region, the state, and indeed around the world have demonstrated that the application of lime to acidic soils can lead to significant improvements in crop and pasture production, especially benefiting acid-sensitive crops such as lentils, chickpeas, and beans.

However, recent trials on Eyre Peninsula have yielded mixed results. A 5-year trial at Koppio, funded by GRDC project DAW00252, revealed that although surface liming effectively increased topsoil pH compared to the control, and combining this with ripping and subsurface placement of lime improved subsoil pH, grain yields were not consistently enhanced by these treatments (Guidera and Masters, 2022).

Soil acidity and associated aluminium toxicity primarily affects the roots of a crop, which can in turn affect other agronomic factors including effective water holding capacity. There is a lag time between lime applications and the resulting interactions with the soil. The majority of Australian wheat varieties are tolerant to soil acidity. However, the recent increase in production of grain legumes and oilseeds, and supposed susceptibility of barley, is causing the impact of acidity on economics and soil health to become more apparent.

This trial, funded under the GRDC SA soil acidity program, is designed with the goal of enhancing soil pH and crop production through the application of surface-applied and incorporated lime. The aim

is to provide valuable insights and solutions to mitigate the adverse effects of soil acidity on Eyre Peninsula's agricultural productivity.

How was it done?

The trial was established on a shallow, acidic loamy sand-over-clay flat at Brooker on lower Eyre Peninsula in May 2020. Heavy infestations of ryegrass have been an on-going issue at this 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 about 15 cm is neutral to alkaline with increasing carbonate at depth.

As previously described (EPFS Summary 2022, p. 73) the trial was established as a randomised

complete block design with four replicates of four treatments. Treatments are listed below in Table 2. Soil mixing treatments were completed by the landholder using a cultivator with sweeps. Lime was sourced from local suppliers.

In 2023 the site was sown to Bendoc beans on 1 and 2 June, with 80 kg/ha MAP applied at seeding. The trial was sown and harvested using plot machinery by SARDI Port Lincoln.

In Autumn 2023 detailed soil analysis was undertaken examining pH trends down the profile and 0-10 cm samples by treatments. For each plot samples were bulked from six sub-samples collected by depth.

Table 1. pH of surface and subsurface layers, measured in control plots in 2020.

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 and labels used.

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

What happened?

Detailed trial results from 2022 can be found in EPFS Summary article ‘Improving soil pH and crop production through the application of surface and subsurface applications of lime to treat acid soils at Brooker’ (EPFS Summary 2022, p. 73). In summary, in 2020 the site was sown by the landholder to wheat (var. Cobra) and managed as per the rest of the paddock. No differences were observed between treatments, which is common in the first year of lime trials. In 2021 the site was sown to wheat (var. Yitpi) using the SARDI plot seeder. Yitpi is considered a more sensitive wheat variety to acidity. While there were some trends the only significant treatments were sulphur which yielded less than the 6 t/ha lime rates.

In 2022 the trial was sown by SARDI to barley (var. Scope CL). Spring biomass and yield results showed the medium (3 t/ha) surface and high lime (6 t/ha) surface and mixed rates significantly ($P<0.05$) increased yield by around 0.8-1.0 t/ha (20-25%) when compared to the controls. Plant testing undertaken during the growing season highlighted that where medium to high rates of lime were applied

that there was a significant increase in molybdenum and a reduction in manganese compared to the controls.

2023 Results

Soil Analysis

In Autumn 2023 soil analysis was undertaken at 5 cm increments and a 0-10 cm sample as well from each plot. Soil samples were bulked from six points per plot in the 5 cm incremental sampling and from fifteen sub-samples for the 0-10 cm sample per plot. Four reps were tested. Figure 1 highlights how the treatments have affected the pH_{Ca} down the profile.

The 6 t/ha rates, both surface and mixed, and the 3 t/ha mixed, modified pH down the profile to the greatest extent. Soil pH at 5-10 cm in plots treated with 3 t/ha surface lime is considerably lower than on the surface. In the 10-15 cm layer, where the B horizon commences, there are less differences in soil pH between treatments, showing that at this depth the impact of liming is diminished.

Plant Growth

Significant differences in growth were evident early in the season with NDVI assessment in mid-August showing all of the medium

and high rates of lime to be significantly greater than the 1 t/ha lime and controls and sulphur.

Plant Testing

Plant testing was undertaken on replicates for five treatments in 2023. This is shown in Table 3, below. These tests highlight higher nitrogen in lime treatments, likely from better nodulation, as well as lower manganese and higher molybdenum from the lime treatments. Zinc and copper have also been reduced. Molybdenum was deficient in the non-limed plots.

Yield Results

The crop was harvested following desiccation by an early glyphosate application by the landholder, aiming to reduce ryegrass seed set. Even so, yield differences between treatments were significant and lime treatments (3 t/ha and 6 t/ha surface and 6 t/ha incorporated lime) applied in 2020, improved the yield of faba beans by approximately 1 t/ha compared to untreated controls. (Figure 3) (100% increase).

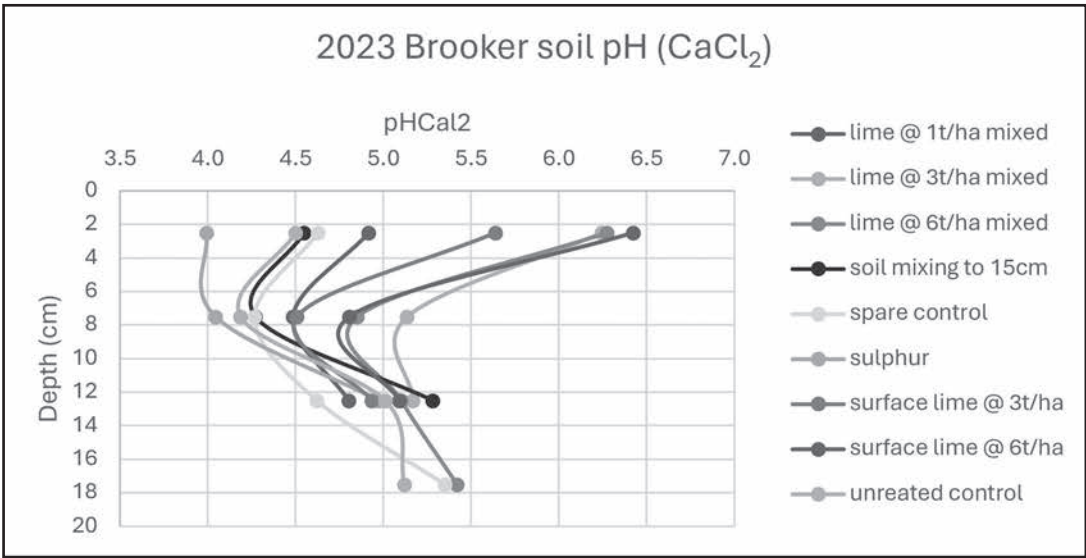


Figure 1. The soil pH down the profile (0-5, 5-10, 10-15, 15-20 cm) for the different treatments.

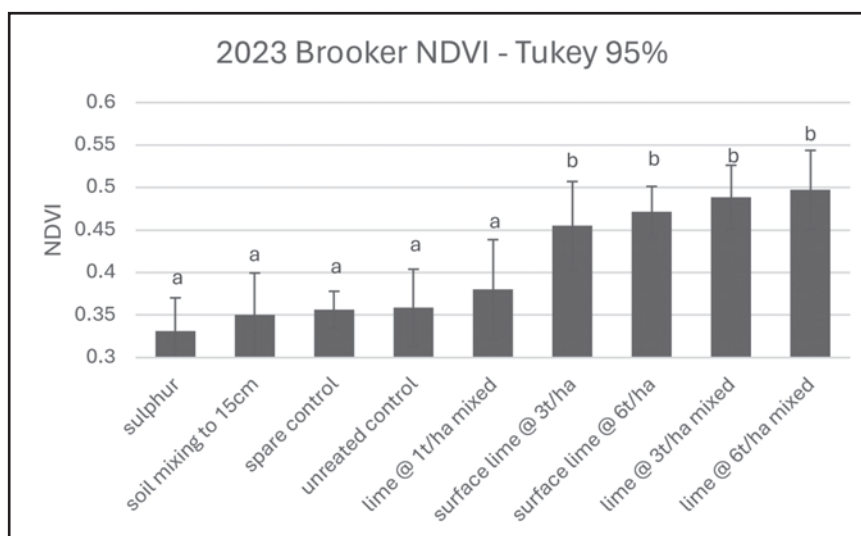


Figure 2. The dry matter (calculated from calibrated NVDI measurement) of the different treatments.

Table 3. Plant tissue test (YEB) results 2023.

	Lime @ 3 t/ha mixed	Lime @ 6 t/ha mixed	Sulphur	Surface lime @ 6 t/ha	Unreated control	Faba bean adequate values	Deficient levels/ below normal
Nitrogen	5.57	5.75	2.77	5.47	3.83	4.3-5	<1.6-3.6
Sulphur	0.27	0.28	0.54	0.26	0.21		
Manganese	54.50	42.75	552.50	54.50	165.25	50-300	
Phosphorus	0.39	0.40	0.27	0.37	0.32	0.3-0.55	<0.16-0.24
Calcium	0.69	0.72	0.75	0.75	0.60	0.6-1.2	
Magnesium	0.20	0.20	0.29	0.20	0.26	0.24-0.5	
Aluminium	31.00	57.25	165.00	82.50	72.00		
Copper	8.78	8.90	11.00	8.43	10.78	5-25	
Boron	16.00	16.00	19.75	16.00	19.25		
Iron	99.25	125.00	100.75	124.75	94.75		
Molybdenum	0.27	0.38	0.03	0.24	0.05	0.4-5.5	<0.19
Zinc	27.25	25.50	78.00	26.75	60.50	28-140	
Potassium	1.94	1.85	2.15	1.91	2.29	2.2-4	
pH (CaCl ₂)	6.05	6.21	3.96	5.91	4.59		

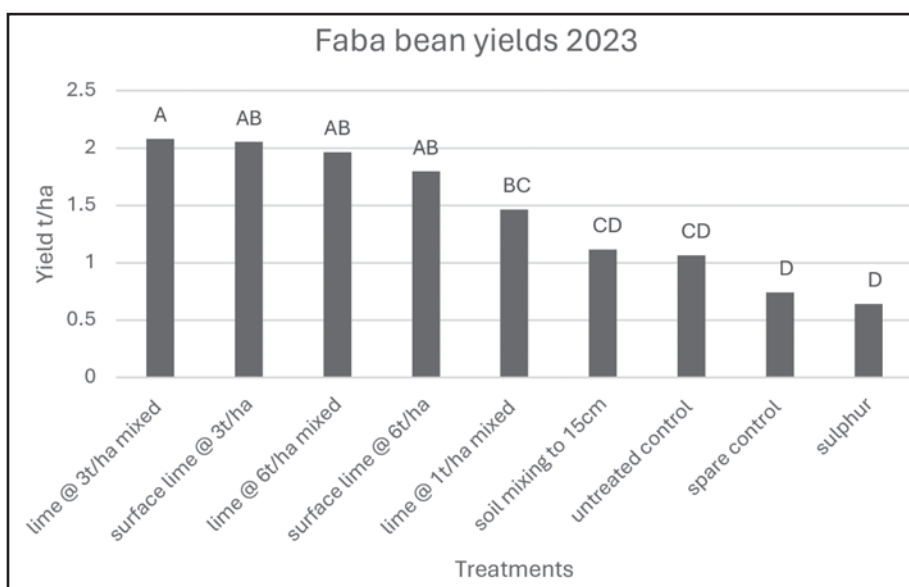


Figure 3. Faba bean yields 2023.

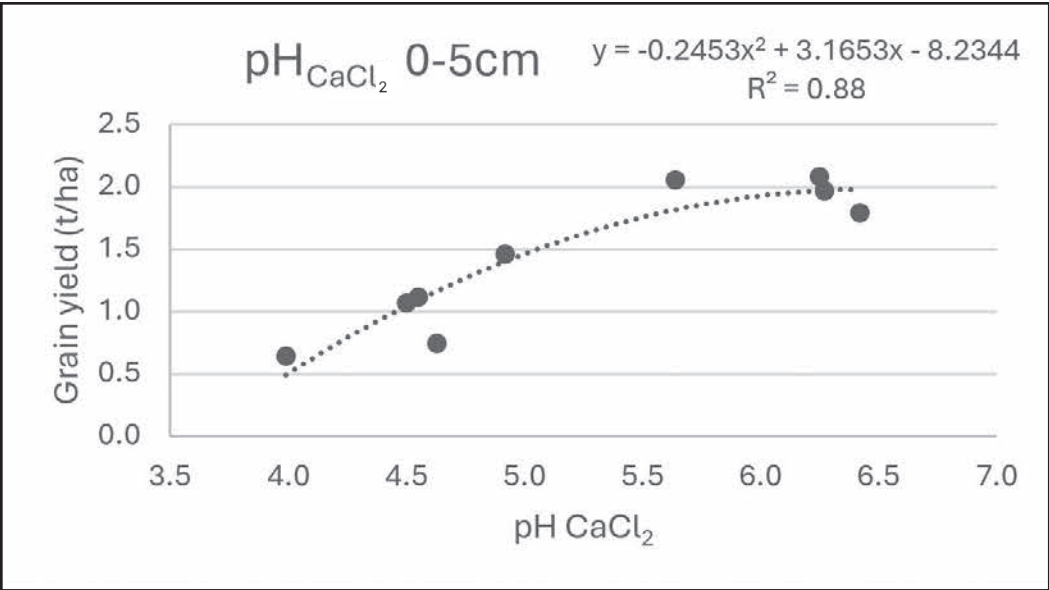


Figure 4. Relationship between yield and topsoil (0-5 cm) pH (CaCl₂) in Faba bean in 2023.

What does this mean?

This trial has highlighted that it takes time for lime to have an effect, and that more sensitive plants such as beans and barley are more responsive to liming treatments. In this situation the application of 3 t/ha lime mixed to 15 cm (costing approximately \$200/ha) has provided a return of around \$1000/ha so far with more years to come. This is based on a yield increase of 1 t/ha for both beans and barley using ball-park prices of \$600/t for beans and \$400/t for barley.

Using grain yield data from the sulphur-treated plots, and three rates of liming, a regression was created to compare yield with pH at this site (Figure 4). In Figure 4 yield is compared with pH_{Ca} of the 0-5 cm layer.

The development of such relationships provides an easy way of assessing yield loss by soil pH value.

It would be of interest to see the trial continued with a more tolerant crop possibly canola as planned by the landholder in 2024.

Acknowledgements

The research reported here is made possible by the significant contributions of the growers (Neil and Leah, and Casey and Kathryn Carr) through both trial co-operation

and the support of the GRDC (DAW00252). We'd like to thank them for their continued support. Thanks also goes to the SARDI Port Lincoln Agronomy team for undertaking sowing, spraying, and harvesting operations at the site. Brett Masters EPag Research and Bonnie Armour (formerly SARDI) are also acknowledged for their earlier work on this site.

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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.
GRDC PROJECT: DAS1905-011RTX, UOA1905-015RTX



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Deep ripping sandy soils on Eyre Peninsula

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Location

Streaky Bay, Mt Damper, Minnipa, Kyancutta, Kielpa, Arno Bay
Dion and Tiffany Williams, Nigel and Lauren Oswald, Wes and Jacqui Daniell, Brett O'Brien, Mark Dolling

Rainfall

Av GSR/2023 GSR mm
Streaky Bay: 352/244
Mt Damper: 290/216
Minnipa: 280/169
Kyancutta: 249/134
Kielpa: 320/210

Plot size

Streaky Bay: 30 m x 4 m x 3 reps
Mt Damper: 30 m x 10 m x 3 reps
Minnipa: 12 m x 100 m
Kyancutta: 15 m x 100 m 2 reps x 2 soil types
Kielpa: 15 m x 100 m (unreplicated)

Yield limiting factors

Dry spring conditions limiting grain yield.
Hostile subsoil layers - carbonates and boron.
Layers of high soil strength on unripped plots.

and less available soil moisture particularly later in the season.

Why do the trial?

Sandy soils make up a significant portion of the agricultural lands on the Eyre Peninsula (EP), comprising approximately 20% of deep siliceous sands or sand over clays, and an additional 30% as calcareous sands or loamy sands. Many of these soils pose multiple constraints, often leading to substantial differences between water limiting potential for water availability and actual observed crop yields. Recent trials conducted under the GRDC sands research and impacts programs on the Eyre Peninsula have shown promising results on some of the sandy soil types seen on EP. It has been demonstrated that strategic deep tillage and the application of soil amendments can effectively address production constraints on sandy soils. However, the efficacy of these methods varies depending on the specific constraints of a soil, specific crops grown in the following years and seasonal conditions. For further insights into past trial outcomes, please refer to articles in the 2019, 2020, 2021 and 2022 EP Farming Systems Summaries (EPFS Summary 2019, p. 99; EPFS Summary 2020, p. 84; EPFS Summary 2021, p. 39, and EPFS Summary 2022, p. 52) regarding the treatment of production constraints on the sandy soils of the Eyre Peninsula. While there are examples of successful deep tillage operations and positive amended additions, continued monitoring into the effects of deep tillage is needed to have information on the legacy or length of effects, both negative and positive.

How was it done?

In previous projects in collaboration with AIR EP, landholders, Davenport Soil Consulting and SARDI researchers, four demonstration sites were implemented:

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

Treatments were designed to address soil constraints such as soil compaction, non-wetting and low fertility, 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 and 2023. In 2023, 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. The Streaky Bay site was self-regenerating medic pasture in 2023.

Key messages

- **Soil variation can impact on effectiveness of deep ripping and other amelioration of sandy soils.**
- **Always soil test before undertaking soil amelioration as other soil constraints like low nutrition, soil acidity or soil toxicities may be present.**
- **Be careful assuming a good legacy of soil amelioration treatments as the effect often is not detected.**
- **Treatment effects impacted on crop development in a drier season like 2023, resulting in quicker crop growth earlier**

Table 1. Summary of trial sites monitored in 2023.

Year established	Site ID/ Location	Demo type	Soil type	Establishment year and project	Key soil constraints	Crop and In season measurements	Treatments
2019	Oswald Mt Damper	Replicated large plot - 30 x 18 m	Siliceous sand over clay	2019 GRDC Sands Impacts project 2022/23 FDF Sandy Soils project	Water repellence, physical, nutrients	2023 - Wheat 2022 - Field Peas Baseline soils (previous years), plant emergence, dry matter, NDVI, grain yield, post-harvest penetrometer resistance, residual soil water	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
2022	Williams Streaky Bay	Replicated smaller plot - 30 x 4 m	Highly calcareous loamy sand	2022 EPLB RAP/ Soils for Life 'Paddock labs' 2022/23 FDF Sandy Soils project	Physical, nutrients	2023 - Self regenerating medic pasture 2022 - Barley Baseline soil (2022), plant emergence, NVDI, dry matter production.	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)+ Phos-acid (40 L/ha) Companion planting - basal (25 kg/ha DAP) + vetch +/- Deep tillage - deep ripping with inclusion plates (IP)
2022	Daniell Minnipa	Un-replicated large plot 15 m x 100 m	Siliceous sand over clay	2022/23 FDF Sandy Soils project	Water repellence, physical, nutrients	2023 - self regenerating medic pasture 2022 - Oats Baseline soils, (2022) plant counts, NDVI, dry matter, penetrometer resistance, residual soil water	Control - unmodified Ripped - deep ripping
2023	Dolling, Kielpa	Un-replicated large plot 15 m x 100 m	Acidic sand over clay	2022/23 FDF Sandy Soils project		2023 - Wheat Soil pH, plant emergence, dry matter, NDVI, tiller counts, post-harvest penetrometer resistance	3 Tyne Delver Controls Agroplow + Inclusion plate Grizzly Ripper Spader Grizzly + Spade Bednar
2023	O'Brien Kyancutta	Replicated (twice) large plot 15 m x 100 m	Siliceous sand over clay and Calcareous sand over clay	2022/23 FDF Sandy Soils project		2023 - Wheat Plant emergence, dry matter, NDVI, tiller counts, post-harvest penetrometer resistance	Lienert delver + spader Plozza plough (to 200 mm) Control Spader Scrub rip

Note: The site at Arno Bay from 2022 was not able to be monitored in 2023 due to treatment markers being removed, as well as being sown to a tillage radish and vetch cover crop. However, it was observed that the non-ripped treatments had lower plant establishment than the observed areas that had been ripped.

In 2023, four sites were monitored where previous ripping and associated treatments were implemented (Table 1), and two new machinery comparisons were conducted at Kielpa and Kyancutta, in collaboration with local farmers and contractors in order to compare deep soil modification operations. The Kielpa site had a soil acidity issue which was detected after the initial soil testing (Table 2) and the site had 2 t/ha of lime spread prior to ripping.

What happened?
Mount Damper - 2019 applied deep ripping and amendments

The 2023 mean yields for the treatments from the Mount Damper site are shown in Figure 1, and Figure 2 shows the NDVI for the different treatments. The NDVI is an indication of the greenness of the shoot biomass and often correlates with crop growth reflecting the speed of maturity across different treatments. The general site analysis of the treatments showed only the dune location (top of sand dune -

central) was statistically significant if analysing all the data together (data not provided).

2023 was characterized by a particularly dry spring, which impacted on overall yields and advantaged earlier maturing crops. The deep ripping with inclusion plates and nutrition yielded closest or above the control in all positions on the dune, while most other treatments yielded lower than the control. The data broken down into dune position is shown in Figure 1 and Figure 2.

Table 2. Soil acidity pH (1:5 CaCl₂) at Kielpa, 24 March 2023.

Depth (cm)	Soil type	
	Red sand (east)	White sand (west)
0-5	5.2	5.0
5-10	4.6	4.7
10-15	4.4	4.4
15-20	6.6	4.6

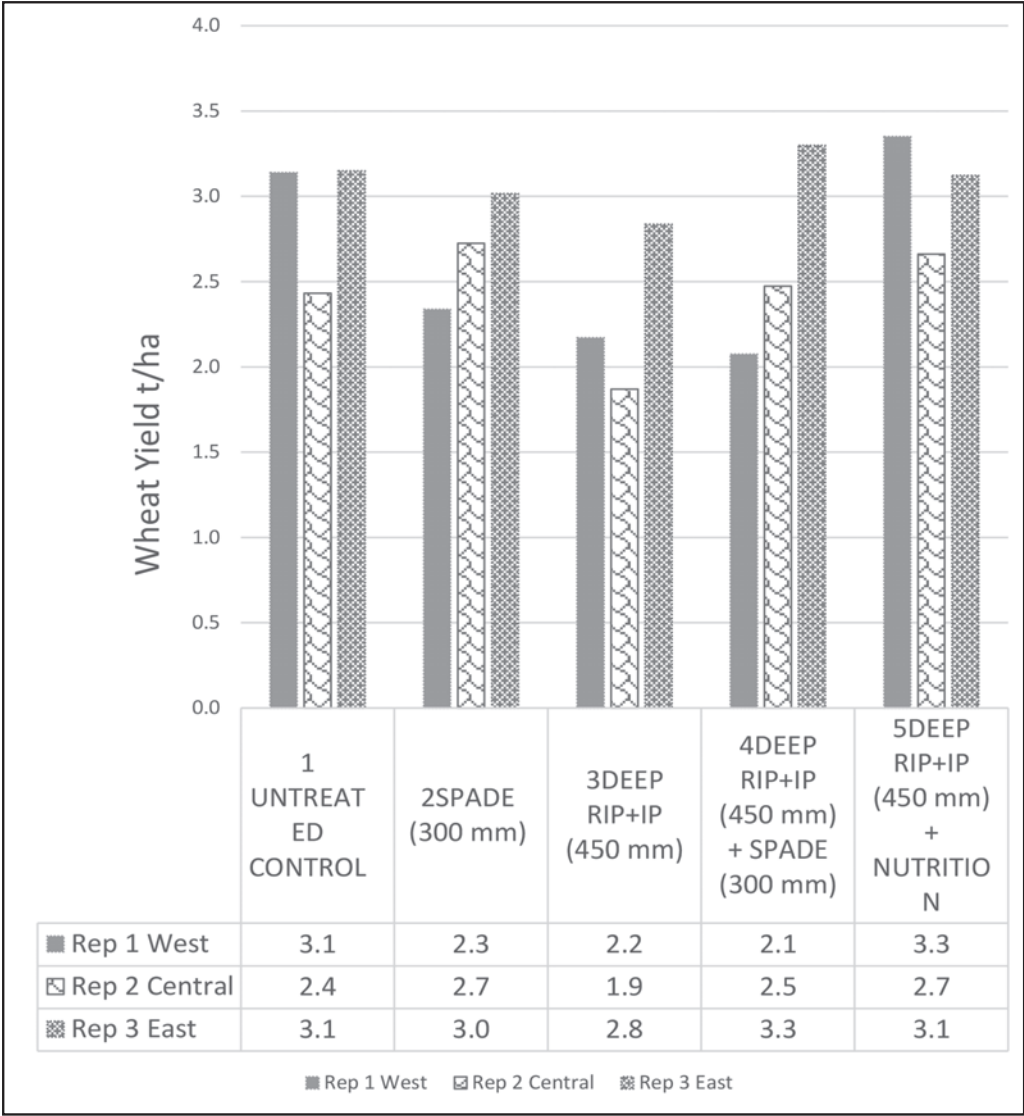


Figure 1. Mean wheat yield (t/ha) at three locations across a sand dune at Mt Damper (Oswald), 2023.

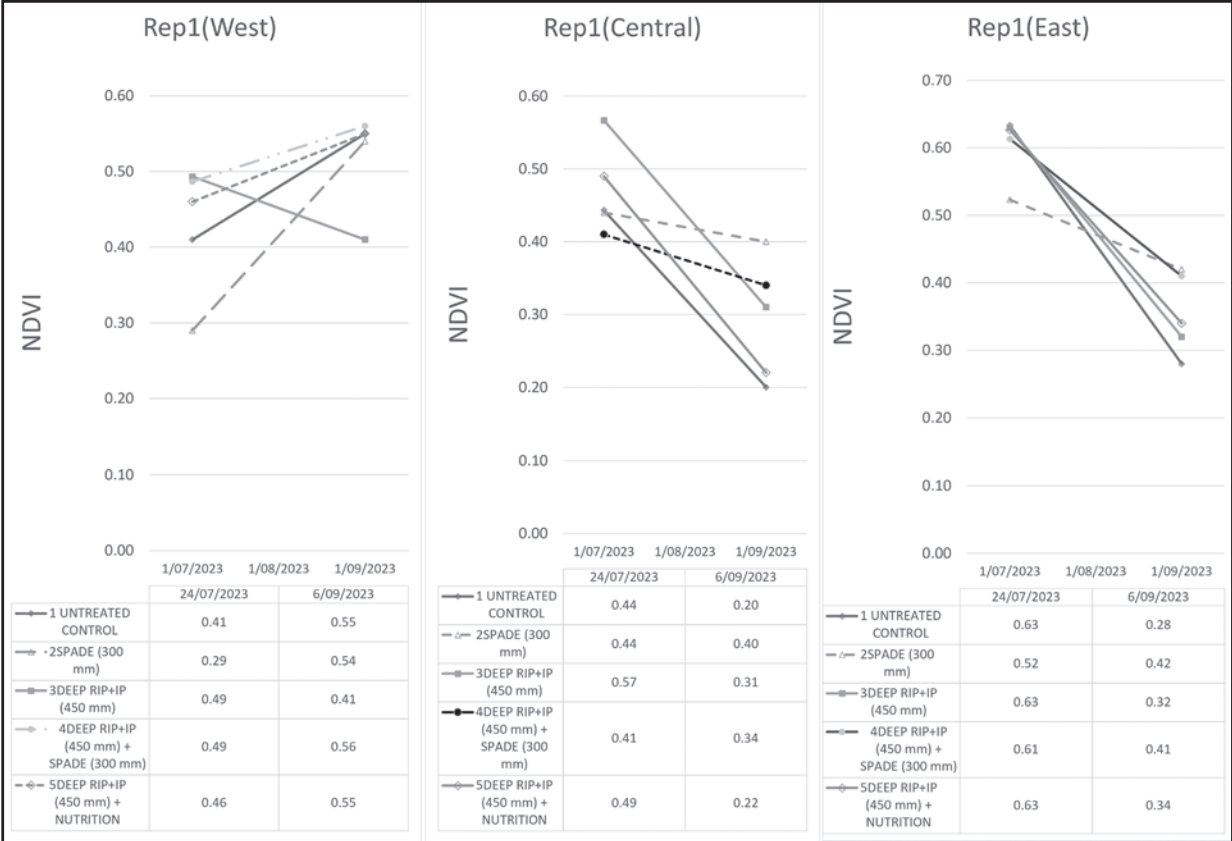


Figure 2. NDVI trends for the 3 different locations at Oswald's in 2023 showing different trends in maturity in a dry spring.

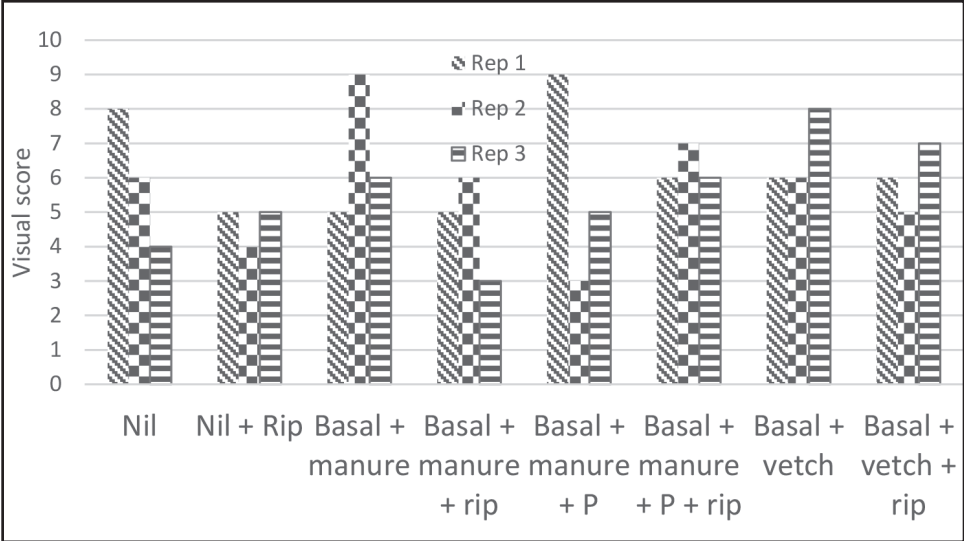


Figure 3. Medic growth visual scores at Streaky Bay, 15 September 2023.

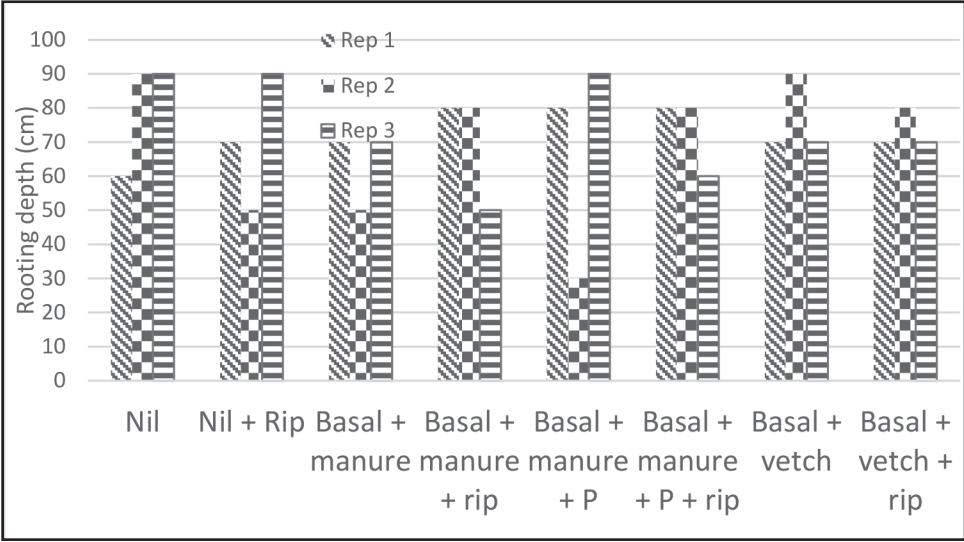


Figure 4. Medic rooting depth at Streaky Bay, 27 November 2023.

Streaky Bay - 2022 applied deep ripping and amendments

In 2023 this site was a self-regenerating medic pasture and there were no measurable residual effects from the deep ripping or nutritional treatments applied in 2022 (Figure 3 and Figure 4).

Minnipa - 2022 applied deep ripping

In 2023 this site was a self-regenerating medic pasture on a ripped siliceous sand. Similar to Streaky Bay, there were no residual effects in medic from the deep ripping treatments despite significant differences in oat biomass and yield in 2022 (Table 3). The penetrometer resistance taken in December 2023 after significant rainfall showed no differences in soil strength between the treatment areas (Figure 5).

Kielpa - 2023 applied ripping machinery comparison

The biomass responses for the ripping comparison at Kielpa

are shown in Figure 6, and the penetrometer resistance reading post December 2023 rainfall are shown in Figure 7. The biomass responses show the grizzly ripper had the most improvement on biomass, with most other treatments being similar to the control plots. Control 1 has a noticeable compaction layer compared to the other treatments (Figure 7).

Kyancutta - 2023 applied machinery comparison

The Kyancutta site had a similar aim to the Kielpa site with different deep ripping machines compared on two different soil types. For the siliceous sand ripping comparison, the spader and scrub ripper yields were very similar to the control. However, the delver type (finished with a spader) delivered 0.25 t/ha and the Plozza Plough around 0.5 t/ha of grain yield improvement over the control (Figure 9). This contrasts with the calcareous soil type, which had a lower overall yield, and in which all

plots were lower than the silicious sand control. The deep ripping treatment in the calcareous soil showed an improvement with the delver with spader having 0.5 t/ha higher grain yield and little differences in other treatments.

In comparing the post December 2023 rainfall penetrometer resistance in the calcareous sand (Figure 9) the Plozza plough was not able to remove the compaction between 200-300 mm, which the spader, and to a lesser extent the scrub rip was able to. This was reflected in the yield trend with the delver-spader combination being the highest, followed by the spader, then the scrub rip and control (Figure 8). This then highlights the potential of compaction in the 200-300mm zone restricting water extraction and root activity, and the possibility of mechanical removal of this layer in the future.

This contrasts with the lack of response in the penetrometer resistance to intervention for the siliceous sand soil type (Figure 10).

Table 3. Medic performance at Minnipa in 2023.

Treatment	Plant establishment (plants/m²)	NDVI (19 Sept)	Dry matter (19 Sept) (t/ha)
Ripped	38	23	1.17
Unripped	35	23	0.96

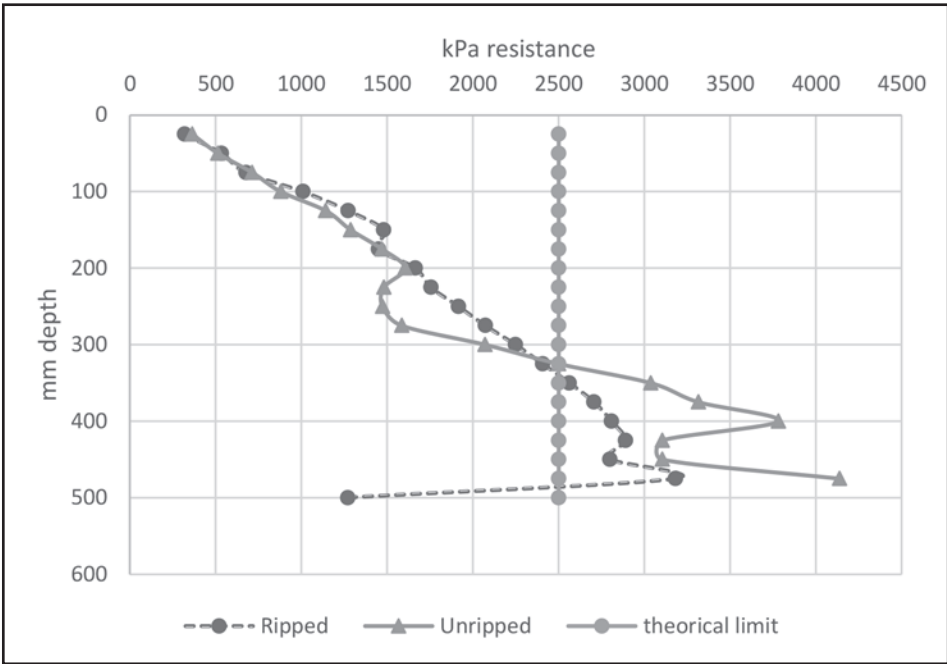


Figure 5. Penetrometer resistance (kPa) at Minnipa, December 2023 (median of four depth probes).

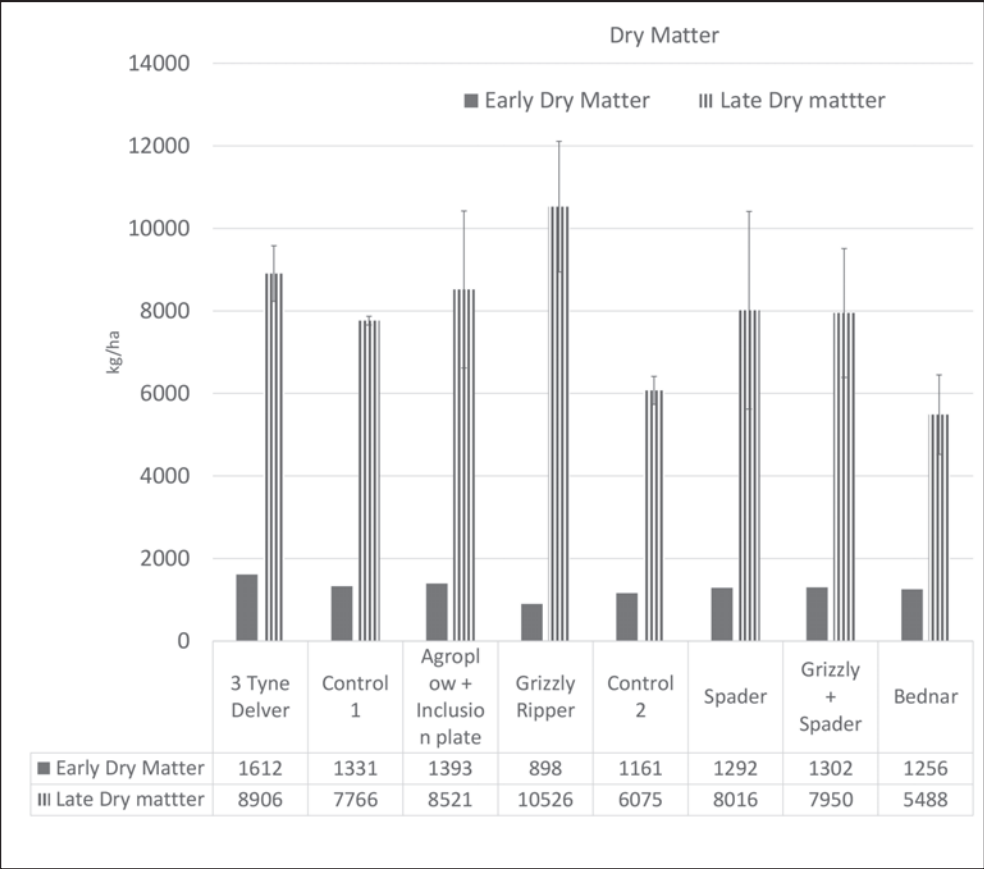


Figure 6. Mean wheat dry matter production (kg/ha) in red sand (east) for the different treatments at Kielpa, 2023 (early dry matter taken 27 July 2023 and late dry matter taken 9 October 2023). Error bars on Late Dry Matter are standard deviation from the treatment means. The order of the graph reflects the layout of the trial (North to South).

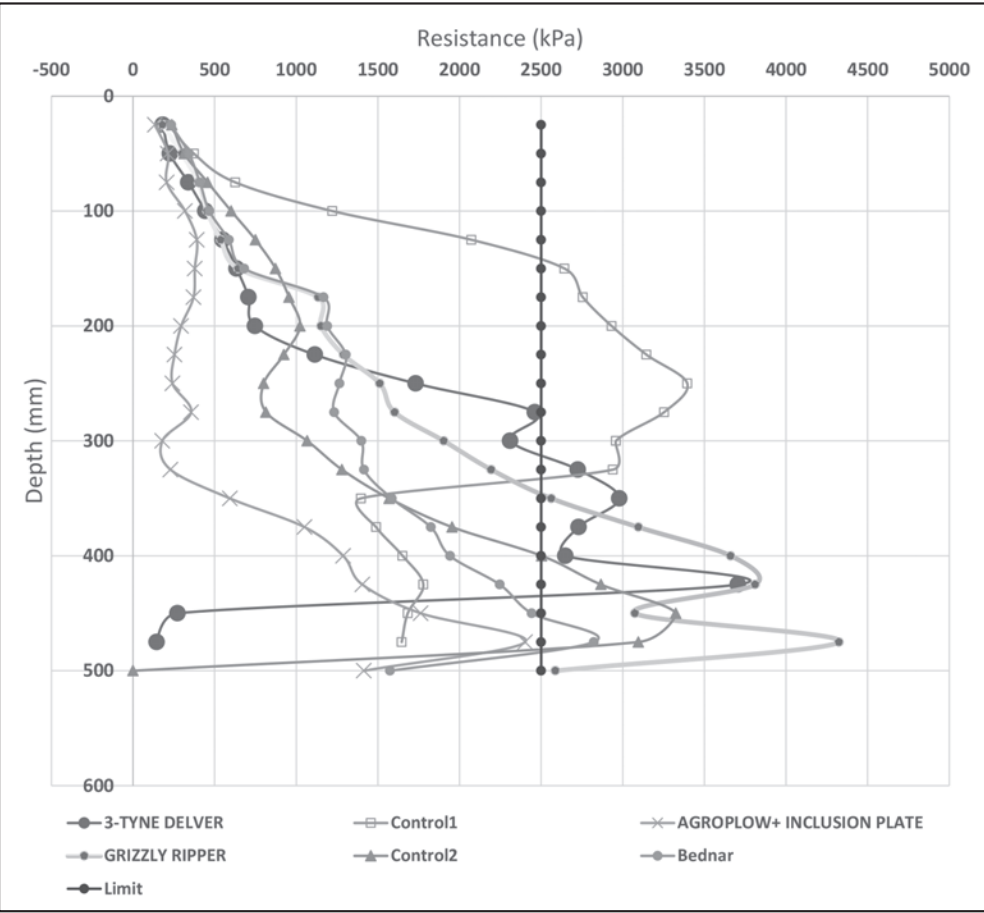


Figure 7. Penetrometer resistance (kPa) at depth for some of the treatments compared the theoretical soil strength limit of 2,500 kPa, 11 December 2023.

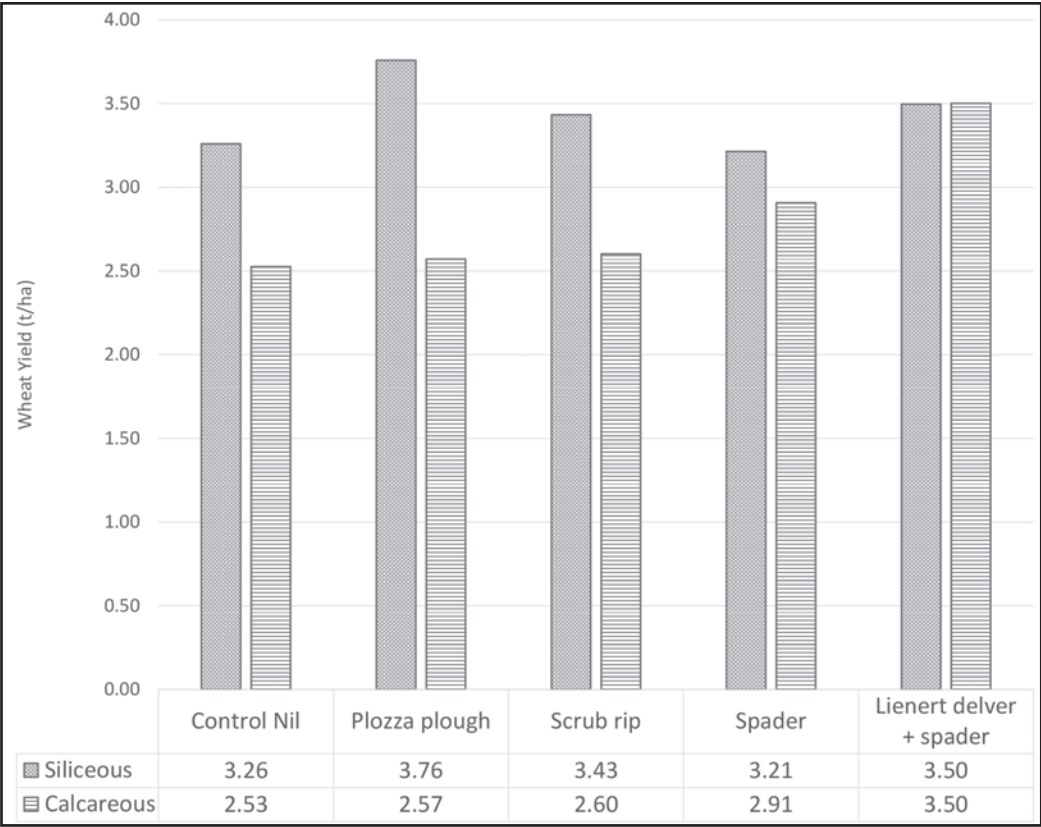


Figure 8. The wheat yield (t/ha) of the different treatments for the two different soil types at Kyancutta in 2023.

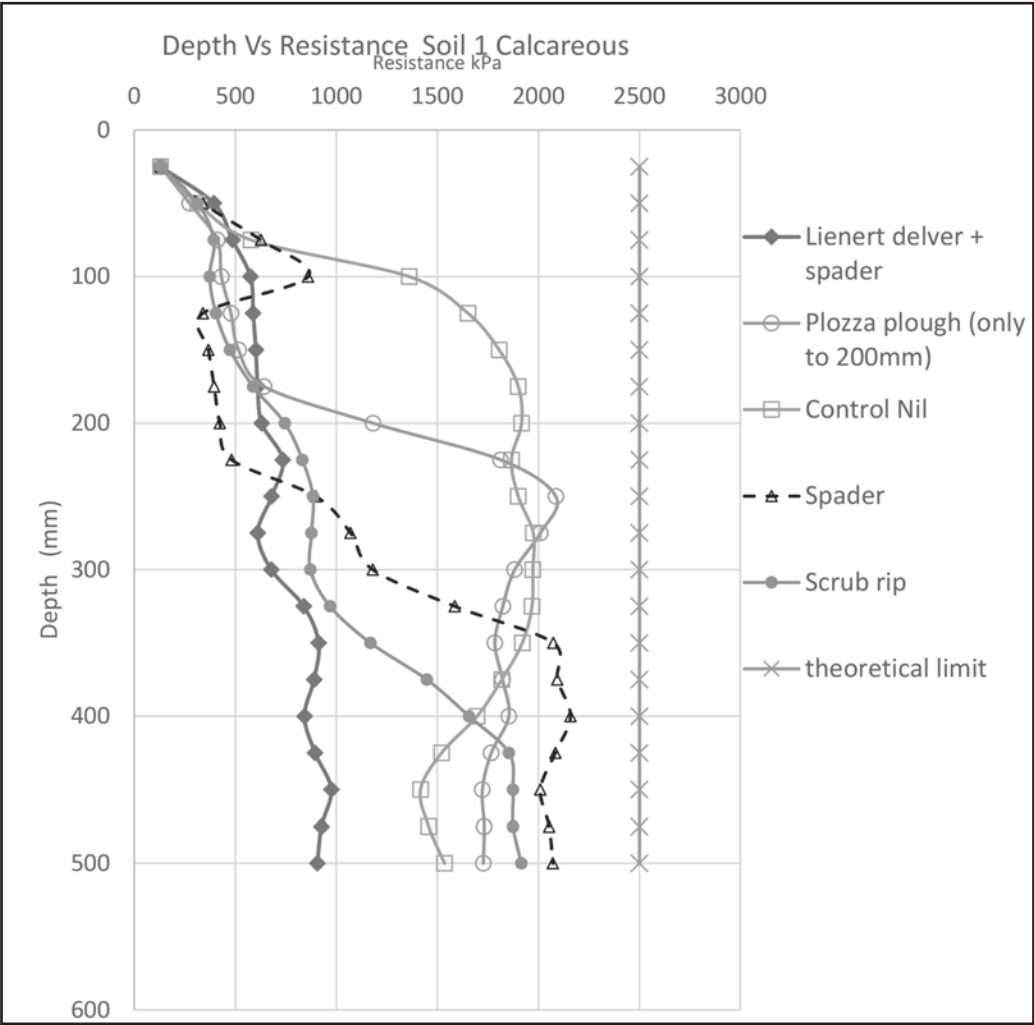


Figure 9. Penetrometer resistance (kPa) in the calcareous soil at Kyancutta in December 2023.

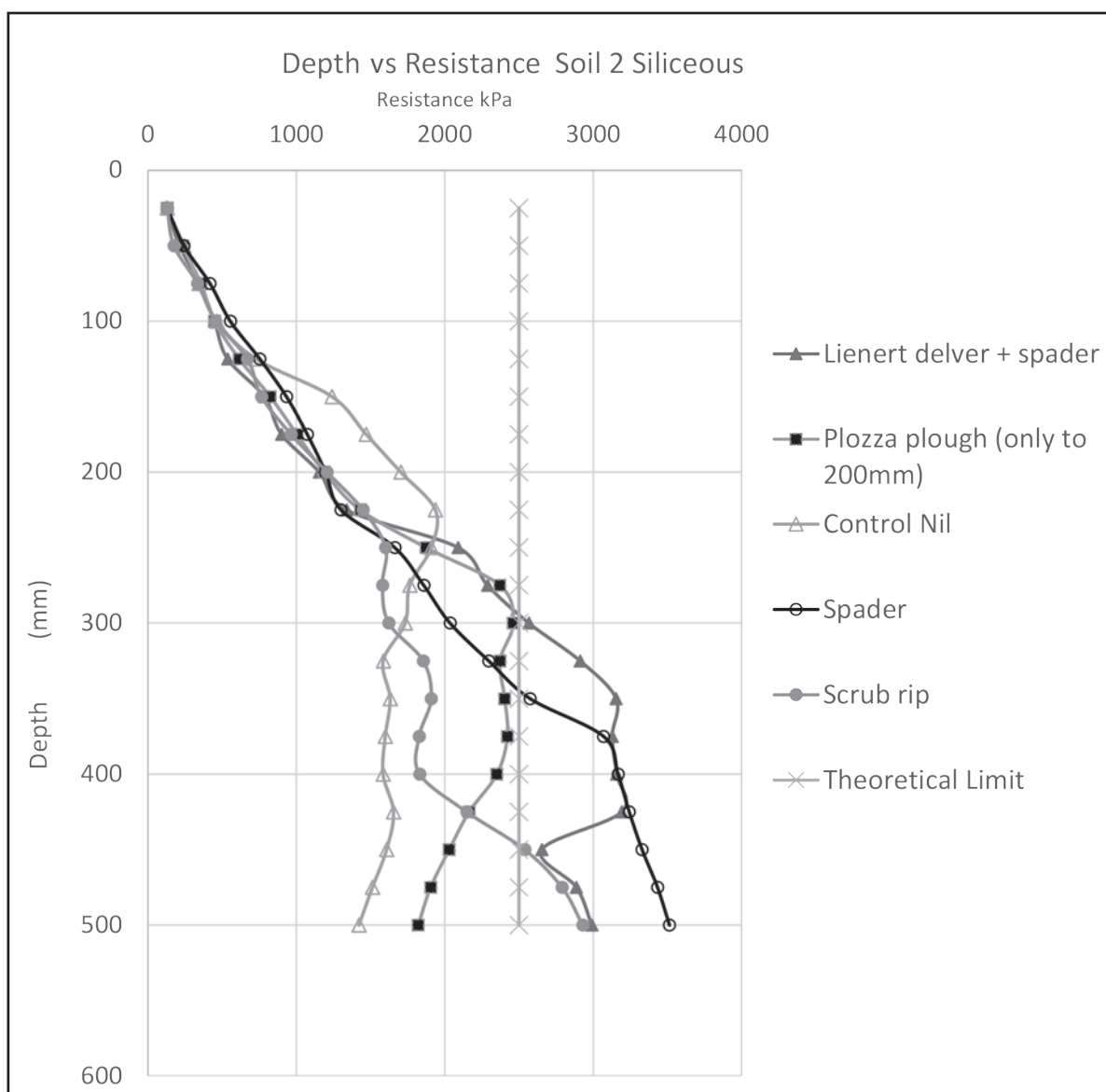


Figure 10. Penetrometer resistance (kPa) in the siliceous sand at Kyancutta in December 2023.

What does this mean?

At the Mt Dampier (Oswald) site, the most significant difference was the influence of the dune position. In 2023 in drier spring conditions a number of the treatments performed worse than the control for wheat grain yield. This may be partly due to the season with a dry spring limiting grain filling due to higher early biomass and earlier crop maturity. Most treatment means were lower than the control, except the ripping with inclusion plate with additional nutrition. It has been speculated that due to higher yields in previous seasons, that some of the treatments are being limited by lower fertility. Any treatments which had delayed crop senescence and grain filling would have been disadvantaged in

a very dry spring that occurred in 2023. This may indicate the need for additional nutrient applications following amelioration, to properly account for additional nutrient removal due to previous higher biomass and grain yields.

The Minnipa (Daniell) site had an improvement in oat production in 2022 with harvest biomass improving by 6.9 t/ha and grain yield improving by 0.6 t/ha following the ripping of a siliceous sand over clay. However in 2023 there were no differences in medic dry matter production. Similar to the Streaky Bay site, the medic pasture didn't seem particularly adapted to take advantage of any improved conditions following the ripping in the 2022 season. There

were no differences between the ripped and control treatments with the soil penetrometer readings (Figure 5) and no differences in the medic root depth measurements by the end of 2023. This doesn't negate possible differences in subsequent seasons. However, there appears to have been significant reconsolidation since the initial intervention.

Penetrometer readings have been generally taken across the plots, and not just confined to the rip line. If penetrometer techniques were implemented to capture data from both on rip lines and the non-rip lines, it might be possible to pick up more legacy effects, whereas the current method just captured data in random locations in the plots.

Similarly, while medic is adapted to the calcareous sand at Streaky Bay, there were no measurable agronomic responses of the residual ripping and nutrient response treatments.

At Kielpa (Dolling's) the results of the deep ripping machinery comparisons were mixed, with differences in soil penetrometer data in the two control strips demonstrating some of the variability across the site, and these differences were also reflected in the biomass differences seen in the two controls as well (Figure 6). The two treatments with spading performed very similarly (Spading and Grizzly + Spading), and had higher biomass means than the adjacent control 2, though interestingly the Grizzly alone had the highest dry matter production. Only the Bednar was lower than either of the control plots in the later biomass cuts (Figure 6). Generally, there was poor correlation between biomass production and the differences seen in penetrometer readings.

The site needs to be resampled in autumn 2024 to investigate the impact of the lime spread, though the control also was spread at 2 t/ha. However, liming doesn't typically affect crop production in the year of application, but the movement of soil through

the different soil amelioration treatments would affect pH.

At Kyancutta (O'Brien's), the plozza plough increased yield by 0.5 t/ha in the silicious sand ripping comparison. The other interventions were all similar to the control. In the calcareous soil, despite having a lower overall yield potential, showed an improvement with the delver with spader of 0.5 t/ha grain yield. The Plozza plough was not able to remove the compaction between 200-300 mm which potentially restricts water extraction and root activity due to compaction.

When considering ongoing soil amelioration, it is important to consider the impact of nutrition if you are producing more biomass and removing higher crop yields. This may interact with phenology which can delay crop growth stage which may be detrimental in a dry finish. Soil variation had a big impact in the effectiveness of soil amelioration. This is seen at Mt Damper across the sand dune, at Kielpa with variation in soil penetrometer controls, and at Kyancutta with different responses from adjacent but different soil types. Soil constraints other than compaction such as acidity and low water holding capacity can impact yield responses. The ability to predict a crop response to a particular soil amendment remains

challenging with an interplay between soil water holding capacity, soil compaction, crop establishment and soil nutrition considerations, and as well as more specific site issues such as water repellence or acidity.

Acknowledgements

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Increasing production on sandy soils - narrowing down what to do and where

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Key messages

- All sandy sites were responsive to both physical interventions and chicken litter (CL) addition. The size of the response varied for each site ranging from up to 127% on the most productive sand (North hill top) up to 191% on the least productive sand (South mid slope).
- The grain yield response to physical incorporation method (deep ripping and spading) and CL was generally greater than 10%, but the ranking of specific treatments varied within each of the three sandy soil trial sites.

- In the absence of CL, there was no benefit from using long versus short inclusion plates in year one. However, in year two both the North sites had improved grain yield from the use of long inclusion plates suggesting greater longevity from the inclusion of more top soil.
- In the first season, spading resulted in a soft soil surface and made seed placement difficult. Consequently, the wheat crop struggled to emerge and impacted crop performance. However, in the second season the soil had consolidated and no issues with seed placement or crop establishment occurred.
- Results from the depth of ripping trials have shown responses to ripping 40-60 cm deep in all six site years. No yield responses were measured from a ripping depth of 20 cm.

Why do the trial?

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

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

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

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

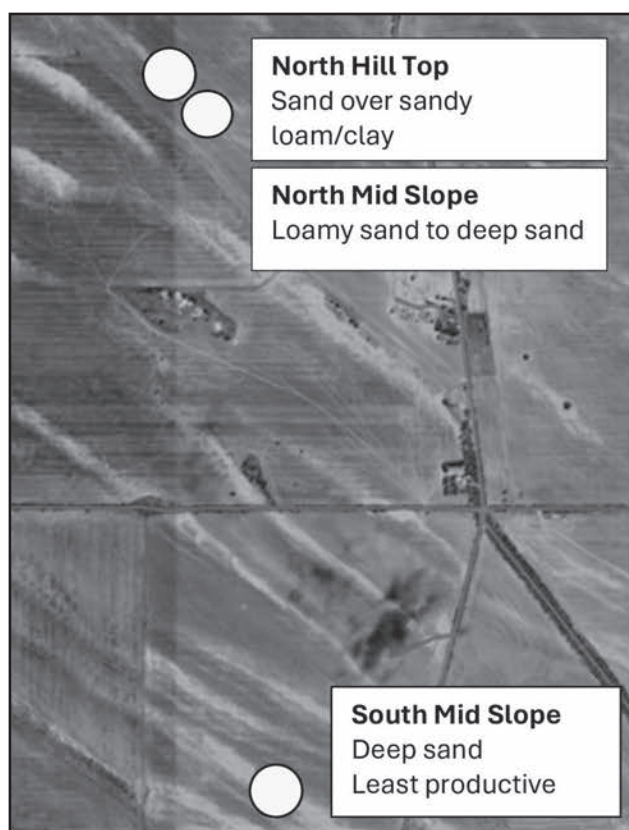


Figure 1. Image showing the three trial locations (white dots) for the sandy soil amelioration sites established at Bute, SA in 2022. (EPFS Summary 2020, p. 108).

How was it done?

Site Selection

Three sandy soil amelioration trial sites were identified at Bute, SA (Figure 1) in 2022. The two sites located in the North paddock (Figure 1) were a duplex sand over loamy sand (North hill top) and a loamy sand transition to a deep sand (North mid slope). Site three was in the South paddock (Figure 1) and the soil was a deep sand (Table 1). Historic crop performance indicated the South paddock was poorer performing compared to the north.

The two deep sands were more acidic at depth (10-20 cm and 20-30 cm) compared to the North hill top site (Table 1). The South mid-slope soil had a lower PBI and CEC compared to the north sites (Table 2). Organic carbon was generally low across all three sites. Soil phosphorus levels were

in the marginal (20-30 mg/kg) to adequate (30-45 mg/kg) ranges across the three sites (Hughes 2020). Sulphur levels were low (<5 mg/kg) at the South mid slope site and become low to marginal (5-10 mg/kg) at the North sites.

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

Trial design and treatments

At each of the three locations (Figure 1) two trials were established to assess depth

of deep ripping (Table 3), soil amelioration practice and chicken litter (CL) addition (Table 4). The whole trial site was spread with 5 t/ha lime (district practice) on 9 May 2022 to address surface and subsurface acidity.

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

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

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

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

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

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

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

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

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



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

Table 5. Summary of seeding details and crop measurements in sandy soil amelioration sites at Bute, SA 2022 – 2023.

Year	Rainfall	Crop, seeding date and fertiliser	Crop assessments
2022	Annual: 451 mm GSR: 314 mm	Razor CL Plus at 110 kg/ha 31 May 2022 MAP Zn at 80 kg/ha + urea at 65 kg/ha Urea in-season 190 kg/ha at the North sites 200 kg/ha at the South site	Greenseeker NDVI Grain yield Grain quality
2023	Annual: 362 mm GSR: 225 mm	Commodus CL barley at 75 kg/ha MAP at 90 kg/ha + urea at 80 kg/ha Urea in-season 100 kg/ha at all sites	Greenseeker NDVI Grain yield Grain quality

Crop assessments

Over the past two seasons the trial has followed a wheat and barley rotation. Various in season assessments have occurred and are summarised below (Table 5) for each trial year. The long-term Bute annual rainfall is 391 mm and growing season rainfall 290 mm.

The results were analysed using Tukey's range test which compares all possible pairs of means and identifies any difference between two means that is greater than the expected standard error.

What happened?

North hill top (most productive sandy site)

By late August crop biomass measured as NDVI ranged from 0.653 – 0.799 (Table 6). Treatments with higher levels of disturbance such as long inclusion, deep

placement and spading resulted in higher biomass. Seed placement was an issue following spading in year one (Tregrove *et al.* 2022). However, this was not observed in year two, with high crop emergence across all three sandy trial sites. Similar to the first season, CL applied to the surface with no incorporation was not beneficial early in the season and produced similar NDVI to the nil.

Barley grain yields ranged from 4.28 t/ha to 5.27 t/ha (Table 6). Yields were closely correlated to NDVI. The highest disturbance treatments (spading, long inclusion and deep place) producing the highest grain yields. Higher grain yields were observed from the use of long inclusion plates (5.20 t/ha) compared to short inclusion plates (4.58 t/ha). This also suggests that long inclusion plate ripping

may provide a useful alternative to spading with reduced erosion risk and a more seeder-ready finish.

Grain quality results showed high retention values (81.2%–94.0%) and low screenings (all samples <5.2%) across the trial. Commodus CL barley is currently undergoing malt accreditation. Applying the malt 1 receival standards to the current results showed test weight, screening and retention for all samples met this standard (Table 6). The only grain quality parameter to effect receival grade was protein. Generally, treatments where CL was not applied fell below or near 9% (range 8.9–9.4%). Spading was the only method to increase protein compared to the nil without CL applied. At the other end of the protein range, spading with CL was higher than 12%.

Table 6. Greenseeker NDVI, grain yield (t/ha), grain yield % of untreated control and grain quality for physical incorporation and CL trial North hill top sandy soil amelioration site, 2023.

Physical incorporation method	Chicken litter (t/ha)	NDVI 16 Aug	Grain yield (t/ha)	Grain yield % of nil	Protein (%)	Test weight (kg/hL)
Nil	nil	0.653 c	4.28 c	100	9.4 cd	70.5 a
Nil	10	0.713 bc	4.58 c	107	10.0 bcd	69.3 a
Deep rip - no inclusion	nil	0.707 bc	4.73 bc	111	8.9 d	70.1 a
Deep rip - short inclusion	nil	0.714 bc	4.58 c	107	9.0 cd	70.2 a
Deep rip - long inclusion	nil	0.761 ab	5.20 ab	121	9.3 cd	69.9 a
Deep rip - long inclusion	10	0.786 ab	5.19 ab	121	10.1 bcd	69.8 a
Deep rip & place	10	0.779 a	5.26 a	123	10.2 bc	70.1 a
Spade	nil	0.767 ab	5.16 ab	121	11.4 ab	68.8 a
Spade	10	0.799 a	5.27a	123	12.8 a	68.9 a
<i>Pr(>F)</i>	<0.001	<0.001		<0.001	0.228	

Table 7. Greenseeker NDVI, grain yield and grain quality for depth of ripping trial North hill top, 2022 and 2023.

Depth of ripping (cm)	Grain yield (t/ha)	Grain yield % of nil	Grain yield (t/ha)	Grain yield % of nil
	2022		2023	
0	4.95 b	100	4.22 b	100
20	4.97 b	100	4.21 b	100
40	5.36 a	108	4.56 a	112
60	5.32 a	107	4.68 a	121
<i>Pr(>F)</i>	<0.001		<0.001	
<i>LSD</i>	0.29		0.14	

In the depth of ripping trial similar observations occurred to 2022. Ripping to a depth of 20 cm did not increase grain yields compared to the nil (Table 7). Ripping depths of 40 and 60 cm produced similar grain yields averaging 4.62 t/ha, 17% higher than the nil. Previous research (DPIRD 2020, McBeath *et al.* 2022) has shown grain yield response from ripping depth can be linked to a reduction in soil strength. However, the response will change depending on site and the depth at which the constraint occurs in the soil profile. The results suggest the optimal ripping depth at the North hill top site is 40 cm.

Ripping depth did not impact any of the barley grain quality parameters measured this season (data not shown). The trial average values were protein 8.9%, test

weight 69.6 kg/hL, retention 90.0% and screenings 3.4%.

North mid slope

Biomass recorded as NDVI on 16 August 2023 ranged from 0.298 - 0.49 with the nil treatment having the lowest value (Table 8). Similar to year one, surface applied CL with no physical incorporation did not increase NDVI compared to the nil. Physical incorporation without CL increased the NDVI, averaging 0.399. This suggests physical soil disturbance without the addition of any amendment improved crop growth. Deep placement of CL was the only method to increase NDVI compared to the comparative treatment with no CL.

Grain yields at this site ranged from 1.85 t/ha in the nil to 3.28 t/ha in the long inclusion with CL treatment (Table 8). Other high

yielding treatments included long inclusion without CL, and higher disturbance treatments of deep placement with CL and spading with no CL. Spading with CL was lower yielding (2.69 t/ha) compared to deep placement of CL (3.15 t/ha). This suggests the increased depth of physical disturbance from ripping compared to spading increased grain yields. Early NDVI results show the crop canopy in the spading CL treatment was not higher than other incorporation methods and it was expected water use would be similar. Crop rooting depth (likely shallower in the spading treatment compared with deep ripping) potentially lead to a reduction in grain yield. Grain quality data also indicates this treatment was water limited, with low retention (72.6%) and higher screenings (10.9%).

Table 8. Greenseeker NDVI, grain yield (t/ha), grain yield % of untreated control and grain quality for physical incorporation and CL trial North mid slope sandy soil amelioration site, 2023.

Physical incorporation method	Chicken litter (t/ha)	NDVI 16 Aug	Grain yield (t/ha)	Grain yield % of nil	Protein (%)	Test weight (kg/hL)	Retention (%)	Screenings (%)
Nil	nil	0.298 e	1.85 d	100	9.7 bc	65.4 a	74.4 cd	7.2 bc
Nil	nil	0.298 e	1.85 d	100	9.7 bc	65.4 a	74.4 cd	7.2 bc
Nil	10	0.365 de	1.93 d	104	10.5 ab	65.3 a	70.0 c	8.7 ab
Deep rip - no inclusion	nil	0.394 d	2.57 c	139	8.5 c	67.1 a	83.9 ab	5.6 cd
Deep rip - short inclusion	nil	0.405 cd	2.68 c	145	8.3 c	66.6 a	84.8 ab	4.4 cd
Deep rip - long inclusion	nil	0.416 bcd	3.08 ab	167	8.5 c	67.8 a	85.8 a	4.4 d
Deep rip - long inclusion	10	0.490 ab	3.28 a	177	9.0 bc	67.3 a	83.4 ab	5.3 cd
Deep rip & place	10	0.490 a	3.15 a	171	9.9 bc	67.6 a	84.0 ab	5.3 cd
Spade	nil	0.413 bcd	3.03 abc	164	9.7 bc	66.0 a	79.7 bc	7.0 bcd
Spade	10	0.468 abc	2.69 bc	146	11.6 a	66.0 a	72.6 d	10.9 a
<i>Pr(>F)</i>	<0.001	<0.001		<0.001	0.053	<0.001	<0.001	

Similar to the North hill top site grain quality was generally high across the incorporation methods with and without CL (Table 8). Grain protein was lower (8.3% - 8.5%) in treatments with physical incorporation and no CL (except spading). As highlighted above, spading was the only incorporation method to have higher screenings compared to the remaining methods.

In the ripping depth trial, the 20 cm depth was not sufficient to improve grain yields in year one or two of the trial (Table 9). In the first season, there was a yield benefit from ripping deeper than 40 cm. However, this season ripping depths of 40 cm and 60 cm produced similar grain yields averaging 2.9 t/ha (59% higher than the nil).

Grain quality (test weight, retention, and screenings) was improved for the 40 cm and 60 cm ripping depths compared to the nil and 20 cm (Table 9). Grain protein was the only quality parameter to be negatively impacted by ripping depth. Protein was reduced in the 40 cm and 60 cm depths (8.9%) and this result relates to yield dilution effects (higher yield = lower protein).

South mid slope site (least productive sandy site)

The NDVI assessment was recorded earlier at this site (25 July) compared to the north sites. The NDVI values ranged from 0.426 in the nil to 0.600 in the long inclusion with CL treatment (Table 10). There was little variation among the physical incorporation

methods with and without CL.

There were large grain yield responses, up to 265% at the South mid-slope site (Table 10). This is consistent with responses observed in 2022. Similar to NDVI there were no grain yield differences among the physical incorporation methods with or without CL. The South mid-slope site was the least productive of all three sands and it is not surprising physical disturbance and the addition of CL applied has increased grain yields. At this site the use of short or long inclusion plates has not provided any grain yield benefit to deep ripping in either season.

Table 9. Greenseeker NDVI, grain yield and grain quality for depth of ripping trial North mid slope, 2022 and 2023.

Depth of ripping (cm)	Grain yield (t/ha)	Grain yield % of nil	Grain yield (t/ha)	Grain yield % of nil	Protein (%)	Test weight (kg/hL)	Retention (%)	Screenings (%)
	2022		2023					
0	4.08 c	100	1.82 b	100	10.0 a	64.8 c	70.6 c	8.1 a
20	4.08 c	100	1.84 b	101	10.1 a	65.3 bc	70.8 c	8.9 a
40	4.55 b	112	2.86 a	157	8.9 b	66.7 b	81.9 b	5.4 b
60	4.92 a	121	2.93 a	161	8.9 b	68.4 a	86.4 a	4.0 b
<i>Pr(>F)</i>	<0.001		<0.001		<0.0001	<0.0001	<0.0001	0.003

Grain quality results show protein levels for CL surface applied or incorporated were similar to the nil (Table 10). However, deep ripping (no inclusion, short or long) without CL reduced grain protein compared to the nil. The spading treatments with and without CL had poorer grain quality in terms of lower test weight, lower retention and high screenings. Similar to the North mid slope site, this suggests the spading depth of 30 cm has not allowed deeper root exploration to fulfill its yield potential.

In the deep ripping trial, the second season results are similar to 2022 (Table 11). The 20 cm ripping depth did not increase grain yields. Ripping depths of 40 cm and 60 cm produced similar yields, averaging 217% of the nil. The results suggest the optimal ripping depth at the South mid slope site is 40 cm.

Grain quality (retention, and screenings) was improved for the 40 cm and 60 cm ripping depths compared to the nil and 20 cm

(Table 11). As observed at the North mid slope site, grain protein was the only quality parameter to be negatively impacted by ripping depth. Protein was reduced in the 40 cm and 60 cm depths and this result relates to yield dilution effects (higher yield = lower protein). However, the protein levels were still within the 9% - 12% range.

What does this mean?

From the topsoil and amendment inclusion trials it is evident that all three sandy soil sites responded differently to the physical and CL treatments (Figure 3). As a general overview from two seasons of results:

- the North hill top site has responded to all physical interventions, with and without CL. The highest yield responses have been observed with methods that employ a high level of disturbance. The deep ripping treatments (50 cm) have not improved grain yield compared to spading (30

cm), suggesting disturbance below 30 cm is not required to ameliorate the subsoil constraints at this site.

- at the North mid slope site, the responses were similar with the deep ripping and spading (without CL) treatments producing high grain yields. The spading with CL treatment at this site has consistently produced poor yields, compared to the other physical incorporation methods. The high yield potential in this treatment may have been limited by the spading depth of 30 cm which has not allowed deeper root exploration and therefore water use.
- at the historically least productive South mid-slope site grain yields were improved from all physical treatments (147% - 190%). Response to CL additions was generally not significant in the first or second season.

Table 10. Greenseeker NDVI, grain yield (t/ha), grain yield % of untreated control and grain quality for physical incorporation and CL trial South mid slope sandy soil amelioration site, 2023.

Physical incorporation method	Chicken litter (t/ha)	NDVI 25 July	Grain yield (t/ha)	Grain yield % of nil	Protein (%)	Test weight (kg/hL)	Retention (%)	Screenings (%)
Nil	nil	0.426 c	1.07 c	100	13.2 ab	65.2 ab	66.7 cd	11.9 bc
Nil	10	0.434 bc	1.27 bc	119	13.9 a	66.1 ab	67.5 bcd	12.1 abcd
Deep rip - no inclusion	nil	0.454 bc	2.20 ab	206	11.1 cde	68.1 a	81.0 a	5.9 d
Deep rip - short inclusion	nil	0.511 abc	2.48 ab	232	10.8 de	67.6 a	78.7 ab	7.5 cd
Deep rip - long inclusion	nil	0.543 ab	2.67 ab	250	10.8 e	67.7 a	78.8 ab	6.9 cd
Deep rip - long inclusion	10	0.600 a	2.83 a	265	12.5 abcd	65.2 ab	75.6 abc	7.6 cd
Deep rip & place	10	0.500 abc	2.67 a	250	12.5 abc	66.1 ab	72.8 abc	7.7 cd
Spade	nil	0.549 ab	2.63 a	247	12.2 bcde	62.8 b	56.6 d	19.3 a
Spade	10	0.598 a	2.05 abc	192	13.5 ab	63.1 b	58.7 d	17.5 ab
Pr(>F)	<0.001	<0.001		<0.001	<0.001	<0.001	<0.001	

Table 11. Greenseeker NDVI, grain yield and grain quality for depth of ripping trial South mid slope, 2022 and 2023.

Depth of ripping (cm)	Grain yield (t/ha)	Grain yield % of nil	Grain yield (t/ha)	Grain yield % of nil	Protein (%)	Test weight (kg/hL)	Retention (%)	Screenings (%)
	2022		2023					
0	3.14 b	100	0.97 b	100	13.3 a	64.7 a	60.7 c	15.4 a
20	3.54 b	113	1.33 b	137	12.3 ab	64.4 a	67.7 b	11.5 b
40	4.69 a	149	2.07 a	213	10.7 b	65.8 a	73.9 a	9.3 bc
60	5.21 a	166	2.13 a	220	10.7 b	67.4 a	77.5 a	7.8 c
Pr(>F)	0.006		<0.001		<0.0001	0.219	<0.0001	0.003

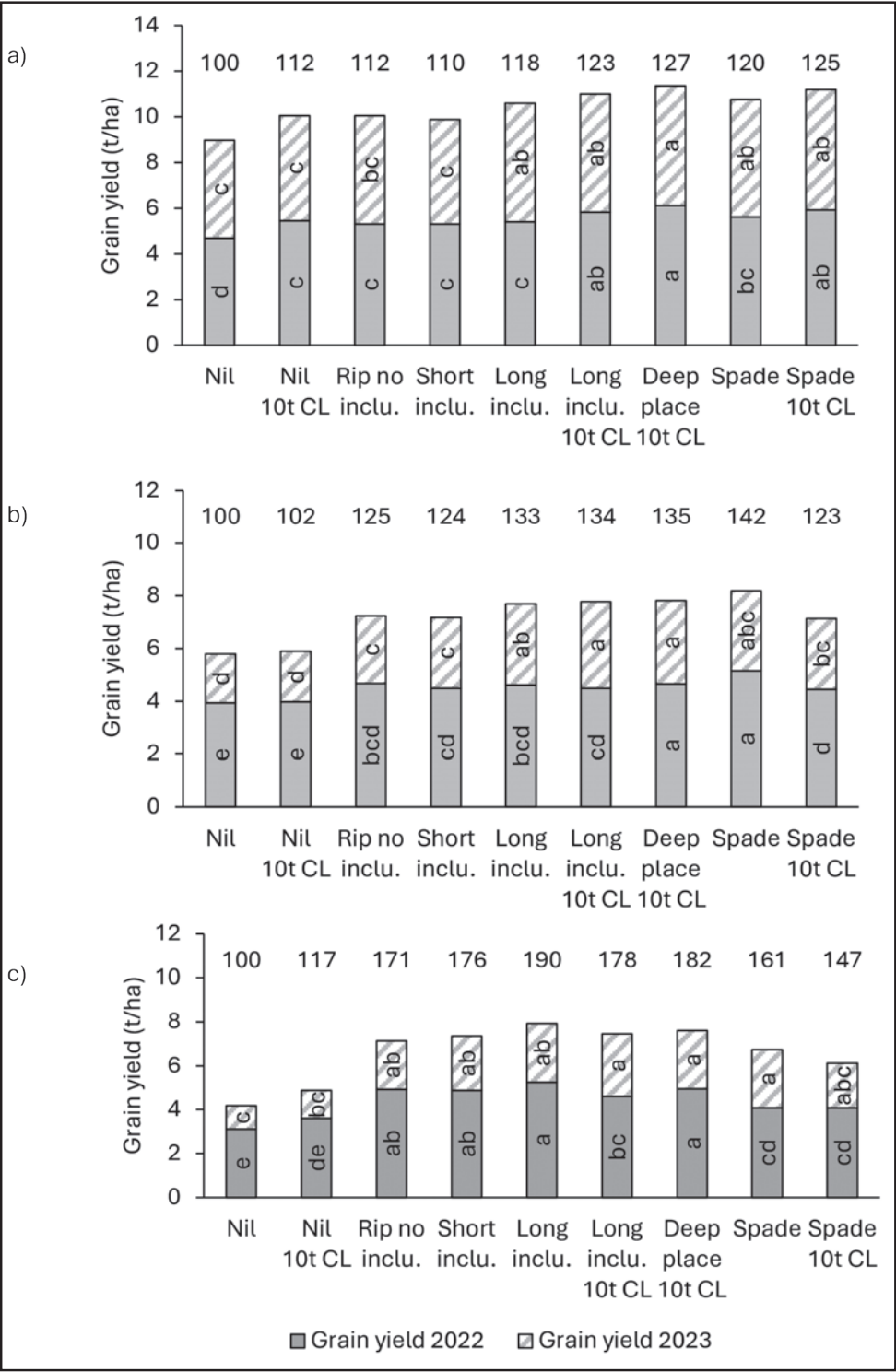


Figure 3. Grain yield (t/ha) response to amelioration technique on a) North hill top, b) North mid slope and c) South mid slope sites near Bute, SA in 2022 and 2023, letters denote significance $P < 0.001$ with in each season and site.

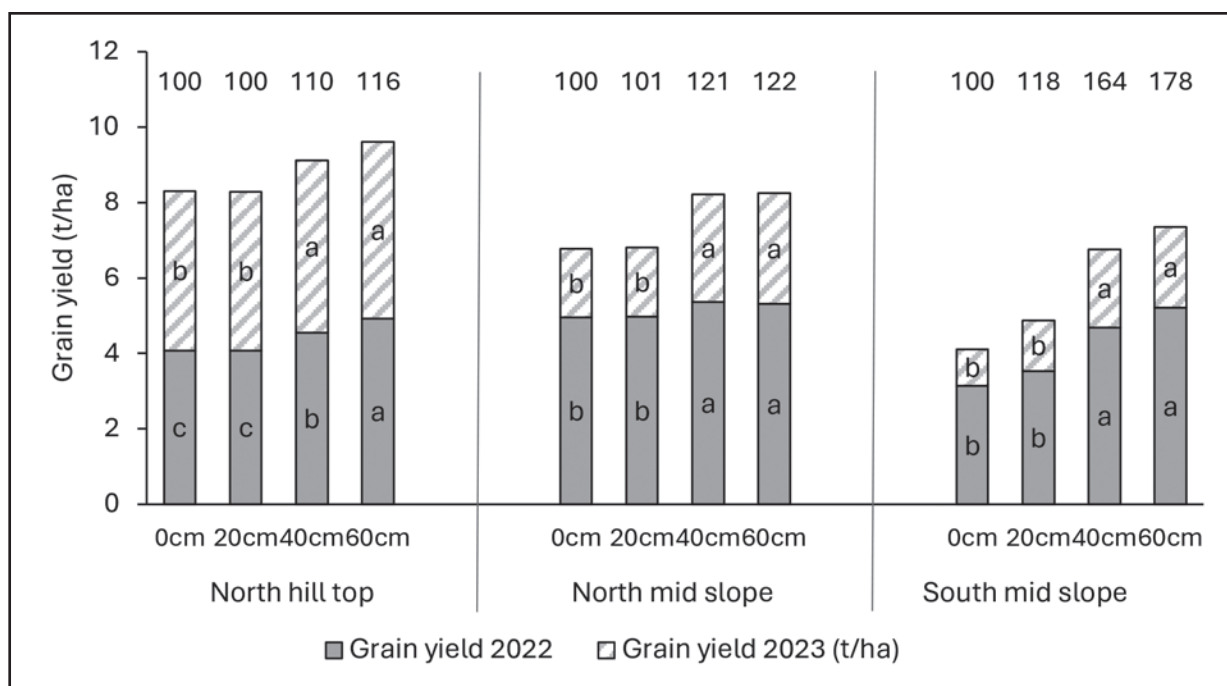


Figure 4. Grain yield (t/ha) response to ripping depth at all three sandy soil sites near Bute, SA 2022 and 2023, letters denote significance $P < 0.001$ with in each season and site.

Results from the depth of ripping trials have shown in all six site years, no yield response to a ripping depth of 20 cm (Figure 4). Previous research has shown ripping depth can be linked to a reduction in soil strength. However, the response will change depending on site and the depth at which the constraint occurs in the soil profile.

Overall, the results from year one and two continue to highlight the importance of understanding your soil type and identifying the target soil constraint and depth. To date the largest yield gains have been observed at the least productive sandy site (South mid slope). When planning to ameliorate sandy areas on-farm, these results show targeting the poorest performing sands will give the greatest benefit.

The longevity of treatments in these trials will be assessed in 2024 where the sites will be sown to lentils.

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The performance of residual and cumulative P applications on soils in the Mid North of SA

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Key messages

- **Residual P (from a one-off application of a high rate in year one) provided a grain yield response in the second and third year at two of the three sites.**
- **The method for applying a high rate (90 kg P/ha) of P fertiliser was not important in these trials. High rates of P applied by either deep banding, spreading MAP or chicken litter spread in front of the seeder, all produced the same yield response at each site and year.**

- **At Hart and Crystal Brook repeated applications of P fertiliser rates showed the crop P requirements were not satisfied by lower rates in the second and third season. The highest repeated P rates (50 and 90 kg P/ha) were still increasing yields in year three at these sites.**
- **Partial gross margin (PGM) analysis showed within the range of MAP prices of \$500-\$1500/t the district practice strategy was never the highest PGM on these P responsive sites.**
- **When MAP reached \$1500/t the chicken litter treatment became the highest PGM at Crystal Brook and one of the highest at Hart, despite freight and spreading costs.**

Why do the trials?

High fertiliser prices have increased grower interest in phosphorus (P) responses on variable soil types and improving returns from P fertiliser inputs. Recently, two SAGIT funded projects (TC219 and TC221) have examined P fertiliser response on a range of soil types with varying soil P availability. The trial locations were determined using soil pH maps and satellite NDVI imagery.

To date 49 P response trials have been established across the Mid and Upper North and Northern Yorke Peninsula (NYP) to validate the P sufficiency index (pHnNDVI) methodology (refer to method section) of predicting P response based on these data layers.

Included in the 49 P response trials were three long term (3 year) trials established in 2021 at Spalding, Crystal Brook and Hart. These three sites are highly P responsive alkaline soil types. The project aims to address the following questions.

- What is the residual value of high rates of P from year 1 in following years?
- What is the effect of repeated high-rate P application vs district practice?
- What alternative application strategies can be implemented at high response sites in lieu of variable rate P application through the seeder?

How was it done?

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

$$\text{pHnNDVI} = \text{soil pH} / (\text{NDVI} / \text{paddock NDVI average})$$

Areas of a paddock with high soil pH (>7) and low relative NDVI (<0.9) result in a high pHnNDVI value and are likely to be highly responsive to applied P. Areas with low pH (<6.5) and high relative NDVI (>1.1) result in a low pHnNDVI value and are likely to be unresponsive to applied P in the paddocks tested.

This methodology has proven useful in determining the optimal site-specific P rate in paddocks tested across the Mid and Upper North and Northern Yorke Peninsula.

At the beginning of 2021 three highly P responsive sites were identified using the P sufficiency index methodology (Table 1). These sites were soil sampled (0-10 cm) pre-seeding in 2021. Soil pH levels ranged from 7.7 - 7.9 pH CaCl₂ which is categorised as moderately alkaline. The DGT-P values were low ranging from 18-23 µg/L (critical limit 60 µg/L). Full comprehensive soil test analysis was conducted for each site and no other nutritional constraints were identified (data not presented)

The crop sown at each location/year were chosen based on the hosting growers' rotation (Table 1). The long-term P fertiliser trials sown at all three sites can be divided into four main management strategies (Table 2) which were used to answer specific questions throughout the project. Phosphorus fertiliser was applied as MAP and nitrogen was balanced at seeding with urea, to match the amount of nitrogen in the 90 kg P/ha treatment. In the main treatments, the fertiliser was applied below the seed using a knife point press wheel system on 250 mm row spacing.

The chicken litter sourced for these trials had a total P concentration of 1.48%, total nitrogen concentration of 4.14% and moisture content of 15.4%. This treatment had a target of 75 kg P/ha broadcast as chicken litter (equivalent to 6250 kg/ha chicken litter) prior to seeding plus 15 kg P/ha as MAP applied below the seed, resulting in a total of 90 kg P/ha. The actual total P applied in the chicken litter treatment was 93 kg P/ha in the first year (Table 2). As the nitrogen in all other treatments

was balanced to the 90 kg P/ha treatment it is important to note that the chicken litter treatment received an additional 178 kg N/ha compared to all other treatments.

Grain yield data was analysed using ASREML in R. Partial gross margin was calculated as cumulative income minus cumulative fertiliser cost.

What happened and what does this mean?

The long-term trials aimed to address three key research areas and the discussion has been structured around responding to these topics.

What is the residual value of high rates of P from year 1 in following years?

Banded MAP

The residual effect of P fertiliser rates (ranging from 0 – 90 kg P/ha) were assessed in year two and three in treatments where district practice applications (15 kg P/ha) followed the range of rates in the first season. The results from year three show at two of the sites, Hart and Crystal Brook, there was still evidence of residual P from high application rates in the first season (Figure 1 and 2). In contrast, at the Spalding site in the third season there was no grain yield response to the range of P rates (0-90 kg P/ha) applied in year one (Figure 3). At Hart in year one, grain yields reached 137% of the untreated where rates of 50 kg P/ha or more were applied. High rates of P continued to produce higher grain yields in year two and three (Figure 1). These results show at Hart residual effects of high P rates in year one, were still being observed in year three.

Crystal Brook was the most responsive site in season one, where grain yields reached 170% of the untreated at a rate of 90 kg P/ha. In the second season the grain yield response to increasing P remained significant with

maximum grain yields coming from the year one 90 kg P/ha application. In the third season the response to high rates of P in year one was not consistent (Figure 2). The 50 kg P/ha applied in the first year remained higher yielding compared to 0 kg P/ha however, the 90 kg P/ha was not different to the untreated.

Similarly, the Spalding site was highly responsive to P rates in year one, reaching 149% of the untreated with 90 kg P/ha. The chicken litter treatment produced higher grain yields than the comparable 90 kg P/ha MAP in all three seasons indicating other yield limitations (Figure 3). Protein data (not presented) showed nitrogen was limiting in year two which may have masked the P response in that season. Higher rates of nitrogen and foliar trace elements were applied in the third season to address any possible nutrient limitations. However, no response to high P rates applied in year one was recorded in year three (Figure 3). This indicates there was no legacy effect of the higher P rates carrying into the third season.

Table 1. Average growing season rainfall (GSR = April – October), soil properties and crop sown for long term P response sites.

Location	Soil pH (CaCl ₂)	DGT P (µg/L)	Colwell P (mg/kg)	PBI	pHnNDVI	2021 crop	2022 crop	2023 crop
Crystal Brook Ave GSR 289 mm	7.8	23	29	88	11.9	Compass barley	PBA Highland XT lentil	Calibre wheat
Spalding Ave GSR 268 mm	7.7	18	20	77	11.7	Scepter wheat	Spartacus CL barley	Commodus CL barley
Hart Ave GSR 291mm	7.9	17	40	110	10.0	Scepter wheat	PBA Jumbo 2 lentil	Calibre wheat

Table 2. Treatment list showing units of P (kg P/ha) applied, the equivalent rate applied as MAP fertiliser (kg/ha) and cumulative P rate for the long-term P response trials in the Mid-North, SA.

Treat	Management strategy	2021 P rate (kg P/ha)	Equivalent MAP (kg/ha)	2022 P rate (kg P/ha)	Equivalent MAP (kg/ha)	2023 P rate (kg P/ha)	Equivalent MAP (kg/ha)	Cumulative P rate (kg P/ha)
1	Residual value of high P rates applied in year one	0	0	15	68	15	68	30
2		7.5	34	15	68	15	68	37.5
3		15	68	15	68	15	68	45
4		22.5	102	15	68	15	68	52.5
5		30	136	15	68	15	68	60
6		50	227	15	68	15	68	80
7		90	409	15	68	15	68	120
8	Alternative P management strategies	Spread MAP (90)*	341 fb 68	15	68	15	68	120
9		Chicken litter (93)**	CL fb 68	15	68	15	68	123
10	Value of repeated P rates over three years	0	0	0	0	0	0	0
11		7.5	34	7.5	34	7.5	34	22.5
12		22.5	102	22.5	102	22.5	102	67.5
13		30	136	30	136	30	136	90
14		50	227	50	227	50	227	150
15		90	409	90	409	90	409	270
16	Compare strategies above to high P rates in year three only	15	68	15	68	0	0	30
17		15	68	15	68	7.5	34	37.5
18		15	68	15	68	22.5	102	52.5
19		15	68	15	68	30	136	60
20		15	68	15	68	50	227	80
21		15	68	15	68	90	409	120

* 75 kg P/ha spread prior to sowing as MAP + 15 kg P/ha banded as MAP

**78 kg P/ha spread as chicken litter prior to sowing + 15 kg P/ha banded as MAP

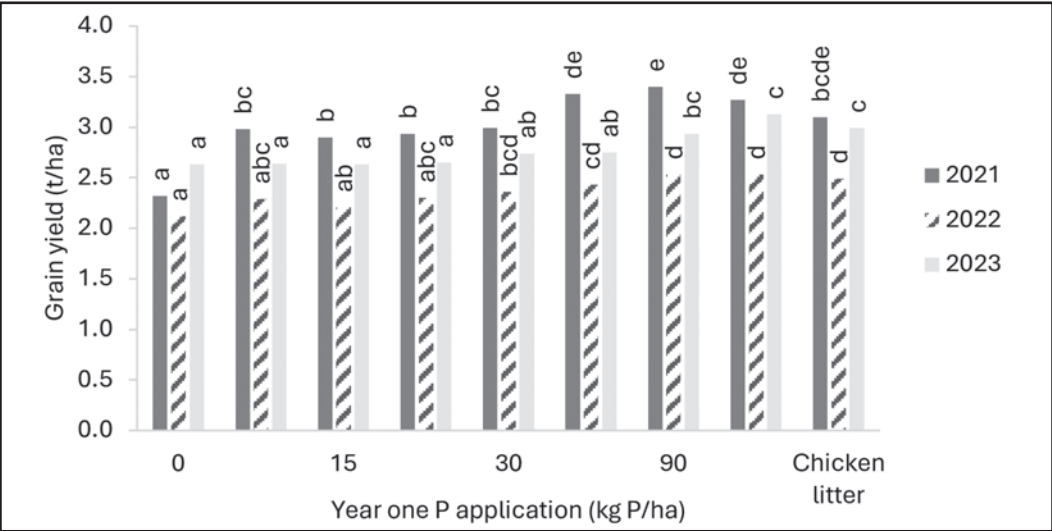


Figure 1. Grain yield (t/ha) over three seasons for P rates applied in year one at Hart, SA from 2021-2023. (P value for all 21 treatments; 2021 <0.001, 2022 <0.001 and 2023 <0.001). Bars within a year level that share a common letter are statistically similar.

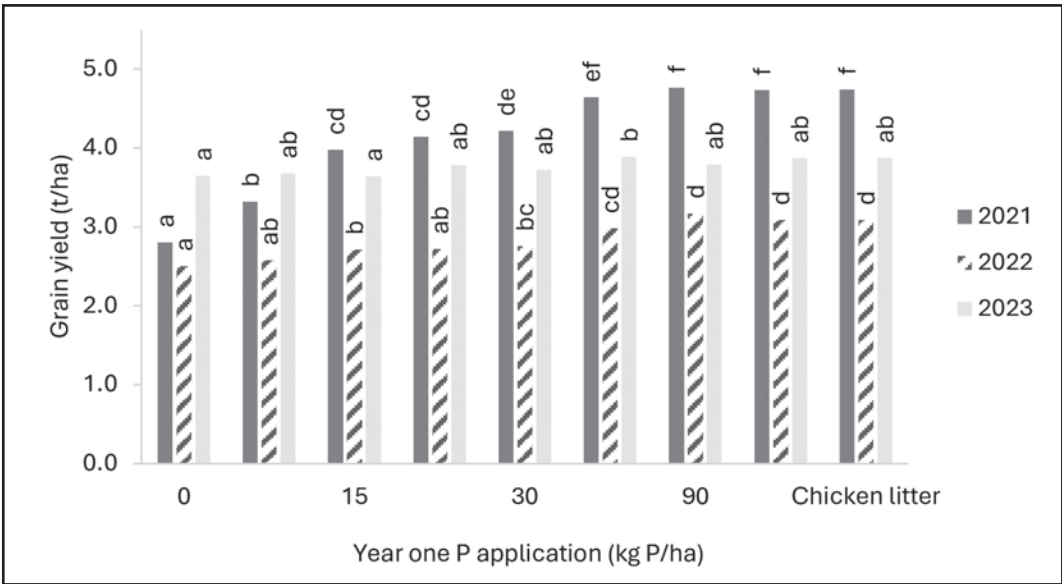


Figure 2. Grain yield (t/ha) over three seasons for P rates applied in year one at Crystal Brook, SA from 2021-2023 (P value for all 21 treatments; 2021 <0.001, 2022 <0.001 and 2023 <0.001). Bars within a year level that share a common letter are statistically similar.

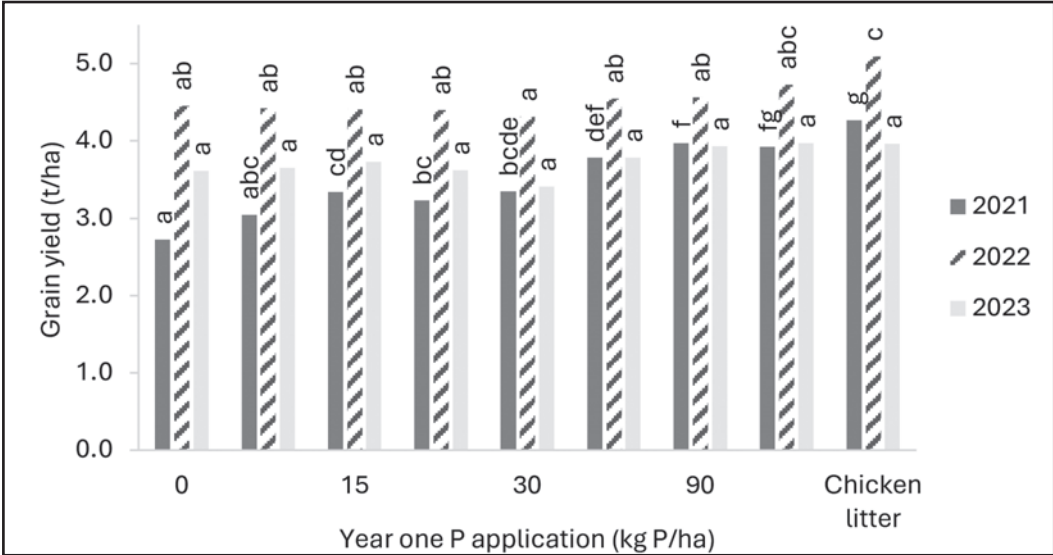


Figure 3. Grain yield (t/ha) over three seasons for P rates applied in year one at Spalding, SA from 2021-2023. (P value for all 21 treatments; 2021 <0.001, 2022 <0.001 and 2023 <0.001). Bars within a year level that share a common letter are statistically similar.

What alternative strategies can be implemented at high response sites in lieu of variable rate P application through the seeder?

Spread MAP and chicken litter application

At all three sites and in all seasons, the spread MAP treatment (75 kg P/ha spread in front of the seeder plus 15 kg P/ha MAP deep banded in year one) produced similar grain yields to the equivalent treatment of 90 kg P/ha MAP deep banded (Figures 1-3). The chicken litter treatment (78 kg P/ha of chicken litter spread in front of the seeder plus 15 kg P/ha MAP deep banded in year one) also produced similar grain yields to the equivalent treatment of 90 kg P/ha MAP deep banded at Hart and Crystal Brook in all three seasons. At these highly P responsive sites this result indicates the P fertiliser efficiency was similar regardless of application method.

At Spalding, grain yields from the chicken litter treatment were higher compared to the 90 kg P/ha deep banded in the first and second season. The chicken litter treatment received an additional 173 kg N/ha compared to other

treatments. Grain protein data (not presented) indicated that the additional N likely contributed to the grain yield response in the first two seasons. In the third season there was no difference between the chicken litter treatments and the equivalent deep banded MAP treatment.

What is the effect of repeated high-rate P application vs district practice?

The district practice treatment refers to the repeated application of 15 kg P/ha (Table 2). This treatment is representative of the P management strategy used by all three trial cooperators in previous years.

The Crystal Brook and Hart sites showed similar responses with highest grain yields coming from repeated P rates of 50 and 90 kg P/ha in the trials in year two and three (Figure 4 and 5). At Hart, repeated applications of 30 kg P/ha were enough to outyield the district practice in years two and three (Figure 4). The same treatment increased yields above district practice in year two at Crystal Brook but no yield advantage was seen in year three. Repeated applications of 22.5 kg P/ha yielded the same as district

practice for the three years at both Crystal Brook and Hart.

It was anticipated that with repeated applications of high rates, the crop P requirements would be satisfied by smaller applications in the second and third season. This was not observed with the highest repeated P rates still increasing yield into the third year at these sites. Further investigation is required to understand if higher yields continue from the highest P rates or if a point of P saturation occurs allowing lower P rates to satisfy crop requirements.

At Spalding, the application of P rates of 50 and 90 kg P/ha resulted in increased yields compared to the district practice in year one (Figure 6). Individual year analysis indicates a small grain yield response above 15 kg P/ha in year two and three. However, the cumulative grain yield analysis shows significant grain yield increases above district practice P rates with repeated applications of 50 and 90 kg P/ha. As discussed above, it is likely that nitrogen was a limiting factor at this site and confounds the grain yield results. The chicken litter treatment was the highest yielding at this site in year two.

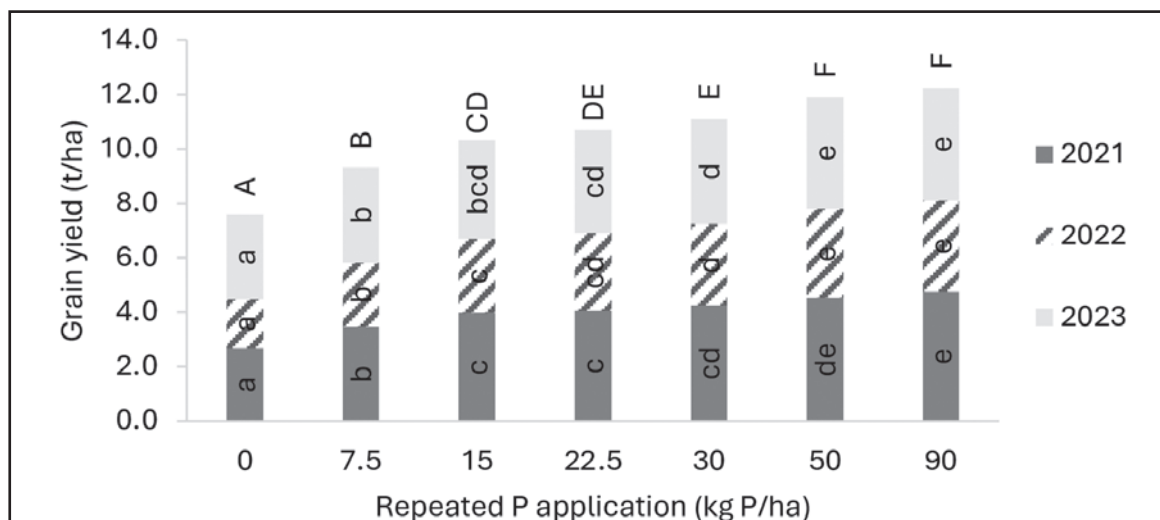


Figure 4. Hart cumulative grain yield for repeated applications of P fertiliser, P values = 2021 <0.001, 2022 <0.001, 2023 <0.001 and cumulative <0.001. Bars within a year level that share a common letter are statistically similar, capital letters refer cumulative yield analysis.

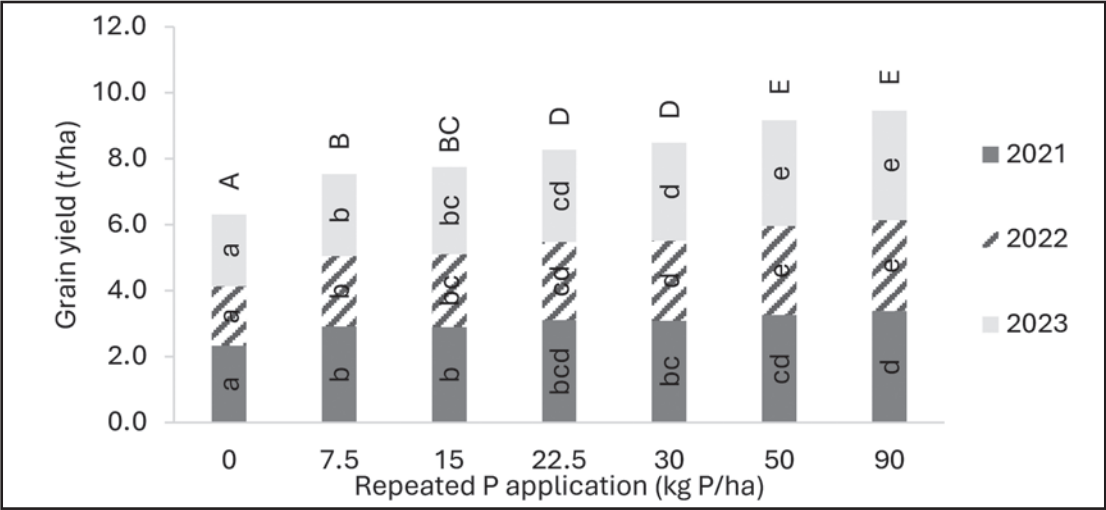


Figure 5. Crystal Brook cumulative grain yield for repeated applications of P fertiliser, P values = 2021 <0.001, 2022 <0.001, 2023 <0.001 and cumulative <0.001. Bars within a year level that share a common letter are statistically similar, capital letters refer cumulative yield analysis.

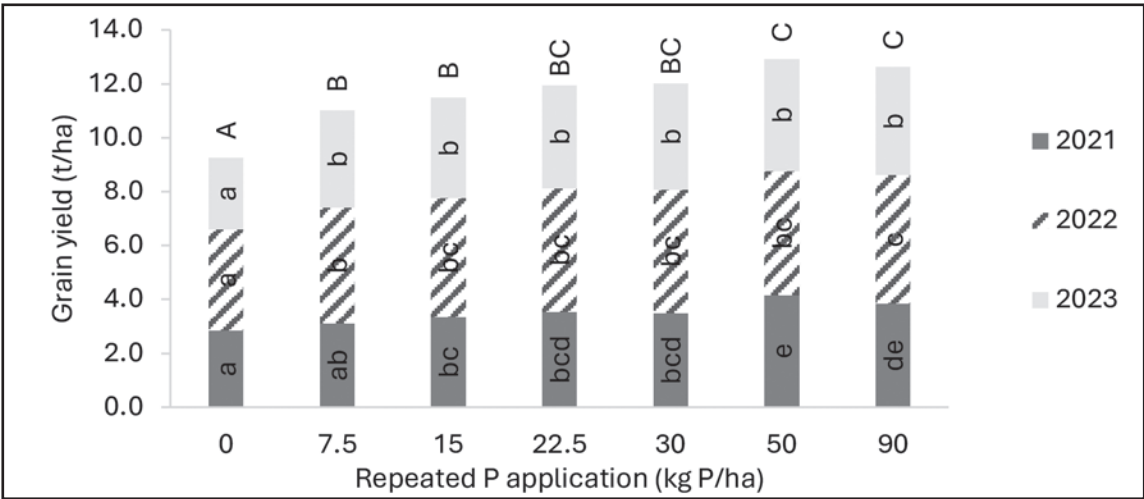


Figure 6. Spalding cumulative grain yield for repeated applications of P fertiliser, P values = 2021 <0.001, 2022 <0.001, 2023 <0.001 and cumulative <0.001. Bars within a year level that share a common letter are statistically similar, capital letters refer cumulative yield analysis.

Economic analysis of the different P management strategies

Whilst the repeated application of high P fertiliser rates has resulted in the largest cumulative grain yields, the cost of fertiliser also needs to be considered. The partial gross margin (PGM) has been calculated on the cumulative grain yield for all sites and presented with variable MAP pricing scenarios (Table 3).

The Spalding PGM values have been impacted by the variability of the site and the N limitation in year one and two, which affected grain yields in all treatments except for chicken litter (Table 3).

The Hart and Crystal Brook sites behaved similarly in terms of grain yields over the three years and therefore the PGMs are similar (Table 3). Firstly, within the range of MAP prices of \$500-\$1500/t the district practice treatment is never the highest PGM on these responsive sites. Therefore, the alternative P management strategies tested have potential to improve profitability. Secondly, when fertiliser prices are low (MAP \$500/t) there is an economic advantage of achieving consistently higher yields with repeated P rates of 50 kg P/ha, which produces the highest PGM for these sites. As fertiliser prices

increase, the optimum P rate for repeat applications declines, ultimately resulting in a lower PGM. This is where the value of residual P becomes important. Under high fertiliser prices (MAP \$1500/t) the one-off high P rates in year one of 50 - 90 kg P/ha has a greater PGM than the repeat high applications. However, we would expect that the repeated applications of higher rates will have higher reserves to support ongoing productivity in the near future, compared with the one-off high application rates. Soil testing planned for these trials will explore this.

Treatment 5-7 show the value of addressing P deficiency immediately, rather than putting it off for two seasons as in treatment 19-21. On average, at Hart and Crystal Brook there is a \$272/ha advantage for addressing deficiency in year one with 30-90 kg P/ha, compared with year three (Table 3).

Under high MAP fertiliser prices (\$1500/t) the chicken litter treatment provided the greatest

PGM at Crystal Brook and one of the highest at Hart (Table 3). This alternative source of P becomes important under high MAP prices assuming the price does not increase from demand because of high synthetic P fertiliser prices. Not only is the chicken litter supplying P to the crop, but it is also supplying other nutrients which can potentially reduce the total synthetic fertiliser inputs, such as urea, to further decrease input costs whilst maintaining

grain yields which ultimately increase PGM further.

Acknowledgements

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Farzad Aslani (SARDI) and David Davenport soil sampling for Eyre Peninsula Landscape Boards Supports Floods (AIR EP).



Table 3. Predicted cumulative yield and partial gross margin (PGM) for the three seasons at differing MAP fertiliser prices.

Treatment	2021 P rate (kg/ha)	2022 P rate (kg/ha)	2023 P rate (kg/ha)	Predicted cumulative yield (t/ha)			MAP \$500/t			MAP \$1000/t			MAP \$1500/t		
				Crystal Brook	Hart	Spalding	Crystal Brook	Hart	Spalding	Crystal Brook	Hart	Spalding	Crystal Brook	Hart	Spalding
1	0	15	15	8.95	7.07	10.78	\$3,477	\$2,901	\$2,763	\$3,409	\$2,833	\$2,695	\$3,340	\$2,764	\$2,626
2	7.5	15	15	9.58	7.91	11.11	\$3,655	\$3,204	\$2,844	\$3,570	\$3,119	\$2,759	\$3,484	\$3,033	\$2,674
3	15	15	15	10.33	7.74	11.48	\$3,882	\$3,104	\$2,935	\$3,779	\$3,001	\$2,832	\$3,677	\$2,899	\$2,730
4	22.5	15	15	10.64	7.88	11.25	\$3,954	\$3,165	\$2,855	\$3,834	\$3,045	\$2,735	\$3,715	\$2,926	\$2,616
5	30	15	15	10.70	8.09	11.07	\$3,967	\$3,235	\$2,799	\$3,830	\$3,098	\$2,662	\$3,694	\$2,962	\$2,526
6	50	15	15	11.51	8.51	12.11	\$4,231	\$3,343	\$3,035	\$4,049	\$3,161	\$2,853	\$3,868	\$2,980	\$2,671
7	90	15	15	11.72	8.86	12.46	\$4,273	\$3,397	\$3,041	\$4,001	\$3,125	\$2,768	\$3,728	\$2,852	\$2,495
8	Spread MAP	15	15	11.68	8.93	12.62	\$4,215	\$3,418	\$3,078	\$3,942	\$3,146	\$2,806	\$3,669	\$2,873	\$2,533
9	Chicken litter	15	15	11.70	8.58	13.32	\$4,065	\$3,126	\$3,099	\$3,963	\$3,024	\$2,997	\$3,860	\$2,921	\$2,895
10	0	0	0	7.60	6.32	9.26	\$2,862	\$2,620	\$2,458	\$2,862	\$2,620	\$2,458	\$2,862	\$2,620	\$2,458
11	7.5	7.5	7.5	9.32	7.53	11.02	\$3,511	\$3,064	\$2,859	\$3,460	\$3,013	\$2,808	\$3,409	\$2,962	\$2,757
12	22.5	22.5	22.5	10.70	8.27	11.95	\$3,994	\$3,280	\$3,011	\$3,841	\$3,126	\$2,857	\$3,687	\$2,973	\$2,704
13	30	30	30	11.10	8.49	12.02	\$4,117	\$3,318	\$2,975	\$3,913	\$3,114	\$2,770	\$3,708	\$2,909	\$2,566
14	50	50	50	11.89	9.17	12.62	\$4,312	\$3,490	\$3,006	\$3,971	\$3,149	\$2,665	\$3,630	\$2,808	\$2,324
15	90	90	90	12.23	9.46	12.92	\$4,158	\$3,328	\$2,824	\$3,544	\$2,715	\$2,211	\$2,931	\$2,101	\$1,597
16	15	15	0	10.08	7.57	10.48	\$3,854	\$3,087	\$2,708	\$3,786	\$3,019	\$2,640	\$3,718	\$2,950	\$2,571
17	15	15	7.5	10.04	7.69	11.12	\$3,800	\$3,106	\$2,856	\$3,715	\$3,021	\$2,771	\$3,629	\$2,935	\$2,685
18	15	15	22.5	10.30	7.90	11.78	\$3,857	\$3,147	\$2,991	\$3,737	\$3,027	\$2,871	\$3,618	\$2,908	\$2,752
19	15	15	30	10.21	7.98	11.84	\$3,807	\$3,162	\$2,994	\$3,671	\$3,025	\$2,857	\$3,534	\$2,889	\$2,721
20	15	15	50	10.46	8.09	11.91	\$3,797	\$3,149	\$2,959	\$3,615	\$2,967	\$2,777	\$3,433	\$2,786	\$2,595
21	15	15	90	10.51	8.40	12.37	\$3,750	\$3,147	\$2,991	\$3,477	\$2,875	\$2,719	\$3,204	\$2,602	\$2,446

Assumed grain pricing wheat \$300/t, barley \$250/t, lentil \$700/t.
Chicken litter \$54.70/t which includes cost of product, spreading and transport (averaged across the three sites).
White cells = grain yields at Spalding which were not nitrogen limited.

Farming Systems

Impact of stripper front and straw length on harvest efficiency, summer weed control, soil moisture retention and pest populations in upper Eyre Peninsula systems

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¹SARDI; ²The University of Adelaide



Location
Cleve - Bammann
Rainfall
Av. Annual: 375 mm
Av. GSR: 250 mm
2023 Total: 288 mm
2023 GSR: 133 mm
Paddock History
2024: Leader lentils
2023: Wheat
2022: Leader lentils
2021: Spartacus barley

Soil type
Red loam
Plot size
18 m x 500 m x 3 reps of stubble treatments to be sown with 24.1 cm row spacing

Location
Minnipa - Scholz
Rainfall
Av. Annual: 325 mm
Av. GSR: 241 mm
2023 Total: 280 mm
2023 GSR: 169 mm

Key messages

- Large plots of stripper stubble and two heights of conventional stubble were set up during the harvest of 2023 at Cleve and Minnipa to measure their effects on soil water evaporation using soil moisture probes.
- Various herbicide strategies have been implemented across the three stubble types to measure the effect of summer weeds on soil water losses over summer.
- The different stubble systems will be sown in 2024 by disc.

Why do the trial?

At the Minnipa GRDC NGN Forum, growers identified the need to better understand the pros and cons of strip and disc systems in their local environments as a high priority. Growers are seeking to better understand which components are key to managing the system and what some of the potential trade-offs might be around transitioning to

a strip and disc system in local soils which include large areas of alkaline and sandy soils. It was hypothesised that the use of strip and disc systems (which reduce evaporation), may contribute to significant yield improvements in years with summer and early autumn rain.

Growers believed there were opportunities for strip and disc systems to minimise soil disturbance, conserve more soil moisture, improve logistics (particularly speed of operations), and potentially improve yields. However, some of the challenges such as the impact of high stubble on summer spray efficacy, an improved pest habitat for snails, mice, and weeds, extra investment into machinery, differing herbicide options for discs with differing amounts of soil throw and integration of livestock, needed further investigation.

Soil type
Red loam flats with undulating sandhills

Plot size
12 m x 230 m long x 3 replicates of stubble treatment to be sown with disc system

How was it done?

Replicated broadacre stubble management treatments were implemented using growers' harvester fronts in November 2023 at Cleve (Bammann) and Minnipa (Scholz). The Cleve soil type is a red loam. The Minnipa site was implemented over two soil types, a red loam flat and a sandhill to capture differences in soil moisture on the different soil types.

The Cleve stubble treatments were implemented on 17 November. The stubble heights at Cleve were stripper stubble at 55 cm high, draper medium stubble at 25 cm high, and draper low stubble at 15 cm high. The entire site was harvested first using the stripper front, and then conventional stubble treatments were created by a second pass with a draper front, so grain losses were only estimated in the stripper stubble.

The Minnipa stubble treatments were implemented on 21 November. Grain harvest losses were captured the same day using trays placed on the ground in front of the different harvester systems. Stubble heights at Minnipa were stripper stubble at 70 cm high, draper medium stubble at 38 cm high, and draper low stubble at 23 cm high.

Rainfall, humidity, wind speed and soil moisture are being measured at both sites. Sentek Drill & Drop Bluetooth soil moisture probes have been placed within the stubble systems to measure at 10 cm intervals to 30 cm soil depth. Gravimetric soil moisture (0-120 cm) has also been manually measured at both sites and this will be periodically taken, along with soil fertility.

A smaller replicated trial to assess the impact of stubble on summer spray efficacy was also implemented across the three stubble systems at both sites. These trials will allow us to measure the effect of weed management on soil water losses over summer. Herbicides were applied at 80 or

120 L/ha output rates, either early in the morning with a lower delta T or at mid-day with a higher delta T.

The herbicide mix used at Cleve was Glyphosate 1.2 L/ha, Garlon 80 mL/ha, Hammer 80 mL/ha, SOA 1 kg/100 L and LI700 400 ml/ha, applied on 20 December, 2023. The herbicide mix at Minnipa was Glyphosate 1.5 L/ha, Garlon 120 ml/ha, SOA 1 kg/100 L, LI700 1 L/ha and Genwet 1 L/100 L which was applied on 5 January 2024. Spray cards were used to capture herbicide coverage (% spray card coverage) in the different stubble systems. The main weeds are volunteer cereals from the previous crop and heliotrope.

What happened?

At this early stage of the research trials only the average % spray coverage data has been presented (Table 1 & 2). At both the Cleve and Minnipa sites an increase in water rate from 80 L/ha to 120 L/ha increased the % spray coverage (Table 1 & 2). The lower stubble had higher spray coverage than the higher stubble.

Table 1. Average % Spray coverage at Cleve with different stubble heights, water rate and Delta T measured on 17 November 2023.

Water rate (L/ha)	Delta T (measured)	Low stubble spray coverage (%)	Medium stubble spray coverage (%)	High stubble spray coverage (%)	Average Spray coverage (%) with different water rates and Delta T
80	Low (3.3)	17.6	18.3	17.1	17.7
120	Low (4.4)	32.4	23.2	23.3	26.3
80	Higher (5.6)	16.2	15.2	12.1	14.5
120	Higher (5.7)	23.8	22.2	22.3	22.8
Average Spray coverage (%) with different Stubble treatments		22.5	19.7	18.7	

Table 2. Average % Spray coverage at Minnipa with different stubble heights, water rate and Delta T measured on 5 January 2024.

Water rate (L/ha)	Delta T (measured)	Low stubble spray coverage (%)	Medium stubble spray coverage (%)	High stubble spray coverage (%)	Average Spray coverage (%) with different water rates and Delta T
80	Low (3.4)	28.0	21.9	16.6	22.2
120	Low (4.5)	36.4	30.4	20.5	29.1
80	Higher (11)	16.6	20.5	9.9	15.7
120	Higher (12)	25.8	22.4	15.1	21.1
Average Spray coverage (%) with different Stubble treatments		26.7	23.8	15.5	

What does this mean?

Further data will be collected over summer in 2024 to determine the impact of stubble management, weed management, pests and environmental conditions on soil water at seeding within these systems. All treatments at both sites will be sown with disc seeding systems in 2024. This research will be continued in 2024 and 2025 to

enable replicated broadacre side-by-side comparisons of different stubble management, summer weed control and the impact on soil water in upper Eyre Peninsula farming systems.

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Elijah Luo spraying with the handboom.



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Stubble management and soil water in strip and disc

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Location
Cleve
Crop
Hurricane Lentils
Rainfall
Av. Annual: 375 mm
Av. GSR: 250 mm
2023 Total: 288 mm
2023 GSR: 133 mm
Paddock History
2023: Hurricane lentils
2022: Maximus barley
2021: Wheat
Soil type
Red loam
Plot size
18 m x 30 m x 3 reps on 24.1 cm row spacing (disc)

Location
Buckleboo
Crop
Ballista wheat
Rainfall
Av. Annual: 349 mm
Av. GSR: 247 mm
2023 Total: 165 mm
2023 GSR: 140 mm
Paddock History
2023: Wheat
2022: Wheat
2021: Lentils
Soil type
Red loam
Plot size
18 m x 30 m x 3 reps on 19.05 cm row spacing (disc) and 22.5 row spacing (conventional plot seeder)

Key messages

- Stripper stubble averaged 64 ± 4 cm high and conventional draper front stubble averaged 15 ± 2 cm high after the 2022 harvest at three sites (Cleve, Buckleboo and Minnipa).
- Unrolled stripper stubble had more established plants at 72 plants/m² compared to the conventional stubble (also unrolled, 27 plants/m²) at Cleve.
- Stripper stubble resulted in a significant yield loss in lentils compared to conventional stubble at Cleve in 2023.
- One site (Minnipa) in a medic pasture in 2023 had fewer weed numbers in the stripper stubble (15 plants/m²) than the conventional stubble (22 plants/m²).
- Spray coverage at Cleve was similar in both the stripper stubble and conventional stubble when a spray air system was used to improve penetration into the stubble.

Why do the trial?

The South Australian Drought Resilience Adoption and Innovation Hub (SA Drought Hub) workshop in August 2021 identified strip and disc strategies as a priority topic for the upper Eyre Peninsula. The workshop was attended by growers, industry organisations, farmer groups, researchers and community members.

A small handful of early adopting farmers have begun using disc sowing systems and stripper fronts for headers on the Eyre

Peninsula, with the aim of retaining more stubble residue at harvest, less soil and stubble disturbance at seeding, and potentially greater rainfall infiltration over the following summer and autumn. Other potential benefits are increased harvest efficiency and improved timeliness of sowing and harvest.

As a result, AIR EP in partnership with Buckleboo Farm Improvement Group (BFIG) and SARDI Minnipa Agricultural Centre, are investigating the impacts of the strip and disc system on upper Eyre Peninsula to address questions around the benefits and risks of using these systems. In these demonstrations, soil water and potential benefits in crop production were monitored.

How was it done?

The SARDI Minnipa Agricultural Centre team and growers delivered three demonstration sites at Cleve (Bammann’s), Buckleboo (Vandeleur’s) and Minnipa (Oswald’s), to address the following research questions:

1. Does soil water increase in strip/disc systems compared to no-till knife point systems?
2. Do strip/disc systems confer other benefits to the farming system, such as increased soil cover, better nutrition, fewer weeds, less disease and pests, higher yields or better soil health?
3. Are there impacts on the efficacy of pre-sowing herbicides in strip/disc systems compared to a conventional system?

Location

Minnipa

Crop

Self-regenerating medic pasture

Rainfall

Av. Annual: 325 mm

Av. GSR: 241 mm

2023 Total: 280 mm

2023 GSR: 169 mm

Paddock History

2023: Medic pasture

2022: Scepter wheat

Soil type

Sandy loam

Plot size

15 m x 12 m x 3 reps on 26.0 cm row spacing (disc) grazed and ungrazed

Tall stripper stubble from harvest of the paddocks in 2022 was cut low to create conventional stubble using the MAC Zurn small plot harvester at Cleve on 28 March, Buckleboo on 29 March and at Minnipa on 6 April 2023. The plot areas were replicated strips based on the width of growers seeding machinery (12 to 18 m wide). The growers' disc seeders were used to sow the crop in 2023 at Cleve and Buckleboo.

Due to the dry start to the 2023 season the Minnipa site (red loam) was not sown to cereal as was planned but was left to regenerate with medic pasture. With the different stubbles already implemented, the opportunity was taken to measure medic regeneration and growth in those stubbles. An electric fence was erected to have a grazed and ungrazed area.

The Cleve site (red loam) compared high and low cut stripper stubble sown with the growers disc seeding system, stubble either rolled or unrolled. The high and low rolled stubble blocks were rolled using a 12.8 m steel roller post plant establishment. The site was sprayed on 18 April and then sown with Hurricane lentils @ 45 kg/ha with 50 kg/ha of MAP, using a NDF SA650 single shoot low disturbance disc system with 24.1 cm row spacing.

At Buckleboo (sandy loam, adequate moisture at seeding) a strip and disc system was compared with a conventional knife point and press wheel seeding system. The site was sown on 4 May with Ballista wheat @ 60 kg/ha with 60 kg/ha of MAP, using a 60 foot John Deere 1890 pro-series disc seeder with 19.1 cm spacing for the stripper system plots. The MAC small plot seeder was used as a conventional system with Harrington knife points and press wheels on 22.5 cm row spacings. Both systems were sown on the same morning using the same seed and fertiliser rate.

Growers prepared the sites prior to seeding with knockdown herbicides. Herbicide coverage within the two different stubbles was compared pre-sowing using a spray card. Coverage (%) was assessed using the SnapCard phone app at Cleve on 18 April, Buckleboo on 3 May and Minnipa on 31 July (grass weed control in pasture).

Initial soil sampling at the sites were taken in late March 2023. Plant emergence was measured at Minnipa on 12 July, Cleve on 29 June and Buckleboo on 26 June. Early dry matter (DM) cuts were completed on 27 July at Minnipa, and at Cleve on 29 June and Buckleboo on 8 August, 2023. Late DM and in-crop soil moisture were measured at Minnipa on 28 July, and Cleve and Buckleboo on 8 and 9 August, 2023 respectively.

Grain was harvested at Cleve on 17 October and Buckleboo on 25 October 2023, using the Zurn conventional front plot harvester with final soil moistures sampled at Cleve and Buckleboo on 20 and 21 November 2023 respectively. Minnipa final soil moistures were sampled on 16 October at medic senescence.

What happened?

At Cleve, standing stripper stubble height averaged 61 cm and the conventional stubble averaged 15 cm (Table 1). Spray coverage was similar across the stubble treatments (Table 1). The broadacre sprayer was a Miller 7380 with spray air system to improve penetration into the stubble canopy using an output rate of 45 L/ha.

Lentil establishment increased in the stripper stubble unrolled (72 plants/m²) and rolled (63 plants/m²) compared to the conventional stubble (unrolled, 27 plants/m²) (Table 1). However, early dry matter was greater in the conventional stubble (Table 1). There were differences in broadleaved weed numbers with the conventional rolled stubble having higher weed numbers (wild turnip, thistle, marshmallow, warts weed) compared to unrolled (Table 1), however there were more mice holes observed in the higher stubble system. The trends in dry matter were similar to final grain yield with the conventional stubble yielding 0.49 t/ha higher than strip and disc stubble (Table 1).

Initial soil water at Cleve was 137 mm in the profile (0-90 cm) at the end of March (data not shown). Gravimetric soil water (%) in August was higher in the unrolled stubble (av. 35%) compared to the rolled treatments (av. 44%) (Table 2). After harvest there were no differences in gravimetric soil moisture between the treatments (Table 2).

Table 1. Stubble height, spray coverage, plant establishment, early dry matter, NDVI, broadleaf weeds, grain yield and harvest pod loss of lentils sown in stripper and conventional stubble at Cleve, 2023.

Stubble Treatments	Stubble Height (cm)	% Spray coverage	Plant Establishment (plants/m ²)	Early Dry Matter (t/ha)	NDVI	Broad-leaf weeds (plants/m ²)	Grain Yield (t/ha)	Harvest pod loss/ m ²
Stripper stubble (high) Rolled	57	6.0	63 b	0.62 b	38 ab	5 bc	0.71 b	22 ab
Stripper stubble (high) Unrolled	64	8.4	72 a	0.65 b	42 ab	7 ab	0.72 b	16 b
Conventional stubble (low) Rolled	14	8.7	20 c	1.15 a	32 b	13 a	1.2 a	25 a
Conventional stubble (low) Unrolled	18	5.6	27 c	1.17 a	45 a	2 c	1.1 a	28 a
<i>LSD (P=0.05)</i>								
<i>Stubble*Rolling</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>
<i>Stubble</i>	4.1	<i>ns</i>	8	0.27	8.6	<i>ns</i>	0.08	6
<i>Rolling</i>	4.0	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>	7	<i>ns</i>	<i>ns</i>

Table 2. Soil moisture (%) in stripper and conventional stubble treatments at 0-90 cm in August and November at Cleve, 2023.

Stubble Treatments	Soil water in August	Soil water in November
Stripper stubble (high) Rolled	38.0	24.8
Stripper stubble (high) Unrolled	42.4	18.7
Conventional stubble (low) Rolled	32.3	23.2
Conventional stubble (low) Unrolled	45.2	20.9
<i>LSD (P=0.05)</i>		
<i>Stubble*Rolling</i>	<i>ns</i>	<i>ns</i>
<i>Stubble</i>	<i>ns</i>	<i>ns</i>
<i>Rolling</i>	8.6	<i>ns</i>

At Buckleboo, average stripper stubble height was 64 cm and conventional stubble height was 14 cm (Table 3). The conventional low cut stubble had higher sprayer coverage than the stripper stubble (Table 3).

Wheat establishment and growth of wheat was the same in both stubbles (Table 3). Weed numbers at the site were low and similar in both stubbles.

Grain yield and grain quality were the same in both stubbles (Table 3). Average grain protein was 11.9 %, screenings were 41% and 1000-grain weight was 38 g.

Initial gravimetric soil water was 46% in late March. Soil water in September was higher in the stripper stubble compared to the conventional low stubble. Soil water measured after harvest were similar in both stubbles (Table 3).

At Minnipa, average height of the stripper stubble was 68 cm, and conventional stubble was 13 cm (Table 4). Medic establishment and early dry matter was similar in both stubbles (Table 4). Low conventional stubble had higher weeds (mainly barley grass and ryegrass) at 22 plants/m² compared to 15 plants/m² in the stripper stubble (Table 4). Soil moisture content to depth

at medic plant senescence was similar in both stubbles (Table 4).

Spray cards were placed within the different stubble treatments on the soil surface before grass weed spraying, with livestock having been in the paddock grazing. Spray coverage with the stripper stubble ungrazed having the highest % spray coverage, similar to the conventional low stubble grazed (Table 5).

Table 3. Stubble height, spray coverage and growth of wheat seeded into stripper and conventional stubble at Buckleboo, 2023.

Stubble Treatments	Stripper stubble (high)	Conventional stubble (low)	LSD (P=0.05)
Stubble height (cm)	64	14	8
% Spray coverage	9 b	14 a	4
Plant Establishment (plants/m ²)	88	94	ns
Early Dry Matter (t/ha)	1.5	1.7	ns
NDVI	0.48	0.48	ns
Gravimetric soil moisture to 90 cm (%) September	31	23.6	7.5
Late Dry Matter (t/ha)	1.9	2.1	ns
Tillers/plant	3	3	ns
Heads/plant	3	3	ns
Grain Yield (t/ha)	1.8	1.8	ns
Grain weight (hL)	80.8	82.0	0.9
Gravimetric Soil moisture (%) post harvest	20	24	ns

Table 4. Stubble height, plant establishment, early dry matter and grass weed numbers of self-regenerating medic and final gravimetric soil moisture in stripper and conventional stubble at Minnipa, 2023.

Stubble Treatments	Stubble Height (cm)	Plant Establishment (plants/m ²)	Early Dry Matter (t/ha)	Grass weeds (plants/m ²)	Gravimetric Soil Moisture to 90 cm after medic senescence (%)
Stripper stubble (high)	68 a	28	0.3	15 b	48.2
Conventional stubble (low)	13 b	44	0.4	22 a	45.1
LSD (P=0.05)	2	ns	ns	8	ns

Table 5. Spray coverage in stripper and conventional stubble of self-regenerating medic pasture in unfenced and fenced areas at Minnipa, 2023.

Stubble Treatments	Spray Coverage (%)	
	Unfenced	Livestock exclusion (fenced)
Stripper stubble (high)	11.2 b	20.4 a
Conventional stubble (low)	16.0 ab	12.4 b
LSD (P=0.05)	5.7	

What does this mean?

Across all sites, the stubble treatments resulted in stripper stubble of 64 ± 4 cm high and conventional draper front stubble system with stubble of 15 ± 2 cm high. Lentil establishment was higher in the stripper stubble than conventional stubble at Cleve, but plant dry matter was higher in the conventional stubble. The grower disc seeder was used to sow both stubbles so the conventional stubble system may have had poorer seed soil contact due to more stubble lying on the ground.

Rolling also improved plant establishment at Cleve. There were no differences in lentil grain yield due to rolling, however, the benefit at harvest of a flatter soil surface is often important. The improved dry matter production of the lentils in the conventional low stubble followed through to a yield improvement in lentils of 0.5 t/ha in 2023. There were no differences in % spray coverage with the different stubble systems using the Miller 7380 with spray air system with a water rate of 45 L/ha used which improved penetration into the stubble canopy.

At Buckleboo, the pre-seeding herbicide application had higher spray coverage with the conventional low cut stubble system than the stripper stubble system. There were no differences in wheat establishment, growth,

tiller number, grain heads or yield due to the different stubble systems.

Self-regenerating medic at Minnipa, established better in the conventional stubble than in the stripper stubble, but there were no differences in dry matter production mid-season. More weeds were present in the lower stubble compared to the stripper treatment. The spray coverage was highest in the ungrazed high stubble compared to the other systems.

In 2023, Buckleboo had higher soil moisture in the stripper stubble compared to the conventional stubble, and at Cleve stubble unrolled treatments had higher soil moisture than rolled. Ideally to test the effect of the additional stubble retained in the stripper system on soil moisture over the summer period the stubble treatments would be established at harvest in 2022.

A new project, NGN project “Impact of stripper front and straw length on harvest efficiency, summer weed control, soil moisture retention and pest populations in the Upper Eyre Peninsula” has been funded by GRDC for two seasons. Stripper stubble and two heights of conventional stubble have been implemented directly after harvest in 2023 at Minnipa and Cleve and are ready for the

2024 growing season to monitor the effects of stubble and soil evaporation. This will provide detailed research on soil moisture, measured using in-situ 0-30 cm soil moisture probes over summer in different stubble systems.

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 the Oswald, Bammann and Vandeleur families for hosting the demonstration sites on their farms. Thanks to Katrina Brands, Marina Mudge, Rebecca Tomney and Cate Scholz for their technical support and assistance in completing field work.



Best practice for early sowing opportunities

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Location
Penong

Rainfall
Av. Annual: 317 mm
Av. GSR: 240 mm
2023 Total: 219 mm
2023 GSR: 125 mm

Paddock history
2022: Wheat
2021: Legume pasture
2020: Wheat

Soil type
Sandy loam

Plot size
10 m x 1.76 m x 3 reps x 25.4 cm row spacing

Location
Cowell

Rainfall
Av. Annual: 260 mm
Av. GSR: 125 mm
2023 Total: 309 mm
2023 GSR: 167 mm

Paddock history
2022: Wheat
2021: Pasture (ploughed with offset disc in November)
2020: Barley

Soil type
Sandy loam

Plot size
10 m x 1.76 m x 3 reps x 25.4 cm row spacing

- **Seed priming increased early crop establishment in Calibre wheat at Penong, but this did not increase grain yield.**

Why do the trial?

More growers Australia-wide are considering dry sowing early due to larger seeding programs. On the upper Eyre Peninsula, in several seasons, dry sowing occurred with seeds placed in the soil for many weeks with limited soil moisture. Although some seeds still germinated, the delayed plant emergence often resulted in poor plant establishment. Therefore, questions were raised by farmers about which soil factors influence seed germination and establishment. A project “best practice for early sowing opportunities” was led by AIR EP and delivered by SARDI Minnipa Agricultural Centre, to build on the results from a past SAGIT investment “Improving the early management of dry sown cereal crops” (S419) by Amanda Cook. In 2021, the SAGIT trial at Minnipa evaluated seeding depth and the new long-coleoptile wheats had the best early and late dry matter. Sowing seed early in a position to utilise any moisture present at the time was important as the deeper sown management treatments had earlier emergence at two sites. The long coleoptile wheats may provide an opportunity for earlier plant establishment and dry matter production where moisture is present below the conventional seeding depth.

The SAGIT research project finished in June 2022 with the following findings:

- Better plant establishment was achieved by separating fertiliser (especially urea) to 3 cm below the seed, which achieved similar germination to using nil fertiliser at seeding.
- If fertiliser separation cannot be achieved in the seeding operation, then using MAP (10:22) with the seed is a safer option than DAP. Also consider applying urea pre or post seeding by broadcasting.

In 2023, SA Drought Hub funded demonstration sites were a tool for engaging farmers and increasing awareness of options to improve early plant establishment and to show the impacts of fertiliser toxicity on seed germination and emergence.

How was it done?

In 2023 two demonstration sites were conducted at Cowell and Penong. The treatments implemented were management options to potentially improve early plant establishment and to show the impacts of fertiliser placement on seed germination and emergence.

The sites were sown on 1 May (Cowell) or 2 May (Penong) with Scepter or Calibre wheat aiming for 180 plants/m². Both sites were sprayed with Weedmaster 2 L/ha, Li700 400 ml/100 ml, Estericide Xtra 680 400 ml/ha, Trifluralin 1.15 kg/ha and Sakura 118 g/ha prior to seeding.

Key messages

- **Poor crop establishment in an early sown crop did not reduce grain yield in the 2023 season.**
- **55 kg/ha MAP + 5 kg/ha urea applied with the seed resulted in the highest final yield at both Cowell and Penong site compared to other treatments.**

Fertiliser rates were 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. Primed seeds were soaked in water or potassium sulphate solution (K₂SO₄) for 4 hours then air dried for 30 minutes in trays immediately before sowing (Table 1).

NVDI and early dry matter were sampled on 4 July at Penong and on 6 July at Cowell. Late dry matter was assessed on 30 August at Penong and 8 September at Cowell. The Cowell trial was harvested on 24 October and Penong on 1 November 2023.

What happened?

Crops were sown early into moist soils in the 2023 season due to April rainfall. The gravimetric soil moisture content measured at sowing (0-10 cm) at Cowell was 4%, with a Phosphorus Buffer Index (PBI) of 74. The key available nutrient levels for 0-10 cm were Colwell phosphorus (P) 7 mg/kg, nitrate nitrogen (N) 11 mg/kg and

Colwell potassium (K) 303 mg/kg. Penong had a gravimetric soil moisture content of 8% in 0-10 cm zone. The 0-10 cm soil test showed a PBI of 91, 13 mg/kg P and N 12 mg/kg and K was 490 mg/kg.

Crop establishment averaged 98 plants/m² at Cowell and Penong, both well below the target of 180 plants/m². The highest establishment rates at Cowell in good sowing conditions were Treatment 4 (60 kg/ha DAP plus 25 kg/ha urea) and Treatment 10 (55 kg/ha MAP + 5 kg/ha urea applied with seed primed in 1% K₂SO₄ for 4 hours) (Table 2). The lowest plant establishments were in Treatment 3 (DAP and urea placement below the seed) and Treatment 5 (DAP with the seed) (Table 2).

At Penong, crop establishment appeared to have two main response groups (Table 2). Most treatments (Treatments 1, 4, 5, 7, 8, 10 and 11) were not significantly different to the Nil control for plant emergence in 2023 (Table 2). The second response group had lower emergence, Treatment 3 (DAP and urea placement below the seed) was similar to Treatment 6

(MAP and urea below the seed), Treatment 2 (Calibre unprimed) and Treatment 12 (Scepter wheat primed 4 hours in water) (Table 2).

At Cowell, Treatment 8 (MAP with seed + 5kg/ha urea) (Table 3) had the highest early dry matter (DM), followed by Treatment 9 (Nil fertiliser). However, the differences in DM weight between Treatment 9 and most other treatments were not significant. Treatment 1 (Calibre, primed) and 2 (Calibre, unprimed) had the lowest early DM weights. There were no significant differences in late DM measured at Cowell.

At Penong, Treatment 8 (MAP with seed + 5kg/ha urea) (Table 3) had the highest early DM weight, but the difference is not very significant when compared with most other treatments that includes the combination of phosphate fertilisers and urea. Treatment 1 (Calibre primed) had the lowest early DM weight. In late DM measurements, Treatment 5 (DAP with seed) had the highest weight, but it was not significant when compared to other treatments. Treatment 1 (primed Calibre) again had the lowest DM.

Table 1. Early sowing treatments at Cowell and Penong in 2023. Scepter was used in all treatments except for first two (*Calibre was used).

Treatment No.	Treatment	Seeding strategy
1	*Calibre, primed with water (4 hours)	Sown at 6 cm with 55 kg/ha MAP + 5 kg/ha urea
2	*Calibre, unprimed	Sown at 6 cm with 55 kg/ha MAP + 5 kg/ha urea
3	DAP + urea below seed	60 kg/ha DAP + 25 kg/ha urea applied 3 cm below seed
4	DAP + urea with the seed	60 kg/ha DAP + 25 kg/ha urea applied with the seed
5	DAP with seed	60 kg/ha DAP applied with seed
6	MAP + urea below seed	55 kg/ha MAP + 30 kg/ha urea applied 3 cm below seed
7	MAP + urea with the seed	55 kg/ha MAP + 30 kg/ha urea applied with the seed
8	MAP with seed	55 kg/ha MAP + 5 kg/ha urea applied with the seed
9	Nil fertiliser	No fertiliser
10	Primed with 1% K ₂ SO ₄ , normal depth (4 hours)	55 kg/ha MAP + 5 kg/ha urea applied with seed primed in K ₂ SO ₄
11	Unprimed, 1 % K ₂ SO ₄ fluid @ 80L/ha, normal depth (control)	55 kg/ha MAP + 5 kg/ha urea applied with the seed, K ₂ SO ₄ solution with seed
12	Primed, normal depth (4 hours)	55 kg/ha MAP + 5 kg/ha urea applied with the seed primed in water

Table 2: Crop establishment (plants/m²) at Penong and Cowell with different seeding strategies in 2023. Scepter wheat was used in all treatments except for first two (where Calibre wheat was used). Significant differences between means at P=0.05 are shown by a different letter.

Treatment No.	Plant establishment	
	Cowell	Penong
1*	101 bcd	132 a
2*	75 ef	72 de
3	63 f	58 e
4	137 a	101 abcd
5	82 def	102 abcd
6	89 cde	75 de
7	109 bc	112 abc
8	89 cde	100 bcd
9 Nil Control	109 bc	115 abc
10	115 ab	110 abc
11	98 bcde	121 ab
12	105 bcd	85 cde
LSD (F prob=0.05)	26	31

Table 3. Early and late dry matter weight (t/ha) with different seeding strategies at Cowell and Penong, 2023. Significant differences between means at P=0.05 are shown by a different letter.

Treatment No.	Cowell		Penong	
	Early DM	Late DM	Early DM	Late DM
1*	1.31 d	5.76	0.29 e	1.17 d
2*	1.48 cd	6.84	0.46 bcd	1.55 bc
3	1.55 bc	7.08	0.39 de	1.33 cd
4	1.7 bc	6.49	0.45 cd	1.51 bc
5	1.62 bc	6.67	0.57 abc	1.98 a
6	1.53 cd	6.55	0.52 abcd	1.42 bcd
7	1.64 bc	6.54	0.47 bcd	1.53 bc
8	1.94 a	7.04	0.61 a	1.6 bc
9 Nil Control	1.78 ab	7.23	0.52 abcd	1.52 bc
10	1.69 bc	6.41	0.52 abcd	1.56 bc
11	1.58 bc	7.15	0.57 abc	1.68 ab
12	1.65 bc	6.81	0.58 ab	1.57 bc
LSD (F prob=0.05)	0.24	ns	0.13	0.29

At Cowell, Treatment 8 (MAP with seed + 5kg/ha urea), Treatment 11 (Unprimed, K₂SO₄ fluid, normal depth (Control)) and Treatment 9 (Nil fertiliser) (Table 4) had the highest yields at just over 3 t/ha. Treatment 1, 5, 6 and 12 had the lowest yields (Table 4).

At Penong, Treatment 8, 9, 10, 11, 12, 2, 4, 7, 6 and 5 had similar higher yield performance (Table 4), and Treatment 12 (Primed, normal depth (4 hours)), 5 (DAP with seed)

and 3 (DAP + urea below seed) had lower yields. Treatment 1 (Calibre primed) had the lowest grain yield (Table 4).

Grain protein at Cowell increased with increasing grain yields, with an average of 11.4% for the trial. At Penong the protein (%) was similar across treatments with the average being 13.6%.

What does this mean?

These demonstrations were implemented to show best management practice for early sowing and plant establishment. The sites had some soil moisture at sowing due to the good mid-April rainfall in 2023.

Table 4. Wheat grain yield (t/ha) and protein (%) with different seeding strategies at Cowell and Penong, 2023.

Treatment No.	Cowell		Penong	
	Grain yield	Protein	Grain yield	Protein
1*	2.38 e	11.5 abc	0.52 c	13.2
2*	2.77 b	11.3 bcd	0.64 ab	13.5
3	2.6 bcd	11.5 abc	0.59 bc	13.2
4	2.74 bc	11.4 abcd	0.62 ab	13.7
5	2.51 de	11.8 a	0.61 b	13.4
6	2.55 cde	11.6 ab	0.64 ab	13.5
7	2.74 bc	11.1 cde	0.62 ab	13.6
8	3.23 a	10.7 e	0.69 a	14.0
9 Nil Control	3.13 a	11.3 bcd	0.62 ab	13.9
10	2.75 bc	11.2 bcd	0.62 ab	13.6
11	3.19 a	11.0 de	0.64 ab	13.5
12	2.52 de	11.8 a	0.61 b	13.9
LSD (F prob=0.05)	0.21	0.45	0.07	ns

Even though urea placed with the seed along with DAP at sowing (Treatment 4) had the highest crop establishment at Cowell in ideal sowing conditions (opposite of the 2022 trial and previous research), and primed Calibre (Treatment 1) had the highest crop establishment at Penong, these early season advantages in plant establishment did not translate into an increase in either early and late dry matter (DM), final yield, nor protein content, meaning that in a season like 2023, higher crop establishment did not necessarily result in higher yields.

MAP with seed (Treatment 8) did not show a high crop establishment at either site, but did have the highest early and late DM's, along with the highest final yield and protein level, indicating low crop establishment in early season did not result in final yield reduction either. In addition, no other phosphate fertilisers and urea combination strategies showed significant improvement in final yield, as base rates of fertiliser applied were adequate for crop demand in a low decile season.

Primed Calibre seeds (Treatment 1) had relatively high crop establishment at Cowell and the

highest crop establishment at Penong but resulted in the lowest early and late DM weights and final yield. However, due to the long, dry period during winter in this growing season, the already established plant roots may have drained soil moisture before other treatments, therefore amplifying the impact of drought that hampered biomass production, resulting in lower final yields.

Even though K₂SO₄ solution did not improve crop establishment, it did improve final yields compared to the crop where seeds were not primed. This result was not shown in the 2022 trial.

These demonstration trials will be continued in 2024 in other regions allow grower extension, discussion and learning of the best management practices for early seeding.

Acknowledgements

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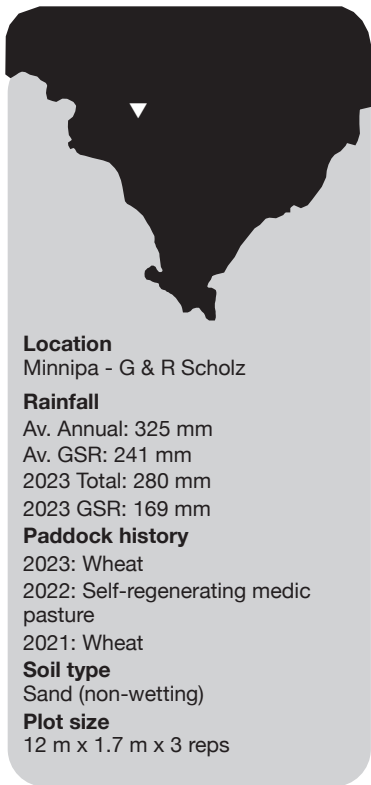
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Developing robust groundcover to promote resilience in low rainfall mixed farms using seed priming

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Key messages

- **Seeding into the soil moisture zone either shallow (2023) or deeper with a long coleoptile variety (2022 and 2023) can best maximise plant establishment and stubble groundcover in non-wetting sandy soil conditions.**
- **In 2022, deeper seeding improved 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 under**

laboratory conditions, but it did not improve plant establishment under field conditions in 2022 and 2023.

- **Soil wetter on a non-wetting sandy soil resulted in a small improvement in wheat crop establishment and early vigour in 2022.**

Background

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

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 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 2023 a trial was implemented to assess value of hydro-priming on a non-wetting sand in the field. The replicated small plot field trial was established in a non-wetting sand near Minnipa to evaluate

the impact of two seed priming levels (12 vs 21 h soaking in water), seeding depth (shallow, medium, deep) and a soil wetter. Using a knife point press-wheel plot seeder, twelve treatments (Table 1) were applied to 6 rows wide x 12 m long field plots which were arranged in a randomised complete block design with three replicates.

The trial was sown on 31 May with AGT Calibre (110-115 mm long coleoptile) at 70 kg/ha with 55 kg/ha MAP banded above the seed. A soil wetter (SE14 at 3 L/ha) was delivered in furrow at 80 L/ha volume for appropriate treatments. The trial area was sprayed pre-sowing and in-crop by the grower.

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 12 or 21 h. The imbibed seeds were air dried on paper towel then placed into seeding envelopes for immediate sowing with a cone seeder. In 2022 seed priming was undertaken at 6 and 12 h.

Crop establishment was assessed twice after sowing (9 and 27 June). Early dry matter cuts and NDVI were taken on 25 August. The trial was harvested on 15 November for grain yield and quality assessment.

Table 1. Experimental treatments and targeted settings.

Treatments	Seeding depth (NB: seeds placed at the bottom of the furrow)	Soil wetter	Hydro-priming (hours)
1	Baseline: at the moisture front ("INTO")	No	0
2			12
3			21
4	30 mm deeper than baseline ("BELOW")	No	0
5			12
6			21
7	30 mm shallower than baseline ("ABOVE")	No	0
8		Yes	0
9		No	12
10		Yes	12
11		No	21
12		Yes	21

Table 2. Soil moisture profile data with depth.

Depth (mm)	0-30	30-60	60-90
Average Gravimetric water content (% w/w)	8.1	7.8	7.2

Table 3. 2023 monthly growing season rainfall for Minnipa (mm).

	Jan-March	April	May	June	July	Aug	Sept	Oct	Nov-Dec	GS (mm)
2023 Season rainfall	38	33	19	48	21	25	15	7	75	169
Long Term Average	46	18	34	43	45	43	32	26	40	241

The 2023 growing season rainfall was below average, with stored soil moisture from the previous summer (November 2022). There was opportunity for very early seeding following a 13 mm break of the season on 15 April, but with an increased risk of frost. Most seeding programs started in mid-late April and were completed in drier conditions with only smaller rainfall events in May. Late May saw two 4.5 mm rainfall events which wet up the soil profile before seeding the trial and broad acre demonstration in late May/early

June. The Minnipa monthly rainfall for 2023 is listed in Table 3. In the 2023 season Minnipa recorded a decile 2 growing season rainfall (April-October) and a decile 4 total rainfall, which was complemented by stored subsoil moisture from summer 2022.

What happened?

Plant Establishment

Seeding conditions in 2023 were into moist conditions with 9 mm of rainfall occurring the week before. The first crop establishment count

was taken 10 days after sowing on 9 June. Shallower sowing had higher initial plant numbers (extra 24 plants/m²) compared to sowing deeper (Table 4).

The second plant counts were taken 28 days after seeding and seeding depth still impacted on plant germination with the shallower sowing and the deeper sowing having better establishment of 123 plant/m² (an extra 15 plants/m²) than the intermediate sowing depth ‘into’ moisture (Table 4).

Table 4. Crop establishment on 9 and 27 June 2023 for the 3 seeding depth treatments. The letters within the table represent the LSD of treatments which are significantly different at LSD (P=0.05).

Seeding depth	Plant establishment (plants/m ²) 9 June	Plant establishment (plants/m ²) 27 June
30 mm shallower than baseline ("ABOVE")	70 b	123 b
Baseline: at the moisture front ("INTO")	60 ab	110 a
30 mm deeper than baseline ("BELOW")	46 a	123 b

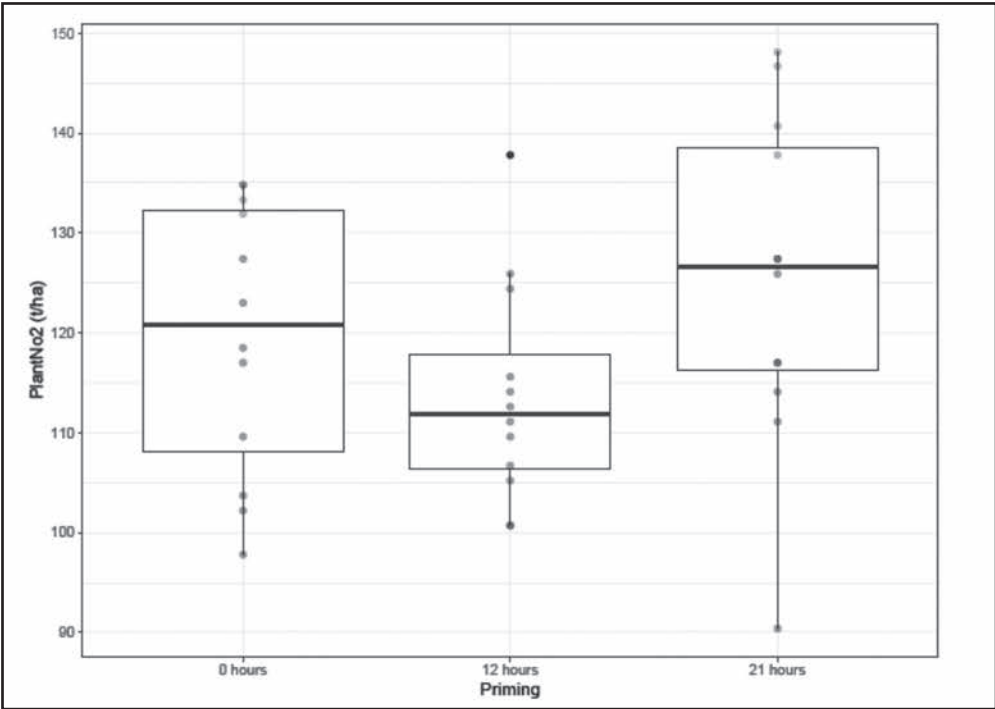


Figure 1. Crop establishment on 27 June 2023 for the 3 seed priming treatments. The letters within the graph represent the LSD of treatments which are significantly different at LSD (P=0.05).

Seed priming for 21 hrs showed a significant benefit over priming for 12 hours (Figure 1) with an extra 13 plants/m² on average. The addition of a soil wetter in furrow provided no significant benefit in plant establishment at seeding in 2023.

Early dry matter (t/ha) and NDVI

In 2023 there were no treatment differences in early dry matter (t/ha) and NDVI readings in season. In 2022 the treatment impact on early dry matter were similar to that on crop establishment with the highest values in the deep seeding treatments.

Grain yield (t/ha) and quality

In 2023 there were no differences in wheat grain yield with seeding position, seed priming or soil wetter, with the trial averaging 0.86 t/ha. 2023 was a decile 2 growing season with a dry winter and spring which limited grain fill.

Grain protein, screenings, test weight or 1000-grain weight were not affected by seeding position, seed priming or soil wetter in 2023. In 2022 deep seeding slightly increased protein content and grain size (1000-grain weight).

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 and the importance of sowing into soil moisture to improve crop establishment.

Overall, the results from the 2022 and 2023 trials confirmed the importance of seeding wheat into soil moisture, most commonly found deeper, to potentially capture benefits in crop establishment, with the potential for both quality and productivity gains in sandy soil conditions.

In an above average season in 2022, 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 in a decile 7 season with significant subsoil moisture storage pre-season.

In 2023, a contrasting decile 2 growing season showed sowing shallow after a 9 mm rainfall event provided better early plant establishment, which was equivalent to deeper sowing by 28 days after sowing. Seed priming for 21 hours showed a benefit over priming for 12 hours for improving crop establishment 28 days after sowing but this was not different to Nil priming. There were no differences in either plant growth or grain yield in this dry season.

Overall, the results provide further evidence that using longer coleoptile varieties to position seed within the soil moisture zone (deeper if needed) will provide better plant establishment, with potential impact on reducing the risk of early erosion. The 2022 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 little effect on late biomass production.

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 both 2022 and 2023. In practice, primed seeds might readily lose absorbed water to surrounding soil when placed in sub-optimal conditions in the soil depending on where the moisture is in the seed furrow, thus potentially cancelling any positive effect of priming. In contrast, sowing into greater soil moisture would also provide more protected moisture levels, expected to allow seed priming benefits to be more reliably expressed. In 2022 the significant but late post-seeding rainfall had resulted in more favourable soil moisture levels, reducing the potential benefits of seed priming due to overly dry soil in the first 3 weeks.

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Department of Primary
Industries and Regions



Fast Graphs for Slow Thinking about Nitrogen

Barry Mudge¹ and Peter Hayman²

¹Barry Mudge Consulting; ²SARDI Climate Applications

Background

Most people will agree that agriculture is a “risky” business. Uncertainty, primarily around seasons and commodity prices, create challenges for decision making. Fortunately in Australia, we have a long history of farmer experience, combined with an excellent R, D and E system which gives us knowledge in how to deal with this uncertainty. But there still remains some decisions that are tough calls - and getting these more right, more often can be important to long term profitability of farm businesses.

GRDC have recognised this issue and have supported a program called the National Risk Management Initiative - or RiskWi\$e for short, to address it. This project aims to improve growers’ management of risks, by empowering them with better understanding of upside and downside of important decisions. RiskWi\$e is a participatory research project involving farming systems groups and research partners from across Australia. On EP, it is being coordinated through AIR EP.

Through RiskWi\$e, GRDC has recognised the importance of farmer psychology. The famous psychologist, Daniel Kahneman, in his excellent internationally best-selling book, “Thinking Fast and Slow”, investigates human rationality and irrationality. He observed that “...most of our judgements and actions are appropriate most of the time... But not always.” Kahneman distinguishes between fast thinking, which is instinctive, recognises patterns and jumps to conclusions,

and slow thinking, which is more deliberative and logical.

The developing field of behavioural science provides us with understandings of why we may not be the pillars of rational decision making that we like to think we are - things like loss aversion, cognitive bias’s, effect of stress etc. The authors also believe that there also remains a significant gap in analytics - tools which apply relatively simple techniques at a farm level to aid decision making.

Comparing the upside and downside of a decision involves weighing up a range of possible futures. This is mentally demanding to do in your head, but relatively easy in a spreadsheet. Our idea is to get the information quickly into a graph that shows the upside and downside of the decision in question (we estimate less than 20 minutes), so that we can then have a useful conversation about the judgement we need to make. This follows the advice of Professor Bill Malcolm, the Farm Management economist from the University of Melbourne: ‘simple figuring and sophisticated thinking’. Below we provide an example of how this process looks.

The Nitrogen Decision Example

Figure 1 describes the decision dilemma of applying additional nitrogen to a mildly deficient crop. Investing in nitrogen is highly profitable when sufficient rainfall is received to take advantage of the additional fertiliser. The simple rule of thumb is that 40 kg of N/ha is required for an additional one tonne per ha of wheat grain. With urea at, say, \$700/t (and an

application cost of \$10/ha) this means that investing around \$70/ha (approx 40 kg N/ha) could result in a return of one tonne of wheat at, say, \$350-400. But low spring rainfall would not allow this return to be realised. On the other hand, farmers are often consoled by the thought that N applied which is unused may still carry-over to other crops in subsequent years.

Estimating the supply of N can be challenging- we can use deep soil testing or look at paddock history for starting N levels then use some estimate for in-season mineralisation from organic matter. And estimating the crop demand for N is even more difficult because of the uncertain finish to the season. The traditional approach is to select a target yield, based on soil moisture, seasonal conditions to date and some guesstimate of what the season might do from now on. The N required for this target yield is then matched up against the estimate of supply to arrive at the additional N which needs to be supplied as fertiliser.

We believe that applying some simple economics and risk to this discussion does not involve a lot of extra work but can provide a rich source of information to aid the N decision question.

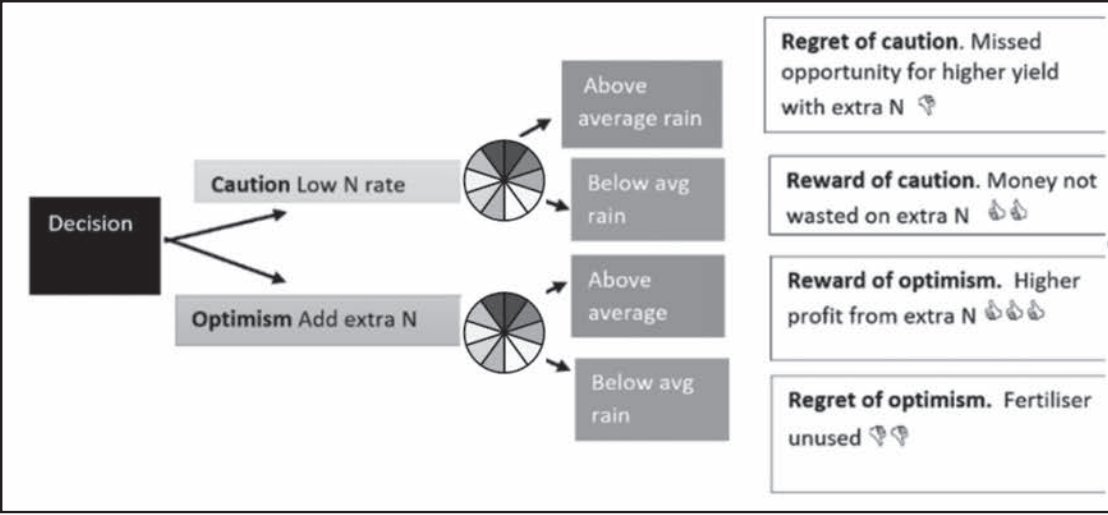


Figure 1. A simple N decision tree that considers an in season tactical decision to add extra N to a crop.

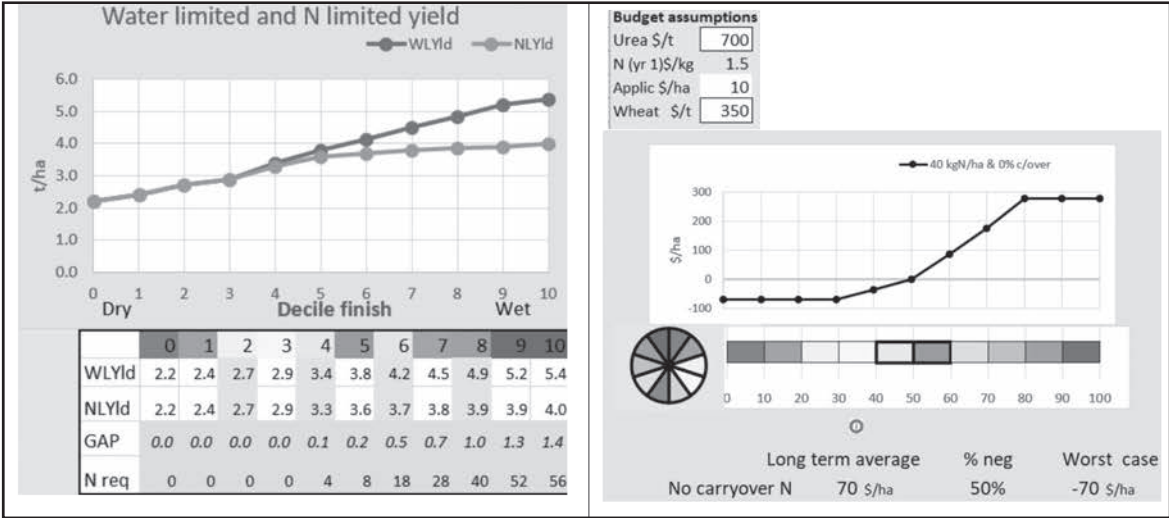


Figure 2. Screenshot of Fast Graphs for Slow Thinking. Left hand panel showing the yield with adequate N and limited by water (WL) and the yield limited by nitrogen (NL). Right hand panel shows the profit by decile graph for the application of 40 kg N/ha, which is similar to aiming for decile 8 where the gap between the water and N limited yield is 1 t/ha.

We have developed a spreadsheet which allows us to do this. This version of Fast Graphs for Slow Thinking wasn't developed as another decision support system for nitrogen; the aim was to explore how the upside, downside and probability weighted average of N decisions are changed by the cost of N and price of wheat, levels of carryover N, and seasonal climate forecasts. In doing this, we were testing the usefulness of a simple decision analysis to run the N budget across deciles, rather than pick a single target yield.

Figure 2 shows that the long-term average return from adding 40 kg N/ha to this crop is assessed at \$70/ha with a break even at around Decile 5. If a farmer was to have

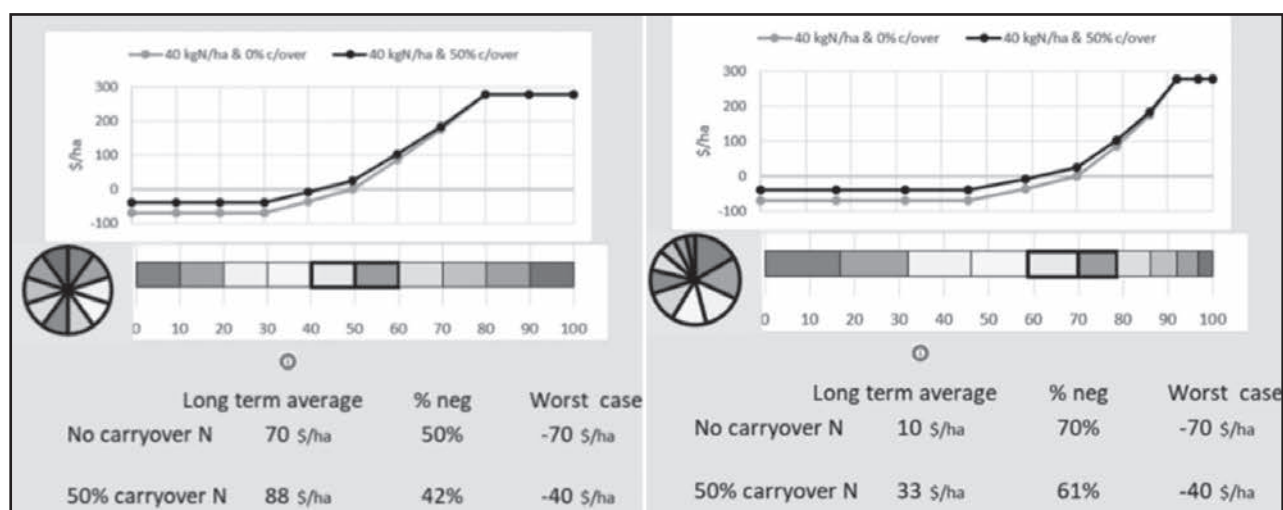
a similar crop over a long period, then applying 40 kg/ha of N would result in an average gain of \$70/ha/year and the result would be positive in 50% of the years.

As indicated earlier, we can also look at changes in seasonal outlook probabilities along with the considerations for carry over N.

A forecast doesn't change the future, it changes the likelihood of different future outcomes occurring. Figure 3a and 3b show the result when the probability of receiving above average rainfall is shifted from 50% to 30%.

Figures 3a and 3b show the return (profit/ha y axis) from adding 40 kg N/ha assuming urea is \$700/t,

urea spreading is \$10/ha and wheat is valued at \$350/t. In Figure 3a the rainfall decile outcomes (coloured rectangles on the x-axis) are equally distributed. In Figure 3b the probability of receiving above average rainfall (coloured rectangles on the x-axis) is shifted from 50% (equally distributed deciles) down to 30% (skewed distribution of deciles to the dry end). In both graphs the lighter line with lighter circles shows returns (\$/ha) from each decile assuming no N carryover into subsequent years. The black line with black circles shows the impact of 50% of applied N carrying over into the following year.



Figures 3a and 3b showing the return (profit/ha y axis) from adding 40 kg N/ha assuming urea is \$700/t, urea spreading is \$10/ha and wheat is valued at \$350/t. In Figure 3a, the probability of achieving above average rainfall is set at 50% (i.e. historic climatology). In Figure 3b, this probability is shifted down to 30%. The % neg is the probability of making a loss.

In assessing the value of N carry-over, the assumptions are that (i) a proportion between 0% and 90% (as selected) of the unused N will be available for subsequent crops, and (ii) the N carried forward to the next crop is valued as a saving in N fertiliser for the subsequent crops. Figure 3a and 3b show how carryover N of 50% reduces the loss in poor seasons but has no impact in rainfall deciles 8 and above because all the N applied in the first year is used by that crop. Including a 50% carryover of unused nitrogen changes the probability weighted average from \$70 to \$88 where there is an equal distribution of rainfall deciles (Figure 3a) and from \$10/ha to \$33/ha where there is skewed distribution of rainfall deciles toward drier outcomes (Figure 3b).

Conclusion

The RiskWi\$e project is about better understanding risk and reward in all parts of the grain

farm and is therefore more than an initiative about N risk-reward. It does however provide a rich opportunity for conversations about the risk and reward of N use in our grain production systems. Because getting N topdressing exactly right is almost impossible due to the variable climate, it is better to consider the consequences of erring on the side of applying a bit extra N or too little N. Budgeting tactically across deciles takes a bit longer than budgeting for a single target yield, but we have found that once growers see the graph showing the upside and downside, decision making becomes more informed and easier.

The end point is more complete conversations about risk and reward which are improved by insights from the behavioural sciences. Our contention is that the applied economic tool of decision analysis has a role, not so much in the answer it provides, but in the conversations it generates about

probability, recency bias, loss aversion and allowing for range of outcomes rather than planning for a single, most likely future. Fast Graphs for Slow Thinking is one approach to stimulate thinking for improved decision making.

A short video describing the use of the Fast Graphs for Slow Thinking N tool in one situation in SA can be accessed through the following link: <https://youtu.be/G8nUHXOLR90>

Acknowledgements

RiskWi\$e (the National Risk Management Initiative), is a 5-year national initiative of around \$30 million that will run from 2023 to 2028. It seeks to understand and improve the risk-reward outcomes for Australian grain growers by supporting grower on-farm decision-making.

RiskWi\$e was established through an investment of the Grains Research and Development Corporation (GRDC).

RiskWi\$e

– the National Risk Management Initiative



Improving risk-reward outcomes through on-farm decisions: RiskWi\$e

Rick Llewellyn, Lindsay Bell and Brendan Brown

CSIRO

Key messages

- **RiskWi\$e is a national risk management initiative officially launched by GRDC in August 2023 and AIR EP is one of 6 lead grower and advisor-based organisations.**
- **It is aimed at developing practical ways to support grain growers to better manage risks associated with production and price volatility and the range of uncertain factors facing farm management decisions.**
- **While nitrogen management is seen by growers as the most challenging of the 'risky' crop agronomy decisions, other major farm-level decisions such as expansion, machinery & technology investment and grain marketing are often seen as particularly difficult.**

Why do the work?

With the level of volatility faced by Australian grain growers among the highest internationally, there have been longstanding calls about the potential benefits from greater representation of risk and incorporating greater consideration of the range of possible uncertain outcomes when making key farm management decisions (e.g. Keogh 2012). Part of this also involves recognising the range of biases that can influence decision-making. And there's no shortage of decision-makers happy to acknowledge that a

bias may have negatively affected some of their farm management decision-making behaviour (e.g. when a particular result in the most recent season's conditions may have overly influenced this season's decision-making). But it is also recognised that being too slow and complicated in making some regular common decisions can raise its own risks. RiskWi\$e is working with local growers and advisors led by AIR EP and similar groups nationally to take a farming systems approach to bridging the gap between the potential for more robust risk-return analysis and practical ways to better inform 'risky' decisions.

How is it being done?

RiskWi\$e is working with growers and advisors in partnership with researchers across Australia through a network of grower-based groups (see logo block below). AIR EP leads the activity on Eyre Peninsula and is one of six action research leads nationally. In the first season (2023) work began with a focus on nitrogen-related decision making including a set of trials of different N-decision approaches and risk levels, as well as other focus paddock activity.

Over 50 field sites have been established across the GRDC Western, Southern and Northern regions in the first season and this field-based activity will be brought together with climate, price and economic analysis through research partners (e.g.

Hayman & Mudge 2024), as well as important consideration of the human-elements of decision-making behaviour.

While nitrogen is recognised as being among the most challenging of the crop agronomy decisions (Figure 1), RiskWi\$e activity will soon expand to tackle other themes identified as being most relevant. These include other major sowing/crop choice decisions and whole-farm business level decisions such as farm expansion, machinery and technology investment decisions and marketing which have consistently ranked as the most challenging 'risky decisions' in consultations with growers (Figure 1).

What does this mean?

A major objective of RiskWi\$e is to enable more growers and advisors to better consider the probabilities of possible outcomes and assess the risk-reward payoffs for important management decisions – in a practical way. Often this may just mean more opportunities for an extra step of well-informed 'simple figurings'. The ultimate aim is to lead to better decisions more often in an increasingly risky farming environment. There will be many opportunities to be part of this collaborative grower group-based initiative at the local level.

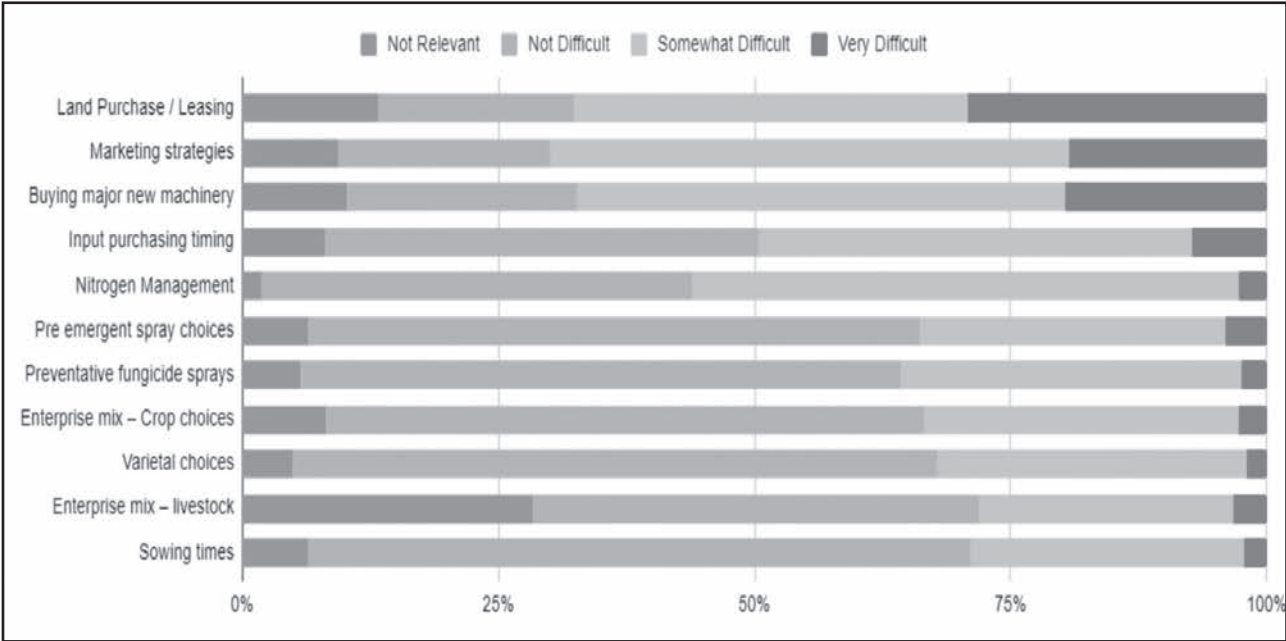


Figure 1. Rating of difficulty (% of growers) of different types of farm management decisions involving risk (based on preliminary 2023 data from 412 grain growers nationally).

References

RiskWi\$: grdc.com.au/research/partnerships-and-initiatives/strategic-partnerships/riskwise

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AARES Conference. (<https://ideas.repec.org/p/ags/aare12/124202.html>)

Acknowledgements

RiskWi\$ is a GRDC-initiative involving the following partners:

RiskWi\$

– the National Risk Management Initiative

GROWER | ADVISOR | EXTENSION GROUPS

RESEARCH PARTNERS

ACTION RESEARCH GROUP LEADS

PRINCIPAL PARTNER

NATIONAL PROJECT LEAD

Establishment of Lower EP cropping systems trial

Andrew Ware¹, Brett Masters¹, Jacob Giles¹, Matt Knowling², Glenn McDonald² and Rodrigo Coqui da Silva²

¹EPAG Research; ²The University of Adelaide



Location
Edillilie - Mark Modra
AIR EP

Rainfall
Av. Annual: 420 mm
Av. GSR: 340 mm
2023 Total: 342 mm
2023 GSR: 268 mm

Yield
Potential: Wheat derived from Yield Prophet 50% probability (4 July)
6.0 t/ha
Actual: Wheat 4.7 - 5.2 t/ha

Paddock history
2022: Canola
2021: Faba beans
2020: Wheat

Soil type
Ironstone gravel, red brown earth, Chromosol

Soil test
pH (CaCl) 0 - 10 cm: 6.77

Plot size
10 m long x 1.5 m wide, with buffer plots either side, planted to the same crop x 3 replicates

Trial design
Experimental: Fully phased crop rotation, with complete plot randomisation

Yield limiting factors
Terminal drought

Key messages

- This is the first year of a long-term experiment looking to shed light on increasing productivity and sustainability of Lower Eyre Peninsula farming systems.
- An early break to the season followed by decile 2-3 growing season rainfall at Edillilie in 2023 saw

conditions get close to waterlogging in late June, but then soil conditions rapidly dried out and bought an early end to the season.

- Conditions weren't suitable for disease to proliferate in pulse, cereal or canola crops.
- There was no response to higher rates of nitrogen, as lower rates of nitrogen were sufficient to reach water limited yields.
- Lentil yielded around 2.0 t/ha, faba bean 2.5 t/ha, canola 3.1 t/ha and wheat 5 t/ha.

Why do the trial?

The trial is part of a network of 9 trials being conducted across SA and Vic as part of the flagship GRDC-University of Adelaide 'Farming Systems South' project (full title: 'Enterprise choice and sequence strategies that drive sustainable and profitable southern Australian farming systems').

The project is motivated by the perceived 'gap' that remains in profitability and efficiency (e.g. gross margin per mm rainfall) despite good single crop agronomy. The project aims to better understand the drivers of profitability and sustainability in farming systems in the southern region, and better realise water-limited potential.

The Eyre Peninsula (EP) trial aims to shed light on the drivers of profitability and sustainability in the Lower EP in terms of strategic

decisions (e.g. proportion of pulse, oilseed and cereals in rotation), tactical decisions (e.g. in-season fertiliser application) as well as the interactions between them. The trial aims to address questions such as: what is the most profitable farming system for Lower EP? Can the yield frontier be lifted through changes to farming systems?

The project is innovative in its (1) evaluation of broader system performance – beyond productivity and explore trade-offs, to better understand "why" systems perform the way they do; and (2) test new systems and how they compare to baseline (e.g. canola-wheat) and alternative systems (e.g. lentil-canola-wheat-wheat), for example, lower input, higher broadleaf proportion, etc.

In addition to agronomic research, the project also involves biophysical modelling and economic evaluation workstreams. The modelling component will enable evaluation of more farming systems with respect to more performance metrics, beyond the trials themselves (e.g. estimation of GHG emissions and its trade-offs with profitability, WUE, etc.).

How was it done?

The Edillilie trial involves the following treatments (Table 1), which were a result of consultation with the AIR EP Medium Rainfall RD&E Committee.

Trial details

Wheat: Calibre sown 12 May 2024

Treatments:

Decile 2 (target yield 4t/ha) - 66 kg/ha N

Decile 5 (target yield 6t/ha) - 112 kg/ha N

Decile 7 (target yield 7t/ha) - 158 kg/ha N

Fungicides applied at GS25 & 49.

Canola: Nuseed Emu sown 12 May 2024 (short season variety sown late as 2023 surrounding crop was also canola)

Treatments:

Decile 2 (target yield 2t/ha) - 75 kg/ha N

Decile 5 (target yield 3.0t/ha) - 121 kg/ha N

Decile 7 (target yield 3.5t/ha) - 167 kg/ha N

Fungicide applied at 10% bloom.

Faba Bean: PBA Samira sown 12 May 2024

Fungicide applied at canopy closure.

Lentil: GIA Thunder sown 12 May 2024

Fungicide applied at canopy closure.

Measurements taken were soil chemistry, starting soil water, Predicta B, weed counts, disease scores, biomass at maturity, grain yield and grain quality.

Table 1. Trial systems/treatments. ‘District practice’ represents the most common practice among local growers (112 kg N/ha applied in 2023). ‘Decile’ refers to a strategy whereby Yield Prophet is used, parameterised with soil water and nutrient sampling results, to determine nitrogen requirements to satisfy a water-limited yield corresponding to a particular rainfall decile.

System ID	Crop rotation	Nitrogen strategies
Baseline	Ca-W	District practice Decile 2 Decile 7
Diverse high value	Lt-Ca-W-W	Decile 2 Decile 7
Diverse	Fb-Ca-W-W	Decile 7

Ca=canola; W=wheat; Lt=lentil; Fb=faba bean.

Table 2. Maturity biomass, grain yield and grain quality measurements collected at Edillilie trial site in 2023.

Crop/N strategy	Biomass (t/ha)	Grain yield (t/ha)	Oil (%)	Test weight (kg/hl)	Screenings (%)	Protein (%)
Canola - D2	9.26	3.12	42.8			
Canola - D7	9.28	3.12	38.8			
Canola - Std	9.38	3.19	40.5			
Faba Bean	6.27	2.54				
Lentil	5.71	2.08				
Wheat - D2	12.32	5.23		80.1	0.9	10.4
Wheat - D7	11.90	4.76		76.6	2.3	12.4
Wheat - Std	12.02	4.79		78.3	2.3	11.3

What happened?

Results are still being analysed by University of Adelaide AAGI group. Table 2 contains preliminary maturity biomass, grain yield and grain quality measurements collected at the site.

What does this mean?

The Edillilie trial has just completed its first year. Given the project's systems focus, requiring the legacy effects within different crop sequences and with different nitrogen strategies, results from 2023 are just the start of the sequences.

There was no positive yield response from higher rates of nitrogen (N) applied above the

Decile 2 treatment, due to the Decile 2 amount being sufficient to reach the water limited yield potential in 2023. There does appear to be a slight negative effect from applying higher rates of N to the wheat, but statistical analysis will need to be conducted to confirm this. Wheat grain quality (particularly test weight) also appears to have been reduced by higher N rates.

One of the critical factors in determining long term profitability of higher nitrogen rates will be if the nitrogen that was not needed for the 2023 crop can be carried over for use in subsequent crops (nitrogen banking) and how that compares to sourcing fixed nitrogen from pulse crops.

Attaining lentil yields of 2 t/ha made the crop a viable alternative to canola in 2023, however the dry finish and lack of water logging may have helped such a positive result. This trial will help assess lentil production in this area over several seasons.

Acknowledgements

GRDC for investing in the Southern Region Farming Systems project. AIR EP Medium Rainfall RD&E Committee for providing advice on treatment structure. Mark and Tamara Modra for allowing us to utilise their land for the trial. Mark Saunders and Gary Miller, EPAG Research, for their assistance on the trial site.

Did long coleoptile wheat varieties have a role for developing robust ground cover on sandy soils at Wharminda in 2023?

Brett Masters and Andrew Ware
EPAG Research



Location
Wharminda Ed and Carolyn and Evan and Lauren Hunt and family Roberts - Verran Agricultural Bureau

Rainfall
Av. Annual: 341 mm
Av. GSR: 252 mm
2023 Total: 358 mm
2023 GSR: 191 mm (Decile 3)

Yield
Potential: 1.6 t/ha wheat
Actual: 2.7 t/ha wheat

Paddock history
2022: Vetch
2021: Barley
2020: Wheat

Soil type
Duplex sand over clay

Soil test
pH, nutrition etc.

Plot size
1.8 m x 4 m x 4 reps

Trial design
Randomised complete block

Yield limiting factors
Nil

reliance on seed reserves and it is recommended that seed intended to be used for deep sowing has high germination and vigour, not affected by weather damage prior to harvest.

Why do the trial?

On the water repellent sands at Wharminda, the years where rainfall is limited at the optimum time for seeding are frequent. This results in low soil moisture in the ‘normal’ seeding depth range (3-6 cm) which can delay sowing and/or cause poor germination, poor early crop vigour and low surface cover for erosion protection. In many years subsurface soil layers contain moisture from earlier summer rainfall with growers wanting to sow crops deeper into this moisture band. However, most of the commonly grown wheat varieties have a shortened coleoptile which can restrict the capacity for plants to emerge and establish in adequate plant numbers from depth (EPFS Summary 2022, p. 48). In 2023, trials investigated the potential for sowing deeper (including with novel long coleoptile varieties) to improve crop establishment on sandy soils at Wharminda under two separate projects: the Australian Government Future Drought Fund (FDF) funded Mallee Sustainable Farming Systems ‘Robust Groundcover’ project in partnership with AIR EP and the Grains Research and Development Corporation (GRDC) funded CSIRO Long Coleoptile Wheat Project). This report summarises the results from the

Future Drought Fund Robust Groundcover trial (FDF RGC) and utilises data collected from the GRDC investment at Wharminda and a contrasting heavier textured soil at Ungarra.

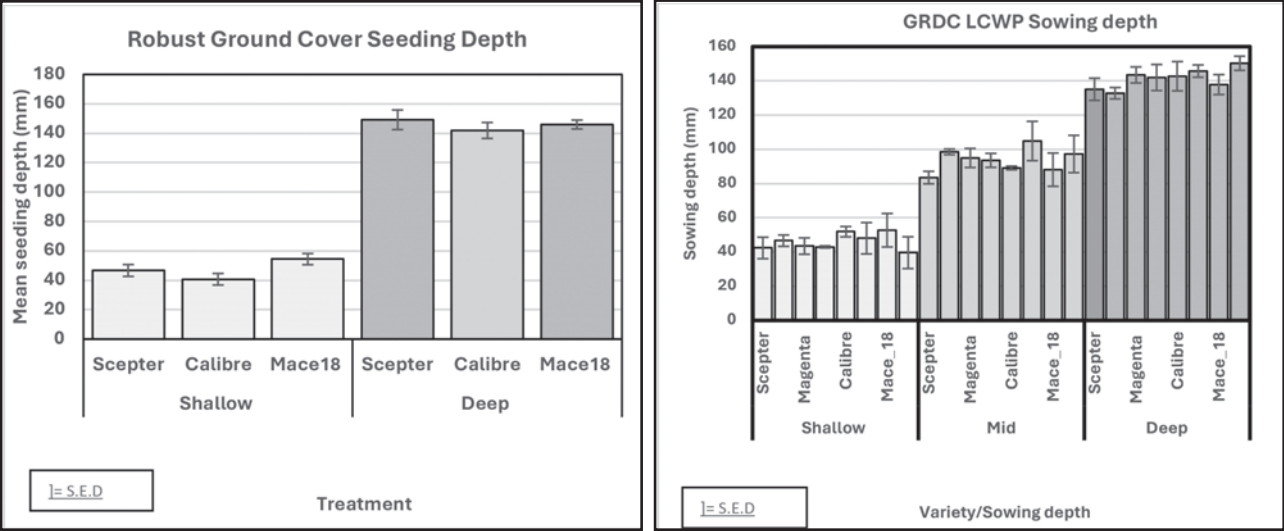
How was it done?

Two widely grown conventional varieties (one shorter coleoptile control (Scepter) and one which has a comparatively longer coleoptile, Calibre) were compared to a new cultivar containing long coleoptile genetics (LC_Mace). Each cultivar was sown targeting two sowing depths, shallow (at 40-60 mm) and at the maximum working depth of the seeder (at least 120 mm). The Wharminda site was sown on 5 May into good subsurface moisture with seeding rates targeting 120 plants/m². The site also received a further 3.5 mm of rainfall immediately after sowing. Plots were fertilised with 80 kg/ha of DAP at seeding and received a further 100 kg/ha of nitrogen during the season.

Measurements were taken for emergence, sub crown internode length, seeding depth, tillers, growth stage, head density, harvest index, grain yield, grain protein, screenings, and test weight. Only a selection of these measurements are reported here. The site was harvested on 7 November 2023. Results were analysed using Genstat®.

Key messages

- Long coleoptile wheat can permit deep sowing to access soil moisture.
- When opportunities arise, it might be possible to use a range of currently available, shorter coleoptile, high yielding genetics sown deeper (6-8 cm) into moisture with only minor establishment and yield penalties.
- When sowing deep, good quality seed is important for emergence due to increased



Figures 1 and 2. Mean sowing depth (mm) by treatment on Wharminda FDF Robust Ground Cover and GRDC Long Coleoptile Wheat projects sowing depth x variety trials in 2023 (error bars show standard error compared to treatment mean).

What happened?

Seeding depths at Wharminda matched targets with average seeding depths on the shallow sown treatments ranging from 41 to 54 mm and 142 to 149 mm on the deep sown treatments (Figure 1). There was no significant difference in sowing depth between varieties sown at the same depth ($P>0.05$).

Further useful information was gained from the adjacent GRDC funded CSIRO ‘Long Coleoptile Wheat’ sowing-depth x variety

trial (conducted on the same site at Wharminda and also on a heavier textured soil at Ungarra), which was sown on the same day with an expanded treatment list including a further 5 cultivars and an intermediate (8 to 10 cm) target sowing depth (Figure 2). Average seeding depths on this trial ranged from 42 to 53 mm on shallow, 83 to 105 mm for intermediate, and 133 to 150 mm on deep sown treatments.

There was rapid emergence of plants in the shallow sown

treatment, with 52 to 76% of the final plant numbers at establishment emerging by 15 May (10 DAS) (Table 1). However, no plants had emerged on the deep sown plots by this date. On shallow sown Scepter and Calibre plots and deep sown LC Mace, plant numbers were close to those at final establishment ($>95\%$) by 23 May (18 DAS), but plant numbers continued to increase on the shallow sown LC_Mace and deep sown Calibre and Scepter plots until 5 June (30 DAS).

Table 1. Mean plant emergence at 2023 Robust Groundcover site at Wharminda on several sampling dates and compared to final establishment numbers.

	Plants/m ²	% of final plant numbers at establishment			Crop establishment when variety sown deep compared to shallow.		
Treatment	15 May (10 DAS)	23 May (18 DAS)	5 June (30 DAS)	15 May (10 DAS)	23 May (18 DAS)	5 June (30 DAS)	(% of shallow sown treatment)
Shallow Scepter	58	92	96	61%	98%	100%	*
Shallow Calibre	66	84	84	76%	97%	97%	*
Shallow Mace 18	45	75	85	52%	87%	98%	*
Deep Scepter	0	36	49	0%	72%	97%	53%
Deep Calibre	0	46	57	0%	80%	99%	66%
Deep Mace 18	0	69	71	0%	96%	99%	83%

Sowing depth was the key driver for crop establishment at Wharminda ($P=0.003$). There was no significant difference between varieties sown at the same depth ($P=0.311$). In 2023 sowing deep resulted in 17 to 47% fewer plants at establishment than sowing shallow.

Assessments of comparative growth were undertaken using NDVI ('greenness index') and Canopeo (% surface cover) in early and late winter. Growth reflected differences in crop establishment with poorer NDVI values and lower % cover where plant numbers were lower. This poor early vigour on the deep vs shallow sown plots continued throughout season. Cool, wet conditions in early winter slowed growth and estimates of crop biomass from NDVI in July were only in the order of 1 t/ha dry matter in the shallow sown treatments (shallow sown), and 200 to 300 kg/ha on deep sown treatments.

These growth differences were also reflected at harvest with deep sown plots yielding 20 to 40% less grain ($P<0.001$) where the same variety was sown shallow. Yields of different varieties sown at the same depth were similar ($P>0.05$) (Table 2). Screenings were comparatively higher in Calibre compared to LC Mace and Scepter ($P=0.002$) sown at the same depth (either shallow or deep).

These results are consistent with the GRDC sowing depth x variety trials at both Wharminda and Ungarra in 2023. The plant establishment penalty for LC Mace when sown at depths >12 cm on the sandy soil at Wharminda in 2023 was only 13% compared to more than 43% on other varieties. Whilst this establishment penalty increased on the loamier soil at Ungarra, LC Mace still had the highest plant numbers when sown deep. However, given good soil

moisture conditions in the top 10 cm at seeding in 2023, shallow sowing resulted in the highest plant numbers and early vigour at establishment. It is worth noting that on the sandier soil at Wharminda most varieties had little establishment penalty ($<20\%$) when sown at the intermediate depth compared to sowing shallow, whilst (apart from LC Mace) sowing at the intermediate depth on the heavier soil type at Ungarra resulted in plant establishment penalties of 20-39% compared to shallow sowing (Table 3).

As was observed in the Robust Ground Cover trial, the poorer early crop vigour and growth from sowing deep at Wharminda in 2023 resulted in lower grain yields compared to sowing at the shallow or intermediate depths (Table 4).

Table 2. Mean grain yield and quality from harvesting Robust Ground Cover trial site Wharminda in 2023.

Treatment	Grain yield (t/ha)	Screenings (%)
Deep Calibre	1.83	2.8
Deep LC_Mace	1.68	1.4
Deep Scepter	1.84	1.7
Shallow Calibre	2.56	0.9
Shallow LC_Mace	2.30	0.5
Shallow Scepter	2.24	0.6

Table 3. Relative plant numbers at establishment as a proportion of the shallow sown varietal control at Wharminda and Ungarra in 2023.

		% of field establishment numbers on shallow sown treatment for variety							
Ungarra	Mid	70	75	79	61	57	84	73	63
	Deep	40	43	43	42	55	56	55	34
Variety x sowing depth		Scepter	Mace	Magenta	Calibre	Scout	Mace_18	Magenta_13	Scout_18
Wharminda	Mid	84	96	84	106	80	84	87	115
	Deep	55	47	60	66	25	87	63	67

Table 4. Comparative grain yields from 2023 Wharminda GRDC LCWP trial when sowing each variety at 8-10 cm and 12+ cm compared to shallow sowing at 4-6 cm.

Wharminda GRDC LCWP Sandy soil 2023 Wheat Yield LC Variety x Sowing Depth (% shallow sowing, 4 cm)								
	Calibre	Mace	LC_Mace	Magenta	LC_Magenta	Scepter	Scout	LC_Scout
8 cm	90%	98%	101%	98%	107%	95%	93%	93%
12 cm	68%	65%	84%	78%	77%	65%	47%	71%

What does this mean?

The Robust Ground Cover trial contrasted strategies of using short and long coleoptile wheat cultivars sown at different depths to improve crop establishment and early surface cover on a sandy soil at Wharminda in 2023. Given good levels of stored subsurface moisture from summer and early autumn rainfall, attempts were made to use tarpaulins to exclude moisture from the surface soil to test the benefit from sowing LC varieties deep into moisture with dry soil at the standard (4-6 cm) sowing depth. However, significant rainfall immediately after seeding resulted in good soil moisture for crop germination in this layer and in 2023 deep sowing (>12 cm) saw reduced early crop vigour, surface cover and grain yield compared to shallow seeding.

This trial and the adjacent GRDC trial suggest that long coleoptile genetics can be used to aid crop emergence if sowing very deep to chase moisture. These results concur with those from Cootra in 2022 (EPFS Summary 2022, p. 92) which demonstrated that in years where surface soils are dry, but there is moisture at depth, cultivars with long coleoptile genetics were able to establish better from deeper sowing.

Results from Wharminda in 2023 also suggested that if there is soil moisture below the traditional seeding depth, current commercial varieties which are grown locally have the capacity to emerge from 6-8 cm with little establishment penalty. Whilst this has improved landholder confidence to sow to 8 cm, plant numbers at establishment were much lower when these

varieties were sown deeper than that and growth penalties should be expected if targeting seeding that deep.

Acknowledgements

Acknowledging the Australian Government’s Future Drought Fund funded Mallee Sustainable Farming Systems (MSF) Robust Ground Cover project for providing the funding to undertake this trial (and the GRDC funded CSIRO Long Coleoptile Wheat Project for establishing complimentary trials at the site). CSIRO for providing the long coleoptile germplasm. The Hunt family for use of their land for the trial. EPAG Research staff (Jacob Giles, Garry Miller, and Mark Saunders) for their assistance.



Section
3

Section Editor:
Amy Keeley
SARDI

Break Crops

Table 1. Eyre Peninsula 2023 NVT canola yields in t/ha and variety yield expressed as a percentage of the site mean and oil content (%) (Source: <https://nvt.grdc.com.au/>).

Nearest Town	Minnipa			Mount Hope			Yeelanna		
Variety Name	Grain yield (t/ha)	% of Site mean yield	Oil % (6% moisture)	Grain yield (t/ha)	% of Site mean yield	Oil % (6% moisture)	Grain yield (t/ha)	% of Site mean yield	Oil % (6% moisture)
Hyola Continuum CL	1.09	102	40.4	3.55	103	49.3	4.07	108	45.7
Hyola Solstice CL	0.96	91	40.6	3.85	111	48.5	4.28	114	45.6
Nuseed Ceres IMI	1.21	114	42.1	-	-	-	-	-	-
Pioneer 43Y92 (CL)	0.96	90	38.4	3.22	93	47.8	3.81	101	44.6
Pioneer 44Y94 CL	1.05	99	38.7	3.61	105	47.7	4.12	109	45.2
Pioneer 45Y93 CL				3.30	96	47.6	3.58	95	44.7
Pioneer 45Y95 (CL)	-	-	-	3.76	109	48.3	3.72	99	43.8
PY421C	1.17	111	37.1	3.60	104	48.2	4.21	112	44.5
PY520TC	-	-	-	3.00	87	46.4	3.24	86	43.1
VICTORY V75-03 CL	-	-	-	3.10	90	49.3	3.22	85	46.4
Site Mean (t/ha)	1.06			3.45			3.77		
CV (%)	6.35			3.90			5.13		
Probability	<0.001			<0.001			<0.001		
LSD (t/ha)	0.11			0.21			0.31		
Sowing Date	28-Apr-2023			28-Apr-2023			27-Apr-2023		

Break Crops



Table 1.(continued from previous page) **Eyre Peninsula 2023 NVT canola yields in t/ha and variety yield expressed as a percentage of the site mean and oil content (%)** (Source: <https://nvt.grdc.com.au/>).

Nearest Town	Minnipa			Mount Hope			Yeelanna		
Variety Name	Grain yield (t/ha)	% of Site mean yield	Oil % (6% moisture)	Grain yield (t/ha)	% of Site mean yield	Oil % (6% moisture)	Grain yield (t/ha)	% of Site mean yield	Oil % (6% moisture)
ATR Bluefin	0.73	93	39.6	-	-	-			
ATR Bonito	0.59	75	39.2	2.68	81	47.1	2.75	81	45.0
ATR Swordfish	0.65	83	40.5	-	-	-	-	-	-
Bandit TT	0.77	98	39.6	3.18	96	46.6	2.96	87	43.1
DG Avon TT	0.80	101	41.2	-	-	-			
DG BIDGEE TT	-	-	-	2.86	86	45.9	3.07	90	43.2
DG Torrens TT	0.67	84	37.4	-	-	-	-	-	-
Hyola Blazer TT	0.72	91	35.8	3.74	113	48.0	3.57	105	43.9
Hyola Defender CT	0.81	102	36.8	3.60	108	47.4	3.67	108	44.9
Hyola Enforcer CT	0.65	82	37.3	3.41	103	47.5	3.60	106	44.9
HyTTec Trident	0.72	91	38.2	-	-	-	-	-	-
HyTTec Trifecta	-	-	-	3.38	102	46.7	3.50	103	44.0
HyTTec Trophy	0.84	106	37.2	3.38	102	46.2	3.70	109	43.9
HyTTec Velocity	1.07	135	39.2	-	-	-	-	-	-
InVigor LT 4530P	0.83	105	36.5	3.34	101	45.8	3.42	100	42.3
InVigor T 4510	0.87	110	37.8	3.45	104	46.7	3.42	100	43.9
InVigor T 4511	0.72	91	39.7	3.30	99	47.9	3.29	96	46.1
InVigor T 6010	-	-	-	3.16	95	47.2	3.19	94	44.4
PY520TC	-	-	-	3.46	104	45.9	3.38	99	43.3
Renegade TT	0.84	106	39.5	3.22	97	47.0	3.50	103	45.0
RGT Baseline TT	-	-	-	3.44	104	48.3	3.24	95	45.5
RGT Capacity TT	0.81	103	39.1	3.37	102	46.7	3.35	98	43.5
SF Spark TT	0.85	107	41.4	3.20	96	48.6	3.24	95	46.5
Site Mean (t/ha)	0.79			3.32			3.41		
CV (%)	8.39			4.03			5.61		
Probability	<0.001			<0.001			<0.001		
LSD (t/ha)	0.12			0.22			0.31		
Sowing Date	28-Apr-2023			28-Apr-2023			27-Apr-2023		

Table 1. (continued from previous page) **Eyre Peninsula 2023 NVT canola yields in t/ha and variety yield expressed as a percentage of the site mean and oil content (%)** (Source: <https://nvt.grdc.com.au/>).

Nearest Town	Yeelanna		
Variety Name	Grain Yield (t/ha)	% of Site Mean Yield	Oil % (6% moisture)
DG Drummond TF	3.78	96	46.0
Hyola Battalion XC	3.58	91	45.0
Hyola Garrison XC	3.56	91	45.6
Hyola Regiment XC	3.83	97	46.6
InVigor LR 4540P	4.29	109	45.1
InVigor R 4022P	3.90	99	45.6
InVigor R 4520P	4.23	108	43.9
Nuseed Eagle TF	3.79	97	45.1
Nuseed Emu TF	4.10	105	45.3
Nuseed Hunter TF	4.40	112	45.6
Nuseed Raptor TF	3.83	97	44.7
Pioneer 44Y27 (RR)	4.17	106	44.0
Pioneer 44Y30 RR	3.94	100	45.6
Pioneer 45Y28 RR	4.03	103	46.5
PY323G	4.27	109	45.5
PY422G	3.79	96	45.5
PY424GC	4.08	104	45.0
PY525G	3.76	96	44.2
Site Mean (t/ha)	3.93		
CV (%)	4.85		
Probability	<0.001		
LSD (t/ha)	0.31		
Sowing Date	27-Apr-2023		

Table 2. Eyre Peninsula 2023 NVT field pea yields in t/ha and variety yield expressed as percentage of site mean (Source: <https://nvt.grdc.com.au/>).

Nearest Town	Minnipa		Yeelanna	
Variety Name	Grain yield (t/ha)	% of Site mean yield	Grain yield (t/ha)	% of Site mean yield
APB Bondi	0.85	93	5.04	114
GIA Kastar	0.70	77	3.63	82
GIA Ourstar	0.84	92	3.57	81
Kaspa	0.96	105	4.48	102
PBA Butler	1.06	116	4.94	112
PBA Gunyah	1.04	114	3.97	90
PBA Noosa	0.97	107	4.42	100
PBA Oura	0.92	101	3.68	84
PBA Pearl	0.89	98	4.59	104
PBA Percy	0.98	108	4.07	92
PBA Taylor	0.98	108	4.76	108
PBA Wharton	0.77	84	4.25	97
Site mean (t/ha)	0.91		4.40	
CV (%)	10.86		6.22	
Probability	<0.001		<0.001	
LSD (t/ha)	0.17		0.45	
Sowing Date	04-May-2023		18-May-2023	

Table 3. Eyre Peninsula 2023 NVT faba bean yields in t/ha and variety yield expressed as percentage of site mean (Source: <https://nvt.grdc.com.au/>).

Nearest Town	Yeelanna	
Variety Name	Grain yield (t/ha)	% of Site mean yield
Farah	5.28	97
Fiesta VF	5.62	103
Nura	4.93	90
PBA Amberley	5.12	94
PBA Bendoc	5.35	98
PBA Marne	5.90	108
PBA Rana	4.70	86
PBA Samira	5.44	100
PBA Zahra	5.34	98
Site mean (t/ha)	5.45	
CV (%)	4.45	
Probability	<0.001	
LSD (t/ha)	0.40	
Sowing Date	18-May-2023	

Table 4. Eyre Peninsula 2023 NVT lentil yields in t/ha and variety yield expressed as percentage of site mean (Source: <https://nvt.grdc.com.au/>).

Nearest Town	Yeelanna	
Variety Name	Grain yield (t/ha)	% of Site mean yield
ALB Terrier	3.89	99
GIA Leader	3.42	87
GIA Lightning	4.47	114
GIA Metro	3.08	79
GIA Sire	3.86	98
GIA Thunder	4.75	121
Nipper	3.74	95
PBA Ace	4.50	115
PBA Bolt	3.96	101
PBA Hallmark XT	3.82	97
PBA Highland XT	4.02	102
PBA Hurricane XT	3.79	97
PBA Jumbo2	3.32	85
PBA Kelpie XT	4.31	110
Site mean (t/ha)	3.92	
CV (%)	10.95	
Probability	<0.001	
LSD (t/ha)	0.72	
Sowing Date	18-May-2023	

Table 5. Eyre Peninsula 2023 NVT lupin yields in t/ha and variety yield expressed as percentage of site mean (Source: <https://nvt.grdc.com.au/>).

Nearest Town	Yeelanna	
Variety Name	Grain yield (t/ha)	% of Site mean yield
Coyote	2.35	116
Gidgee	2.25	111
Jenabillup	2.09	103
Lawler	2.10	104
Mandelup	1.82	90
PBA Barlock	2.26	112
PBA Bateman	2.18	108
PBA Gunyidi	2.13	105
PBA Jurien	2.12	105
Rosemont	1.72	85
Wonga	1.84	91
Site mean (t/ha)	2.03	
CV (%)	6.40	
Probability	<0.001	
LSD (t/ha)	0.22	
Sowing Date	02-May-2023	

GRDC Lentil Check Groups 2023

Zhaohan (Elijah) Luo^{1,2}, Amanda Cook^{1,2}, Nicole Baty¹, Andy Bates³ and Michael Hind³

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Key messages

- **Lentil management strategies in the low rainfall areas of upper Eyre Peninsula (UEP) varies significantly from season to season due to rainfall and emergence timing.**
- **Paddock selection is crucial for lentils.**
- **Lentils can be sown as deep as 7 cm if required.**
- **Be cautious when using herbicides on sandy and alkaline soils for lentils.**

- **Multiple fungicide applications is not always beneficial on the UEP for lentils depending on the season and in season decision making is required.**
- **Further research into lentil management in low rainfall environments with highly alkaline soils is required.**

Background

Lentil production in the low rainfall regions of South Australia, especially the UEP has rapidly expanded in the past few years, with the latest data showing an estimated total lentil growing area of approximately 30,000 hectares across Western and Eastern EP, and a total production of 41,000 tonnes of lentils in the 2023 season (PIRSA, 2023).

Growers who attended the Minnipa NGN (National Grower Network) forum in August 2022

identified that whilst local (Minnipa) rainfall patterns were similar to those experienced on the Yorke Peninsula (Figure 1), lentil yields achieved locally were substantially lower.

There is a significant body of research into lentil agronomy and production, however, most studies have occurred in higher rainfall regions than those usually experienced on UEP and, in areas with slightly longer growing seasons or on soil types not typical of the UEP environment.

The purpose of the GRDC funded Lentil Check Groups is to encourage peer to peer learning, enabling growers to get together to have facilitated discussion with local agronomists, draw from research expertise and learn from each other around how to resolve issues and what was working locally.

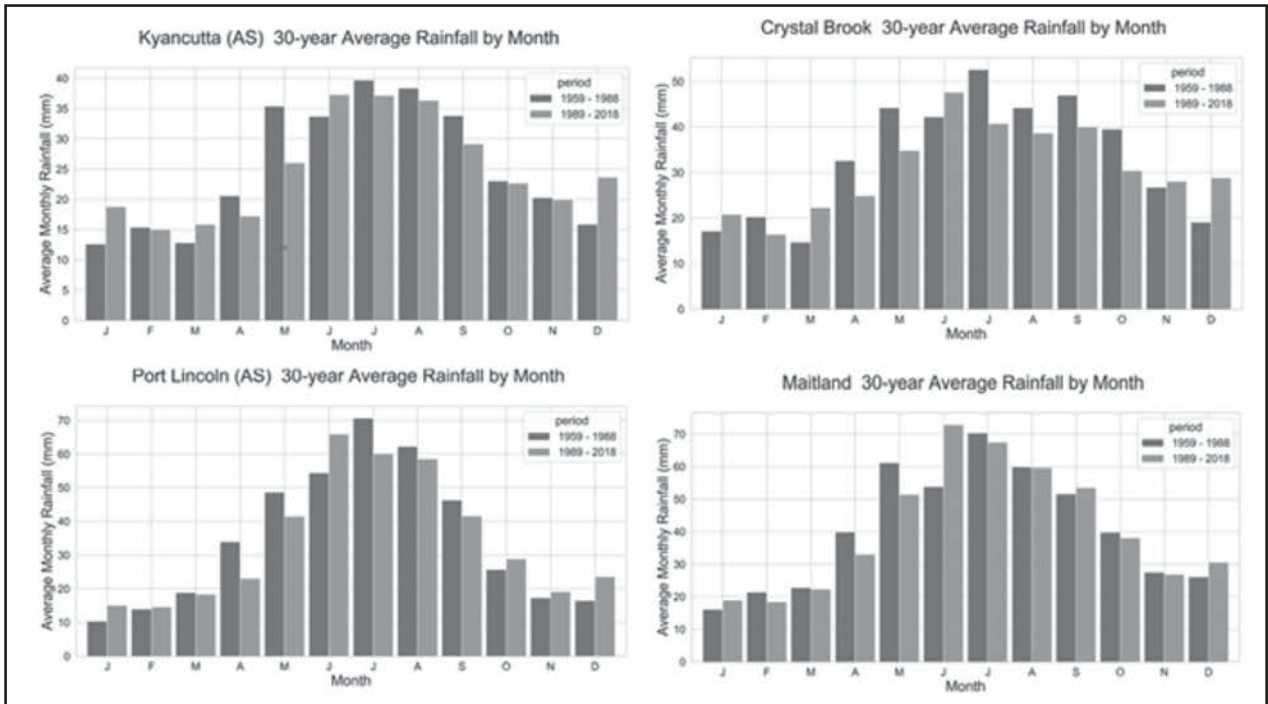


Figure 1. The annual rainfall pattern of low and high rainfall regions of Eyre Peninsula (Kyancutta and Port Lincoln) compared to similar regions on the Yorke and Northern Yorke Peninsula (Crystal Brook and Maitland) in from 1959-2018 (1959-1988 darker columns, 1989-2018 lighter columns) (BOM, Regional Weather and Climate Guide - Eyre Peninsula, 2019) (BOM, Regional Weather and Climate Guide - Northern and Yorke, 2019).

What happened?

In the 2023 season, four GRDC funded Lentil Check Groups were established at Kimba, Lock, Mudamuckla, and Minnipa, and a total of 78 growers and 12 agronomists/consultants/industry representatives attended. Two meetings were held at each location. The pre-seeding grower group meetings were held in April and the post-emergence grower group meetings were held in July. This program was highly valued by local growers and agronomists.

Topics covered at the pre-season meeting were seed quality and inoculation, time of sowing, seeding depth, herbicides, establishment, biomass, plant structure and early crop management.

Topics covered at the post-emergence meeting were herbicides, timing of fungicide application, pest monitoring, management and insecticides, timing of desiccation, harvest grain quality and risks (fires).

To summarise:

Sowing

Paddock selection is crucial for a successful lentil crop - lentils do not grow well on shallow soils, saline soils, soils with high boron levels, sandy soils, and present significant management challenges on rocky paddocks.

Weed control options in lentils are limited and most pre-emergent herbicide options rely on keeping herbicides away from the seed and crop roots to ensure safety. Dry sowing of lentils is not encouraged on sandy alkaline soils due to increased herbicide mobility risk and reduced crop safety. Most pre-emergent herbicides rely on moisture post sowing for “activation” and are ineffective in dry soils. However, when applied to dry soil, they can move quickly to the root zone with a wetting front.

It is most desirable to obtain good pre-seeding control of broadleaf weeds with knockdown chemicals, and to set up paddocks to have low numbers of problem broadleaf weeds in the seasons prior to sowing lentils.

Medic is one of the major weeds encountered when transitioning from a crop/medic pasture type rotation to one based on grain legumes. Options for medic control are limited in lentils, and the medic seedbank needs to be depleted prior to including lentils in the rotation.

Herbicide choices in lentils will depend on the likely weed spectrum, time of sowing, moisture conditions at sowing and those predicted for the week after sowing, soil type, seeding system, and always involve a compromise between crop safety and the acceptable level of weed control. There is no “recipe” that suits all growers and all systems; therefore, a degree of adjustment of process is required on each farm to tailor for specific paddock needs.

The use of Group E inoculant at seeding is still essential on most UEP paddocks. The most effective way to apply rhizobia is to mix rhizobia peat with seeds immediately before seeding. This will usually provide the greatest number of rhizobia per hectare. Rhizobia forms a symbiotic relationship with lentils by enhancing nodule formation on the roots to fix N directly from the atmosphere - the more nodules there are on the roots, the greater the potential for N fixation.

If lentils, vetch, or peas have been grown regularly in a paddock which have been inoculated properly and have produced well nodulated crops, the response to additional inoculant input will decline. The Predicta rNod soil test can help identify the numbers of rhizobia in the soil and the

likelihood of response to additional inoculant. Most paddocks on UEP are still responsive to the addition of Group E rhizobia at seeding. Some growers have reported sowing lentils as deep as 7 cm into the soil without a reduction in emergence. This strategy has been used to reduce the risk of herbicide damage and to place seeds into moisture to ensure rapid emergence.

The length of the growing season on Upper EP often limits biomass production. Biomass is highly correlated with yield potential in lentils grown in low rainfall environments. One way to encourage biomass production in low rainfall areas is to have a system that can establish lentils in April when the opportunity arises. Dry sowing of lentils is not encouraged on alkaline sandy soils due to the mobility of some herbicides in soil water and the inability to control specific weeds in crop.

Most growers do not recommend zero row spacing in lentils due to difficulty at harvest due to lodging. PSPE herbicide use depends on the soil type and targeted weeds, for more information please see Navneet Aggarwal's article, page 141.

During growing season

Control weeds early. Lentils are not very competitive and early weed pressure will significantly impact on lentil biomass. It is important to “score” weed control and crop effect in each paddock so a useful data is recorded and can be used to make future decisions on appropriate herbicide combinations and their risks. For further details please see Navneet Aggarwal's article, page 141.

Rolling lentils will reduce the harvest difficulty in lentils. Do not apply herbicide 7-10 days before and after rolling. Ensure every part of the paddock is rolled. The direction of rolling should be along the rows to keep herbicides out of furrows. Delaying rolling is a useful tactic to reduce the risk of pre-emergent herbicide damage in some soils but care should be taken to ensure this timing does not extend to when plants become too large and are damaged by rolling.

Foliar disease management strategies will depend on the season. In seasons with good early crop emergence, crops will be more likely to reach canopy closure. In these years, a pre canopy closure application of fungicide will be required. In most seasons, this single application for Botrytis grey mould (BGM) disease will be sufficient as disease background levels are generally low, and spring rainfall conditions are not always conducive to disease progression up the canopy. In wet years, multiple fungicide applications will be required to manage BGM. Ascochyta blight (AB) is not well established on UEP. As more lentils are grown, more disease inoculum will be present, and this disease may have greater impact in years with wet winters and springs. More research into lentil disease management of BGM and AB in low rainfall environments is still required.

Monitoring for insects is important. Seedling plants are very susceptible to mites and lucerne flea. Human consumption grains have strict delivery standards and there is little tolerance for insect damage grains. Etiella moth larvae and native budworm larvae are the main insect pests that require attention from August to October.

Harvest

Desiccation timing is important. It can be a difficult decision in paddocks where lentils do not mature evenly. Desiccating too early can result in lower yield and potential grain quality issues, but desiccating too late can result in significant pod losses due to wind. Most growers compromise on desiccation timing. Some paddocks may be treated earlier to ensure any grass weeds present are sprayed prior to developing seed. Some growers with larger programs “stagger” their desiccation application to better fit with expected harvest capacity. Some manage according to predicted weather, broadleaf weeds/contaminants present in specific paddocks, harvest logistics, etc., but the key is to harvest them as soon as they are mature to minimise the risk of losses and shattering.

Possible future research directions suggested by growers:

1. Strategies to increase plant height for better harvestability.
2. Quantifying the impact of herbicide residues on wheat following lentils.
3. Disease management of BGM and AB in low rainfall environments
4. In row broadleaf weed control.
5. The fit for Metribuzin tolerant lentils in low rainfall regions.
6. Density of weeds and yield impact on lentils.
7. Continued seeding systems research needed on herbicides and lentil crop safety.

Acknowledgement

Lentil Check Groups are funded by GRDC under project UOA2105-013RTX NGN-Lentil check discussion groups to maximise profitability of lentil production in the Upper Eyre Peninsula.

Thank you to Andy Bates and Michael Hind from Bates Agricultural Consulting for facilitating the Lentil Check Group meetings and sharing their advice and experiences with local farmers to increase the knowledge of local lentil systems and to other local agronomists, consultants and expert growers who are involved in the meetings, Leigh Davis; Nutrien Ag, Jake Hull; West Coast Ag, Bella Heron; Elders, James Cant; AGRA Independent Agronomy and Peter Kuhlmann; Mudabie. Thank you to Navneet Aggarwal for traveling from SARDI Clare to share his results and findings from his trials on herbicide in lentils on UEP.

Thank you to GRDC for funding these discussion groups to increase the total productivity and profitability of UEP farming systems. Thank you to all the growers who hosted these discussion groups and those who attended.

Reference

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Expanding lentil options on the upper Eyre Peninsula

Sarah Day^{1,2} and Amy Keeley^{1,2}

¹SARDI; ²The University of Adelaide



Location
Kimba - Trevor Cliff
Buckleboo Farm Improvement Group

Rainfall
Av. Annual: 349 mm
2023 Total: 231 mm

Soil type
0 - 10 cm: Loam clay
10 - 60 cm: Clay

Soil test
pH (CaCl₂): 7.1
Ammonium N: <1 mg/kg
Nitrate N: 19 mg/kg
Phosphorus: 33 mg/kg
Potassium: 277 mg/kg
Organic Carbon: 0.65%

Plot size
12 m x 1.5 m x 3 reps

Trial design
Randomised complete block design

Key messages

- **Developments in lentil variety agronomic characteristics and herbicide tolerance traits will assist expansion of lentil production into low rainfall zones.**

Why do the trial?

Lentils have become a popular break crop and cash crop across many regions in South Australia, with production rapidly expanding into regions where lentils have not been traditionally grown, such as the upper Eyre Peninsula. The commercialisation of new lentil varieties and new herbicide tolerance (HT) traits provides growers with a selection of agronomic management options. A field trial with the aim to assess

grain yield production of different lentil varieties was established on the upper Eyre Peninsula in 2023.

How was it done?

A lentil variety field trial was sown near Kimba on 10 May 2023. The field trial tested nine varieties of lentil with varying agronomic traits, sown in a randomised complete block design with three replicates per variety (Table 1). All varieties received the same agronomic management, as per local best standard practice. The field trial was harvested on 2 November 2023. Data was statistically analysed using ANOVA and Fisher's least significant difference test in Genstat 23rd Edition.

What happened?

Grain yield differences between lentil varieties was observed at Kimba in 2023 (Figure 1). GIA Thunder, PBA Highland XT, PBA Hallmark XT, GIA Lightning and PBA Hurricane XT were the highest yielding varieties, yielding more than GIA Leader, PBA Kelpie XT, GIA Metro and GIA Sire (Figure 1). The high yielding varieties are popular among growers in low to medium rainfall zones in South Australia due to their high yield potential and imidazolinone (IMI) tolerance. Lentil varieties with improved IMI tolerance provides growers with the opportunity to expand weed control options with a post-emergent IMI application.

GIA Metro and GIA Sire have dual herbicide tolerance, and although they are lower yielding than the other varieties tested in this study, these varieties have a unique fit in the farming system. GIA Metro is the first lentil variety with combined IMI tolerance

and metribuzin tolerance. This unique combination of herbicide tolerances will expand lentil production and weed control options, particularly on lighter textured soils that are prone to Group 5 herbicide damage. Grain yield of this variety is lower than existing lentil varieties in the absence of weed pressure, or where weeds are controlled effectively without crop damage from metribuzin. Therefore, GIA Metro is best suited to lighter soil types where Group 5 herbicide damage is more likely an issue, paddocks with high density weed populations, or paddocks with populations of Group 2 resistant weeds.

GIA Sire is the first lentil variety with combined IMI tolerance and improved tolerance to clopyralid soil residues from a prior crop applied according to product label directions. GIA Sire is not well suited to low fertility sandy soils and low rainfall frost prone environments. GIA Sire is best suited to agronomic practices that maximise growth, harvest height and grain yield, as this variety is slow growing and has a short plant height. GIA Sire has a unique fit and will produce higher yields over existing lentil varieties where significant levels of clopyralid soil residues are present.

Table 1. Agronomic characteristics of lentil varieties at Kimba, 2023. Source: 2024 South Australian Crop Sowing Guide.

Variety	Market category	Vigour	Plant height	Flowering time	Maturity time	Lodging resistance	Pod drop	Shattering
Imidazolinone Tolerant								
GIA Leader	MRS	Moderate	Medium	Mid/late	Mid/late	MR	MR	MR
GIA Lightning	SRP	Moderate	Medium	Mid/late	Mid	MR	MR	RMR
GIA Thunder	SRP	Moderate	Medium	Mid	Mid	MRMS	MR	RMR
PBA Hallmark XT	MRS	Mod/good	Medium	Mid	Mid	MR	MR	R
PBA Highland XT	MRS	Mod/good	Medium	Early	Early/mid	MR	MR	MR
PBA Hurricane XT	SRP	Moderate	Medium	Mid	Mid	MR	MR	R
PBA Kelpie XT	LRS	Mod/good	Medium	Early/mid	Early/mid	MRMS	MR	R
Dual-Herbicide Tolerant								
GIA Metro	LRS	Mod/poor	Short/med	Late	Mid/late	MR	MR	RMR
GIA Sire	SRP	Poor	Short	Mid/late	Mid	MR	MR	RMR

Key: R = resistant, RMR = resistant to moderately resistant, MRMS = moderately resistant to moderately susceptible, MS = moderately susceptible, S = susceptible. Market category: MRS = medium red split, SRP = small red premium round (football), SR = small red round (football), LRS = large red split.

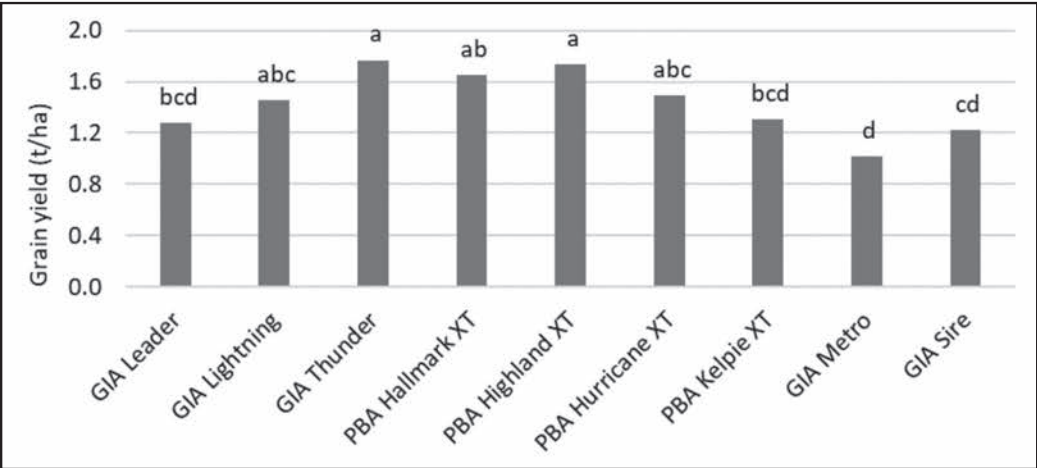


Figure 1. Lentil variety grain yield production at Kimba, 2023. Bars labelled with the same letters are not significantly different ($P=0.009$).

What does this mean?

Lentil can be sensitive to herbicide use in dry conditions and light soil types. The commercialisation of new and dual HT traits in lentil varieties will aid the expansion of lentil production on the upper Eyre Peninsula. New varieties and HT traits will expand weed control options and reduce the reliance and resistance risk of Group 2 herbicides. Future developments in HT traits and improved yield potential will further assist growers with the expansion of lentil production, providing higher yielding varieties with improved and/or dual herbicide tolerances traits.

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 Port Lincoln is gratefully acknowledged and appreciated.



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Department of Primary
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SARDI
SOUTH AUSTRALIAN
RESEARCH AND
DEVELOPMENT
INSTITUTE

Section
4

Section Editor:
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SARDI

Cereals

Table 1. Upper Eyre Peninsula 2023 NVT barley yields in t/ha and variety yield expressed as percentage of site mean (Source: <https://nvt.grdc.com.au/>).

Nearest Town	Darke Peak		Elliston		Minnipa		Piednippie	
Variety Name	Grain Yield (t/ha)	% of Site Mean Yield	Grain Yield (t/ha)	% of Site Mean Yield	Grain Yield (t/ha)	% of Site Mean Yield	Grain Yield (t/ha)	% of Site Mean Yield
Alestar	1.42	73	3.49	89	1.66	83	1.67	83
Beast	2.22	114	4.24	108	2.11	106	2.26	112
Buff	1.93	99	3.69	94	1.85	93	1.89	94
Combat	2.29	117	3.96	101	2.14	108	2.06	102
Commander	1.45	74	3.27	83	1.64	82	1.82	90
Commodus CL	2.24	115	4.08	104	2.09	105	2.09	103
Compass	2.12	108	4.11	105	2.24	113	2.33	116
Cyclops	2.14	109	3.87	99	1.96	98	2.08	103
Fathom	2.05	105	3.61	92	2.25	113	2.09	104
La Trobe	2.10	108	3.73	95	2.04	102	2.03	101
Laperouse	2.00	102	3.72	95	2.02	101	1.96	97
Leabrook	2.07	106	4.04	103	2.18	110	2.14	106
Maximus CL	2.32	119	4.16	106	2.07	104	2.04	101
Minotaur	1.75	90	3.88	99	1.90	96	1.95	96
Neo CL	1.82	93	4.10	105	1.95	98	1.83	91
RGT Planet	1.69	87	4.01	102	1.99	100	2.05	102
Rosalind	1.97	101	4.35	111	2.03	102	2.08	103
Scope CL	1.57	81	3.68	94	1.69	85	1.91	95
Spartacus CL	2.02	103	3.44	88	1.95	98	1.83	91
Spinnaker	1.60	82	4.12	105	2.02	102	1.87	93
Titan AX	2.00	103	4.04	103	1.86	94	2.08	103
Yeti	1.94	99	4.09	104	2.19	110	2.11	105
Zena CL	1.61	82	3.68	94	1.85	93	1.54	76
Site mean (t/ha)	1.95		3.92		1.99		2.02	
CV (%)	7.51		4.04		3.74		5.36	
Probability	<0.001		<0.001		<0.001		<0.001	
LSD (t/ha)	0.26		0.28		0.13		0.18	
Sowing Date	26-May-2023		16-May-2023		23-May-2023		19-May-2023	

Cereals

Table 2. Lower Eyre Peninsula 2023 NVT barley yields in t/ha and variety yield expressed as a percentage of site mean (Source: <https://nvt.grdc.com.au/>).

Nearest Town	Cummins		Wanilla		Wharminda	
Variety Name	Grain Yield (t/ha)	% of Site Mean Yield	Grain Yield (t/ha)	% of Site Mean Yield	Grain Yield (t/ha)	% of Site Mean Yield
Alestar	5.60	86	5.14	85	2.15	96
Beast	6.31	97	6.32	104	2.77	124
Bottler	5.80	89	5.05	83	1.65	74
Buff	6.13	94	6.01	99	2.02	91
Combat	6.87	105	6.40	105	3.53	158
Commander	5.86	90	5.52	91	2.41	108
Commodus CL	5.95	91	5.80	95	2.44	109
Compass	6.23	95	5.92	97	2.60	116
Cyclops	7.72	118	6.40	105	2.46	110
Fandaga	6.07	93	5.88	97	2.26	101
Fathom	6.26	96	6.31	104	2.14	96
La Trobe	5.90	90	5.98	98	1.77	79
Laperouse	7.55	116	6.34	104	2.01	90
Leabrook	6.08	93	6.29	103	2.75	123
Maximus CL	7.24	111	6.67	110	2.28	102
Minotaur	7.00	107	6.18	102	2.12	95
Neo CL	7.49	115	6.78	112	2.12	95
RGT Planet	5.98	92	5.55	91	1.95	88
Rosalind	6.36	97	6.31	104	1.87	84
Spartacus CL	6.25	96	6.19	102	1.72	77
Spinnaker	6.11	94	5.95	98	1.28	57
Titan AX	6.52	100	5.96	98	3.13	140
Yeti	7.54	116	6.93	114	2.49	111
Zena CL	6.26	96	5.57	92	1.61	72
Site mean (t/ha)	6.53		6.08		2.23	
CV (%)	5.08		4.39		6.95	
Probability	<0.001		<0.001		<0.001	
LSD (t/ha)	0.54		0.45		0.27	
Sowing Date	12-May-2023		17-May-2023		11-May-2023	

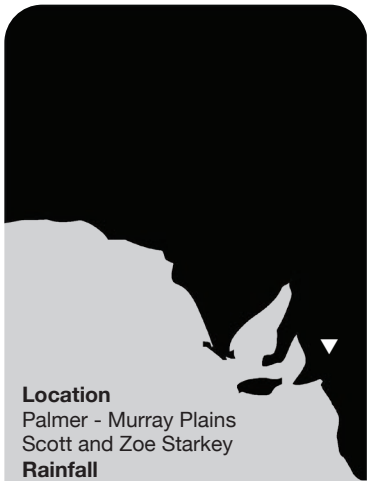
Table 3. Upper Eyre Peninsula 2023 NVT wheat yields in t/ha and variety yield expressed as a percentage of site mean (Source: <https://invt.grdc.com.au/>).

Nearest Town	Kimba		Minnipa		Mitchellville		Penong		Piednippie		Nunjirkompita	
	Grain Yield (t/ha)	% of Site Mean Yield	Grain Yield (t/ha)	% of Site Mean Yield	Grain Yield (t/ha)	% of Site Mean Yield	Grain Yield (t/ha)	% of Site Mean Yield	Grain Yield (t/ha)	% of Site Mean Yield	Grain Yield (t/ha)	% of Site Mean Yield
Ballista	4.43	105	1.63	111	3.14	111	0.82	107	1.38	99	0.73	107
Boree	4.31	102	1.55	105	2.48	88	0.81	106	1.36	97	0.73	107
Brumby	4.40	104	1.58	107	2.51	89	0.78	102	1.35	97	0.68	99
Calibre	4.70	111	1.64	111	3.49	123	0.97	127	1.42	102	0.75	111
Catapult	4.42	105	1.55	105	2.94	104	0.73	95	1.31	94	0.60	88
Chief CL Plus	3.87	92	1.40	95	1.57	55	0.69	90	1.35	97	0.63	93
Cosmick	3.85	91	1.46	99	3.03	107	0.74	97	1.41	101	0.74	109
Cutlass	4.05	96	1.37	93	2.83	100	0.66	86	1.41	101	0.51	75
Dozer CL Plus	4.24	100	1.42	96	2.96	105	0.85	111	1.36	98	0.70	103
EG Titanium	3.86	91	1.33	90	2.42	85	0.61	80	1.34	96	0.68	100
Emu Rock	3.79	90	1.34	91	3.40	120	0.78	102	1.30	93	0.70	103
Genie	4.07	96	1.24	84	2.95	104	0.65	85	1.14	82	0.54	79
Hammer CL Plus	4.09	97	1.53	104	2.03	72	0.83	108	1.45	104	0.83	122
LRPB Anvil CL Plus	4.03	95	1.22	83	3.22	114	0.84	110	1.33	95	0.70	103
LRPB Dual	4.10	97	1.37	93	2.96	104	0.75	98	1.34	96	0.67	99
LRPB Major	3.99	95	1.55	105	2.83	100	0.74	97	1.36	97	0.69	101
LRPB Matador	4.66	110	1.66	113	3.21	113	0.89	116	1.40	100	0.69	101
LRPB Trojan	4.13	98	1.53	104	2.35	83	0.71	93	1.41	101	0.59	86
Mace	4.05	96	1.50	102	2.51	88	0.79	103	1.37	98	0.71	104
Razor CL Plus	4.25	101	1.61	109	2.79	98	0.76	100	1.55	111	0.77	113
Reilly	4.14	98	1.40	95	3.07	108	0.64	84	1.41	101	0.69	101
RockStar	4.32	102	1.58	107	2.55	90	0.81	106	1.46	105	0.71	104
Scepter	4.49	106	1.57	107	2.64	93	0.82	108	1.42	101	0.68	99
Sheriff CL Plus	4.21	100	1.44	98	2.34	82	0.69	90	1.22	88	0.62	92
Soaker	4.41	104	1.46	99	2.59	91	0.86	113	1.39	100	0.62	91
Sunblade CL Plus	4.16	99	1.59	108	3.16	112	0.78	102	1.49	107	0.84	124
Sunmaster	4.49	106	1.66	112	2.96	104	0.75	98	1.40	100	0.77	113
Tomahawk CL Plus	5.01	119	1.68	114	2.68	95	0.87	114	1.56	112	0.71	104
Vixen	4.24	100	1.51	103	3.47	122	0.87	114	1.32	95	0.71	104
Yitpi	3.95	94	1.42	96	2.62	93	0.57	74	1.50	107	0.44	64
Site mean (t/ha)	4.22		1.47		2.83		0.76		1.39		0.68	
CV (%)	4.22		4.08		6.24		6.07		4.44		6.55	
Probability	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001	
LSD (t/ha)	0.31		0.11		0.31		0.08		0.11		0.08	
Sowing Date	03-May-23		23-May-23		05-May-23		05-May-2023		19-May-2023		18-May-2023	

Characterising the optimal flowering period for the Murray Plains

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Location
Palmer - Murray Plains
Scott and Zoe Starkey

Rainfall
Av. Annual: 300 mm
Av. GSR: 195 mm
2023 Total: 250 mm
2023 GSR: 118 mm

Paddock history
2022: Vetch brown manure
2021: Wheat
2020: Wheat

Soil type
Calcareous sandy-loam

Soil test
pH: 8.65 (0-30 cm), 9.39 (30-60 cm)

Plot Size
9 m x 1.37 m x 3 reps

Trial design
Split plot design with Time of sowing main-plot and species sub-plot

Yield limiting factors
Frost, heat, drought, late sowing

Key messages

- **Modelling suggests that the optimal flowering period (OFP) for wheat at Palmer is between the 25 August and 8 September, based on climatic data from 1973-2023.**
- **The mid to slow spring wheat (Rockstar and Denison) more reliable option across seasons for early sowing compared to winter wheat, although new quick winter Mowhawk performed well in last two seasons.**
- **The range in optimal sowing dates for current elite wheat**

varieties varies from the 2 April to 19 May dependent on development speed and sufficient soil moisture.

- **Modelling suggests that the optimal flowering period (OFP) for barley at Palmer is between the 2 and 26 August, based on climatic data from 1953-2023.**
- **Very quick spring barleys have an optimal sowing range of the 12 April to 23 April in the Murray Plains, significantly earlier than the same wheat phenology with sufficient soil moisture for germination.**
- **No yield penalty in 2021 and 2023 for barley flowering in early to mid-August.**

Why do the trial?

Flowering time is an important determinant of potential grain yield for cereals which can have significant yield reductions from environmental stresses that include frost, heat and drought. The optimal flowering period (OFP) is defined as the period where the combined risk of these environmental stresses is lowest, and where grain yield potential is maximised. It is important to match variety phenology, to sowing date to ensure flowering time occurs within the optimal period. This project aimed to both identify the OFP for the Murray Plains region for wheat and barley, as well as identify different phenology types that are adapted for earlier sowing in the low rainfall zone (LRZ).

How was it done?

Three seasons of field trials were established east of Palmer (2021-23) which consisted of ten

wheat and eight barley varieties as well as novel breeding lines with different phenology (Table 1). In 2023, there were three sowing/germination dates of 15 April, 11 May and 9 June. Due to insufficient soil moisture at sowing, the first two sowing dates had 10 mm of supplementary in-furrow irrigation to ensure plant establishment. Additionally, there was a dry sown treatment that was sown on 4 April that had multiple false breaks, with majority of plants establishing from a rain event on 26 May. The trial was sown with a 6-row research plot seeder with 22.86 cm row spacings. The trial was designed and analysed in a split-plot design with 3 replicates. Growth staging and flowering time, in particular (Z65), were key measures used to help determine and validate the OFP. Grain yield was also used to characterise the OFP. Grain samples were analysed for standard quality parameters and mature head samples were taken to assess grain sterility, further identifying potential environmental stress that may have influenced grain yield. Nutrition, weeds, pests and diseases were managed using local grower practice and as to not limit grain yield.

Differences between treatments were identified with an analysis of variance in the statistical package GenStat 23rd Edition. at the 5% significance level. Modelling of the OFP was completed using APSIM Classic 7.10. The methodology for the creation of the OFP followed methods by Flohr *et al.* (2017), utilising climatic data from SILO Long paddock patch-point (-34.85, 139.20) for up to the past 70 years.

Table 1. The (a) wheat and (b) barley varieties evaluated in the field trial at Palmer with their relative maturity groups using the National Phenology Initiative classifications (Celestina et al 2023).

(a)	Variety	Maturity Group	Released	(b)	Variety	Maturity Group	Released
	Anvil CL Plus	Very Quick-Quick	2022		Beast	Very Quick	2020
	Vixen	Quick	2018		Commodus CL	Very Quick-Quick	2021
	Calibre	Quick-Mid	2022		Cyclops	Very Quick-Quick	2022
	Scepter	Quick-Mid	2015		Maximus CL	Very Quick-Quick	2020
	Rockstar	Mid	2019		Compass	Very Quick-Quick	2015
	Sheriff CL Plus	Mid	2018		RGT Planet	Quick	2017
	Valiant CL Plus	Mid-Slow	2021		Pixel	Slow Winter	Not released
	Denison	Slow	2020		Newton	Slow Winter	2023
	Longsword	Quick Winter	2017				
	Mowhawk	Quick Winter	2023				
	Illabo	Mid Winter	2019				
	DS Bennett	Slow Winter	2018				

What happened?

Grain yield of wheat and barley across different germination dates

Consistent with previous years (2021 and 2022, data not shown), barley significantly ($p = 0.007$, $LSD = 0.061$) outyielded wheat. There was also a significant species by time of sowing interaction ($p = 0.004$, $LSD = 0.105$), with optimal (11 May) or early sowing significantly higher yielding. Scepter, Calibre and Rockstar were the most adaptable wheat varieties across different germination dates (Table 2). Scepter achieved peak yield for the wheat of 2.67 t/ha from germination on the 11 May and flowered on 2 September in 2023. Mowhawk was the pick of the winter wheat for early sowing and later germination dates. However, Rockstar was the highest yielding variety from the 15 April germination.

For the barley, Beast was the pick across all germination dates, being the standout variety with the dry finish. Peak yield was 3.75 t/ha from the 15 April germination and flowering on the 7 August. It is clear in Table 2 that earlier sowing resulted in higher yields for barley. The longer season winter barley varieties Pixel and Newton failed to produce any significant yield across germination dates from the

dry finish. However, they produced the highest yields in 2022 with the late spring rain and being a decile 9 season (data not shown).

Slower developing wheat varieties suited for early sowing in the Murray Plains

There were no early sowing (April) opportunities for the duration of the project, so 10 mm of supplementary in-furrow irrigation replicated an April germination. The chance of a 10 mm rain event in April for the Murray Plains is low (30% chance, Australian CliMate). However, this project provides valuable comparison of long season varieties suited to early April sowing with main season varieties sown outside of the optimal period. Scepter is the benchmark wheat variety, performing well from a range of sowing dates and being a popular variety in the region. Any longer season variety needs to at least match Scepter with early sowing across different seasons to be a viable option. All longer season varieties were slower to reach flowering compared to Scepter, but few consistently matched yield, even with Scepter sown before its optimal sowing period (Table 3). Mid-spring variety Rockstar outyielded Scepter every season and had flowered 5 to 9 days later. Denison also performed well but was lower

yielding in 2022. Out of the winter wheats, the new variety Mowhawk (quick winter) matched Scepter in the two seasons it was evaluated. It also flowered 31 and 36 days later from the same sowing date. It does show significant promise in raising the yield potential of winter wheats in the LRZ as DS Bennett was the only other winter wheat to outyield Scepter.

Defining the Optimal Flowering Period for wheat and barley at Palmer

The number of climatic data years used in the APSIM runs proved important for both wheat and barley at Palmer to determine the OFP. In Figure 1, the relative grain yield curves using the last 30, 50 or 70 years of climatic data are displayed. The modelling shows that using only more recent years of data, the OFP shifted earlier and simulated yields severe yield declines from later flowering. The most significant decline was between the past 50 and 30 years data (Figure 1) where there is an increased decline in yield from late flowering. This decline is driven by decreasing growing seasons rainfall driving the OFP earlier due to lack of moisture availability and heat. The risk from early flowering on yield potential has limited differences over the time period, suggesting the frost risk has not changed for the Murray Plains.

Table 2. The mean grain yield for each variety of (a) wheat and (b) barley at four germination dates (15 April, 11 May, 9 June and a dry sown blocks germinating majority on the 26 May).

(a)	Site mean yield: 2.03 t/ha	Yield (t/ha) across Germination Date				
		15-Apr	11-May	9-Jun	DRY	Mean
	Anvil CL Plus	1.58	2.06	2.11	1.75	1.87
	Vixen	2.21	2.47	1.92	2.27	2.21
	Calibre	2.23	2.53	2.01	2.49	2.31
	Scepter	2.41	2.67	1.94	2.36	2.34
	Rockstar	2.59	2.59	1.62	2.30	2.28
	Sheriff CL Plus	2.21	2.26	1.74	2.06	2.07
	Denison	2.48	2.60	1.51	2.19	2.19
	Valiant CL Plus	2.39	2.30	1.47	1.96	2.03
	Longsword	2.11	1.85	1.61	2.06	1.91
	Mowhawk	2.42	2.45	1.93	2.04	2.21
	Illabo	1.70	2.02	1.30	1.86	1.72
	DS Bennett	1.21	1.34	1.00	1.25	1.20
	TOS Mean yield	2.13	2.26	1.68	2.05	
	P-value	0.018				
	LSD ($p \leq 0.05$)	0.484				

(b)	Site mean yield: 2.13 t/ha	Yield (t/ha) across Germination Date				
		15-Apr	11-May	9-Jun	DRY	Mean
	Beast	3.75	3.37	2.23	2.93	3.07
	Compass	3.23	2.81	2.20	2.85	2.77
	Commodus CL	3.47	2.89	2.04	2.51	2.73
	Cyclops	3.08	3.08	2.42	2.53	2.78
	Maximus CL	3.02	3.25	2.57	2.61	2.86
	RGT Planet	3.15	2.69	1.62	2.69	2.54
	Pixel	0.13	0.13	0.07	0.17	0.13
	Newton	0.05	0.18	0.15	0.19	0.14
	TOS mean yield	2.49	2.30	1.66	2.06	
	P-value	<0.001				
	LSD ($p \leq 0.05$)	0.376				

Flowering time for peak grain yield for wheat for the 2021 and 2023 field trial came within 2 days (1 Sept and 2 Sept) of the simulated OFP for the past 50 and 70 years (3 Sept) of climatic data (Figure 2). The one anomaly that does not fit the long term run for wheat was 2022, which was defined by a decile 9 growing season rainfall and very wet spring. Therefore, water was not a limiting factor to grain yield with late flowering. Peak yield for 2022 field results occurred a month later (3 October) than the simulated OFP as the seasonal conditions through September and October were mild and did not limit yield

potential. This highlights the limitations of a simulated OFP as it is an average of all seasons and does not show the effect of extreme seasons.

For the barley, 2021 was within 2 days of the past 70 years of climatic data; while the 2023 season was 1 day off the past 30 and 50 years climatic data (Figure 2). However, consistent with the 2022 season for the wheat, peak yield for the barley came 1 month later than the simulated OFP. There was a positive trend for early flowering in the barley, with no yield decline from early flowering in both 2021 and 2023. However, flowering did not occur in July in either

season, this limits the ability to validate the simulated OFP which suggests yield potential can be maximised from flowering in late July. The simulation suggests flowering in July can occur from achieving establishment in April. It would be expected that there would be a yield decline from the increased frost risk and reduced photoperiod/solar exposure as flowering occurred earlier into July.

Table 3. The mean grain yield and flowering dates for slower wheat phenology types across early times of sowing for the 2021, 2022 and 2023 seasons in comparison to the most popular wheat variety in the region Scepter and Vixen. Z65 = flowering date, germ = germination.

	2021		2022		2023		Mean Yield (t/ha)	Years out-yielding Scepter No. years
	20 April germ		12 April germ		15 April germ			
	Yield (t/ha)	Z65	Yield (t/ha)	Z65	Yield (t/ha)	Z65		
Vixen	2.88	9 Aug (-9)	2.28	4 Aug (-9)	2.17	21 Jul (-10)	2.44	0
Scepter (Control)	3.46	18 Aug	2.49	13 Aug	2.41	31 Jul	2.79	-
Sheriff CL Plus	3.39	26 Aug (+8)	1.9	17 Aug (+4)	2.21	10 Aug (+10)	2.50	0
Rockstar	3.51	23 Aug (+5)	3.08	22 Aug (+9)	2.59	9 Aug (+9)	3.06	3
Denison	3.59	2 Sep (+15)	2.43	8 Sep (+26)	2.48	23 Aug (+23)	2.83	2
Valiant CL Plus	2.77	4 Sep (+17)	2.02	10 Sep (+28)	2.39	21 Aug (+21)	2.39	0
Longsword	2.65	8 Sep (+21)	1.71	19 Sep (+37)	2.11	2 Sep (+32)	2.16	0
DS Bennett	2.87	3 Oct (+46)	2.71	8 Oct (+56)	1.21	28 Sep (+58)	2.26	1
Mowhawk	-	-	2.78	18 Sep (+36)	2.42	1 Sep (+31)	-	2
Illabo	-	-	2.33	24 Sep (+42)	1.7	11 Sep (+41)	-	0

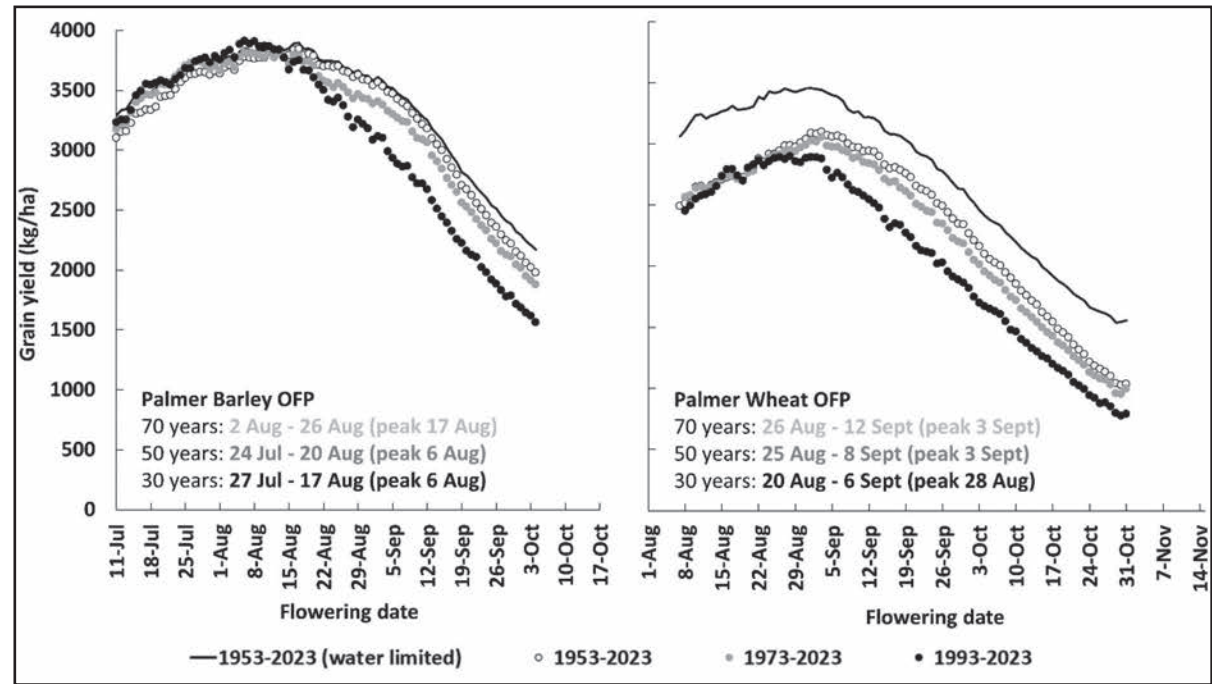


Figure 1. A simulation of the optimal flowering period (OFP) for a very quick barley variety Compass (a) and a quick-mid wheat variety Mace (b) at Palmer in the Murray Plains. The solid line shows the water limited maximum potential yield using the past 70 years of climate data without any frost or heat reductions in yield. The white, grey and black dots represent the frost, heat and drought 15 day running mean yield over the past 70, 50 and 30 years respectively. The flowering dates for the OFP are displayed as well as the flowering date of peak grain yield for each year run.

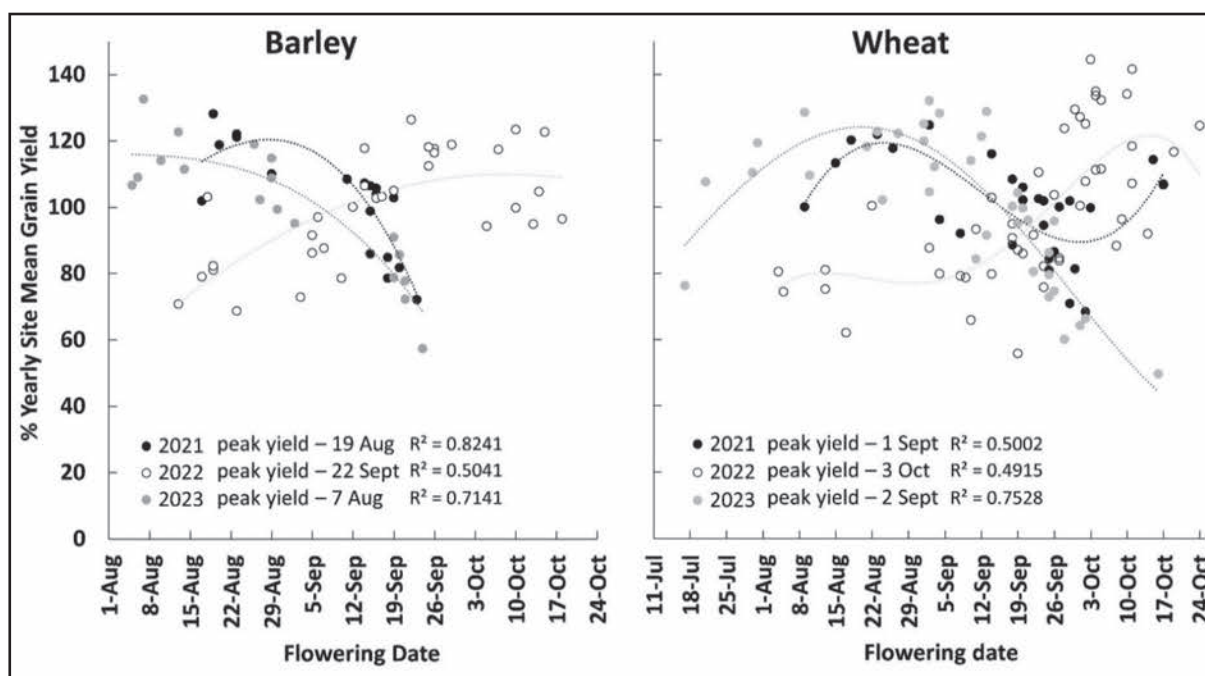


Figure 2. A comparison of the grain yield vs flowering date across the three seasons of field trials for all barley (a) and wheat (b) varieties and times of sowing at Palmer. A percentage of the yearly site mean yield is used to represent and compare relative grain yields across each season. The site mean yield for each season for barley and wheat respectively was: 2021 - 3.6 and 2.88 t/ha, 2022 - 4.24 and 3.07 t/ha, 2023 - 2.83* and 2.03 t/ha. The flowering date of peak grain yield for each year is shown. *mean yield of barley 2023 excluding Newton and Pixel winter barley due to crop failure.

Optimal sowing times across species and phenology type

By using the field derived data for flowering time, optimal sowing dates were produced for different phenology types in wheat, and for a very quick spring barley. Based on previous work by Flohr *et al.* (2017), the past 50 years of climatic data was used as the proxy for the simulated OFP for wheat and the target date for flowering (3 Sept). When the past three seasons of flowering and sowing dates are plotted, trendlines can be developed and used to estimate the best times to be sow (into wet soil). Figure 3 (a-d) demonstrates the variation in optimal sowing dates for the range of spring wheat phenology types. These sowing dates start from early April for the slow spring Denison

through to 19 May for Anvil CL Plus (very quick-quick). Although, the OFP duration is approximately 2 weeks, targeting when peak yield on average occurs (3 Sept) will allow for buffering room for if the growing season is warmer or cooler than average, and therefore speeding up or slowing down relative development. This seasonal temperature variation is evident in the slopes of the lines, where 2022 was cool and 2023 quite warm, which resulted in varieties flowering later and earlier in these seasons respectively (Figure 3).

However, for very quick spring barley the sowing dates to flower on 18 August (date of peak yield from past 70 years) become early in the season (Figure 4).

The field derived data suggests that the optimal sowing range would be between the 12 and 23 April. Traditionally, this would be significantly earlier than normal for the Murray Plains, but it demonstrates that frost is not the driving factor for yield in the region rather available soil moisture is important. It would be expected that flowering on 18 August would come with an increased chance of frost. However, across three seasons there has been negligible/no frost damage in the barley, even with the wheat having damage when flowering at the same time.

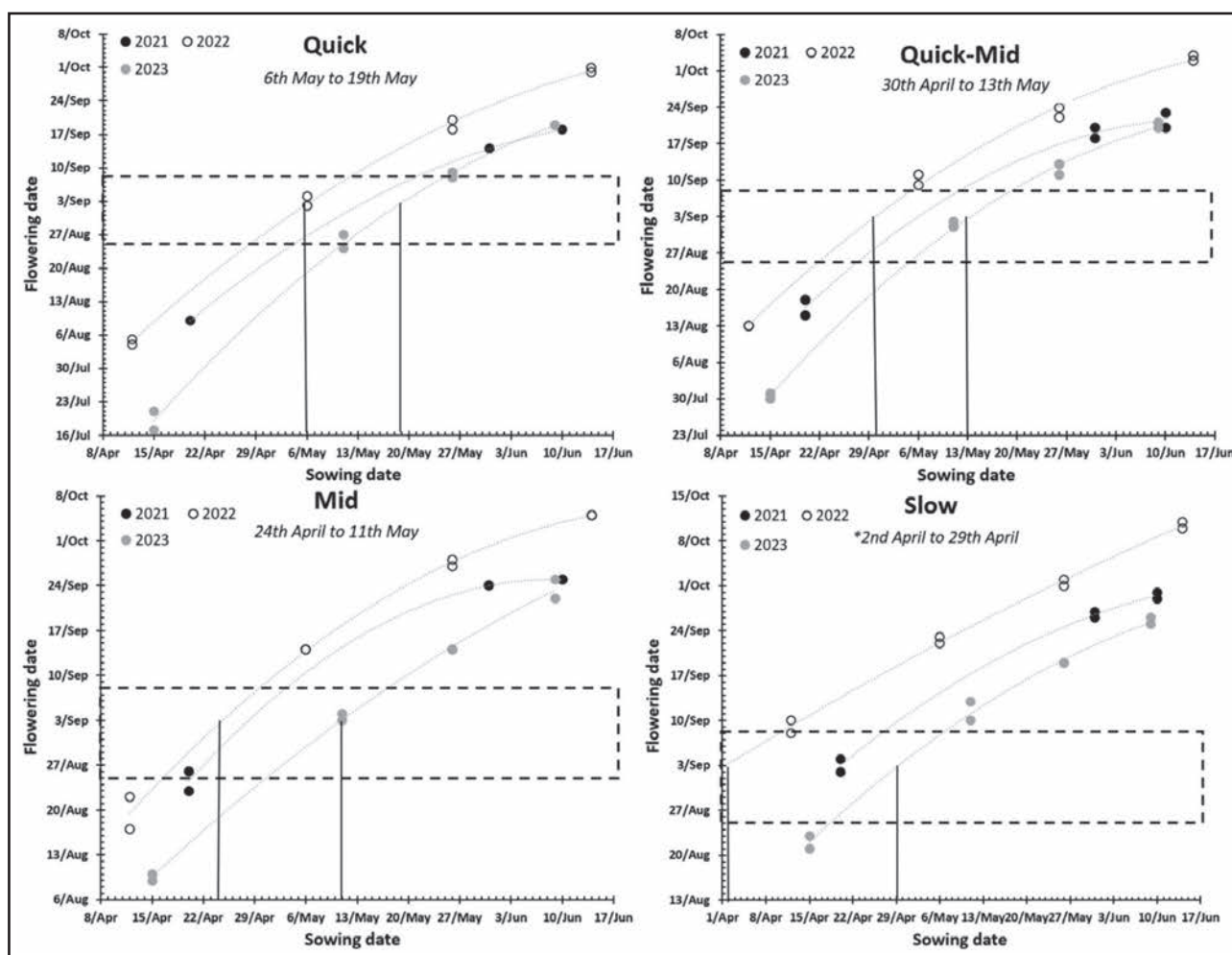


Figure 3. The optimal sowing dates for (a) quick (Vixen/Anvil CL Plus), (b) quick-mid (Calibre/Scepter), (c) mid (Rockstar/Sheriff CL Plus) and (d) slow (Denison/Valiant CL Plus) spring wheat phenology types. Developed from field derived flowering and sowing dates from the 2021, 2022 and 2023 growing seasons in the Murray Plains. The thick dotted box depicts the OFP as simulated in APSIM, and the vertical black lines the sowing dates required to flower at the simulated peak yield on the 3 of September. The dashed line of best fit depicts the average for the 2021, 2022 and 2023 seasons. *The line of best fit is extrapolated past earliest flowering points on graph to predict optimal seasonal sowing date so interpret start of OFP date with caution.

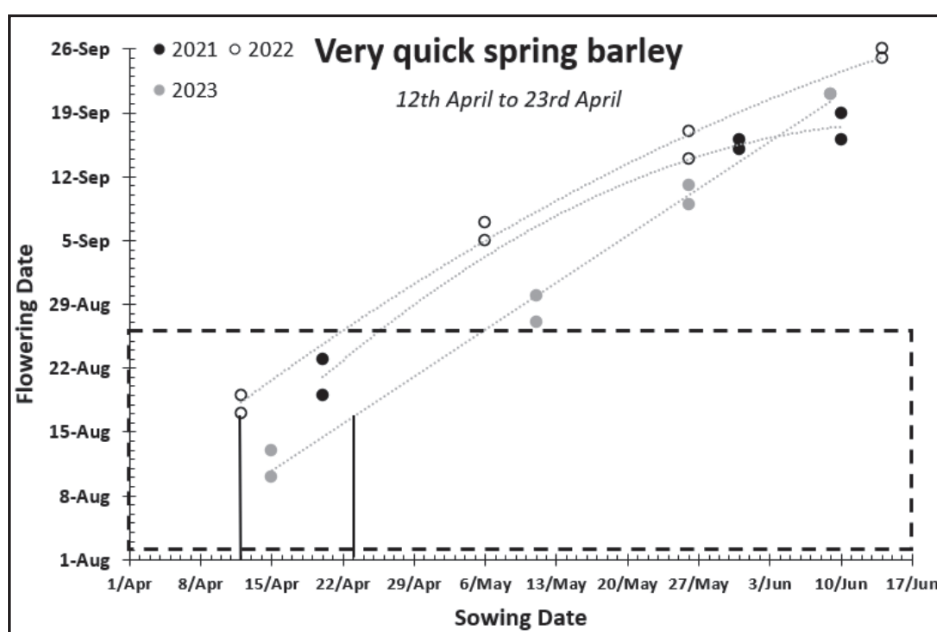


Figure 4. The optimal sowing dates for very quick spring barley at Palmer. Developed from field derived flowering and sowing dates from the 2021, 2022 and 2023 growing seasons for Beast, Compass and Commodus CL in the Murray Plains. The yellow box depicts the OFP as simulated in APSIM, and the vertical black dotted lines the sowing dates required to flower at the simulated peak yield on the 17 of August. The dashed line of best fit depicts the average for the 2021, 2022 and 2023 seasons.

What does this mean?

APSIM simulations of wheat at Palmer using the past 50 years of climate data, suggests the OFP for the Murray Plains is between the 25 August and 8 September. The 2021 and 2023 field seasons matched the OFP well, with maximum grain yield coming in the middle of the simulated OFP. However, maximum grain yield from the 2022 trial was much later than the simulated OFP due to the cooler and wet finish. This highlights the fact that averages are used to determine the timing and duration of the OFP, which do not account for extreme seasons, like 2022. Further research of flowering time in high decile rainfall seasons needs to be conducted to better understand how growers can optimise flowering to returns in high yielding seasons with high gross margins.

There is currently a large range in wheat phenologies in current elite varieties, with new winter wheat genetics (Mowhawk) coming through that might improve the yield potential for this phenology group and early sowing opportunities. However, currently slower spring wheats such as Rockstar and Denison are showing greater adaptability and yield stability from early sowing in multiple seasons. Scepter, a quick-mid wheat still remains a solid benchmark for grain yield from its optimal sowing range of the 30 April to 13 May.

The optimal flowering and sowing dates for spring barley in the LRZ may be earlier than what is currently practised. APSIM modelling and field derived data has shown a tendency for peak yields to coincide with a flowering date in August. The OFP using the past 70 years of climate data was from 2 to 26 August; this required a sowing date between 12 to 23 April for very quick spring barley such as Compass to flower within the OFP. The OFP starts earlier into July when using the past 30 and 50 years, however flowering dates for the trial did not get this early for barley so could not be validated. The key takeaway from the field trials was that two out of the three seasons did not see a grain yield penalty from flowering too early (peak yield in early to mid-August in 2021 and 2023). Only in a decile 9 spring in 2022, that there was a penalty from flowering too early due to excessive rainfall in September and October. However, further barley time of sowing trials (with flowering dates in July) need to be done to further validate these results across seasons.

For the Eyre Peninsula, Flohr *et al* (2017) characterised the wheat OFP for Cleve, Cummins and Lock, as well as Minnipa which is the most similar to the Murray Plains. Minnipa's OFP was from the 22 August to 8 September for quick-mid wheat with an APSIM produced optimal sowing date

of the 6 May. This fits right in the middle of the sowing range for a quick-mid wheat for Palmer using field derived data. The rest of the developed sowing dates may be useful for growers on the upper EP too that experience a similar frost, heat and drought risk to the Murray Plains. Additionally, the flowering time data compared to Scepter for early sowing would be useful for selecting a potential slower developing variety for upper EP, that normally has earlier season breaks than the Murray Plains.

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MURRAY PLAINS
FARMERS



Oaten hay yield and quality response to agronomic levers

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Key messages

- **Oaten hay varieties respond similarly to different agronomic levers - choose high yielding varieties with best genetic quality traits to optimise production of export quality hay.**
- **Sowing early maximises hay yield but not always quality - let the variety maturity rating guide the ideal sowing time. Sow with higher plant densities than grain crops, and supply 60-90 kg/ha of nitrogen depending on starting soil N levels to drive biomass without penalising quality.**
- **Cut oaten hay crops at watery ripe (Z71) not later to avoid the risk of hay quality declining.**
- **Strobilurin fungicides applied to manage crop disease four weeks before cutting reduced discolouration by saprophytes on the outside of the windrow compared to the control.**

Why do the trial?

The Australian export fodder industry has increased year on year over the last decade, now exporting about 1.2 million tonnes of hay, valued at more than \$500 million. Over the past 10 years, the main export production states were Western Australia, South Australia and Victoria, averaging 40%, 31% and 21% of production volume respectively (AgriFutures Export Fodder Program Strategic RD&E Plan 2021–2026).

The AgriFutures Australia Export Fodder program invests in oaten hay quality research to influence grower practices and strengthen Australia's position as a supplier of choice within our export markets.

The National Hay Agronomy (NHA) project (2019-2022) was an investment with the objectives to:

- improve agronomic guidelines to maximise oaten hay production and quality (variety selection, nutrition, optimum seeding date to increase quality and decrease risk)
- clarify the potential for growth regulators in oaten hay production
- update disease management guidelines for oaten hay crops

How was it done?

To improve agronomic guidelines, a core trial series evaluated the performance of eight different varieties sown with three or six different nitrogen (N) rates and two sowing dates across three seasons (12 trials located in Western Australia (WA); Muresk (2019 to 2021), South Australia (SA); Hart (2019 to 2021), Victoria (Vic); Kalkee (2019), Rupanyup (2020), Wallup (2021) and New South Wales (NSW); Yanco (2019), Yenda (2020), Wagga Wagga (2021). Additional regionally specific trials were sown to 1) Evaluate five new oat varieties in WA; Muresk (2021) and SA; Jabuk, Tarlee (2021)), 2) Compare Kingbale versus its parent Wintaroo (four trials: WA; Wongan Hills, Muresk (2020), SA Tarlee, Lameroo (2020)) 3) Measure the effects of growth stage at cutting on hay performance (two trials:

WA; Muresk (2020), Vic; Rupanyup (2020)), 4) Investigate the role of grazing in mixed farming systems and its impact on oaten hay (four trials: NSW; Dirnaseer, Gerogery (2020), Yenda (2020, 2021), Wagga Wagga (2021)), and 5) Identifying the target plant density for export oaten hay in NSW; Gerogery (2019 to 2021), Yanco, Marrar (2019), Dirnaseer, Yenda (2020), Wagga Wagga (2021)).

Glasshouse screening and field trials evaluated Moddus® Evo for lodging management (four trials: WA; Nunile, Highbury (2019), SA; Tarlee (2020), Vic; Kalkee (2019)) and ProGibb® SG for assisting panicle emergence (four trials: WA; Wongan Hills (2020), SA; Booleroo, Lameroo, Tarlee (2020)). Note, ProGibb® SG is not registered for use in oaten hay.

The project conducted a review of plant diseases impacting oaten hay and produced disease management factsheets with updated management guidelines for red leather leaf, Septoria, oat stem and leaf (crown) rust. Disease surveillance occurred on 20 crops annually (Vic, WA), and disease management trials were conducted for red leather leaf (RLL) (six trials: Vic), Septoria (five trials: WA), oat leaf (crown) rust (two trials: WA) and saprophyte suppression (management of weather damage) (five trials: WA, Vic)

What happened?

The following summarises key oaten hay agronomy results from the National Hay Agronomy trials 2019 to 2021.

Time of sowing

- Earlier sowing (late April/early May) increased the opportunity to maximise hay yield but did not always maximise hay quality compared to a conventional sowing time.
- Earlier sown hay tended to have thicker stems and lower crude protein, but had higher water-soluble carbohydrates (WSC) (except Koorabup) compared to sowing in late May/early June. This trend was not always consistent across sites and years but was the general trend when the data was averaged.
- The variety response to sowing date was variable, and not easily predicted at the start of the season; often the pattern of in-season rainfall had the most influence.

Nitrogen rate

N applications drove more biomass, taller and greener plants, and increased the risk of lodging, especially in susceptible varieties.

- Peak hay yield was achieved with 90 kg N/ha, although 60 kg N/ha was adequate when sites received below-average rain during critical growth periods.
- Nitrogen was not a major driver of hay quality defects (thick stem diameter, or high acid detergent fibre (ADF), neutral detergent fibre (NDF) or lignin), but was linked to increased crude protein and decreased WSC. Applying >90 kg N/ha increased the risk of not meeting industry WSC guidelines for premium hay of more than 22%.
- Varieties responded the same to increasing N rates for hay quality traits, across a range of seasons. More N could be applied to varieties with higher

genetic WSC, for example, Yallara, before they drop a grade, potentially growing more hay of export quality.

- The response to N was generally consistent between the planting dates, albeit with varying degrees of impact.
- Across trials, both season and variety were the larger drivers of hay quality rather than the rate of N applied.

Variety choice

Hay yield and quality was assessed for four dual-purpose varieties (Carrolup, Durack, Williams and Yallara) and four hay-only varieties (Brusher, Koorabup, Mulgara and Wintaroo).

- Brusher and Wintaroo were the leading varieties for hay yield, when yields were averaged across years, sites, N treatments and sowing dates, at the first sowing date (late April/early May), while Wintaroo had the highest yield of the second sowing date (late May/early June). The varietal hay yield differences at the early sowing date were 1.0t/ha and 0.6t/ha when sowing was delayed. Brusher lost the most hay yield with delayed sowing (1.8t/ha), while Carrolup and Durack were the least affected, with only a 1.0t/ha reduction in yield.
- Brusher and Wintaroo were most likely to experience lodging, followed by Mulgara. Varieties differed in stem diameter, with Carrolup, Durack and Koorabup averaging 0.5mm narrower stems than Mulgara, Williams and Wintaroo. Wintaroo was most likely to produce hay with a stem diameter wider than 6mm, the upper limit for premium hay.
- Brusher was more variable across years, sites, N treatments and sowing dates in its hay greenness, as measured by a Soil Plant Analysis Development (SPAD)

chlorophyll meter, than the other seven varieties. Durack hay was the greenest, averaging five SPAD units darker than Carrolup, Mulgara and Wintaroo, which were the lightest green. Williams varied the least in the greenness of all the varieties. Their greenness was related to their performance and suitability for the different sowing dates.

- Hay variety quality traits were measured in the NHA trials.
 - Digestibility - Brusher, Mulgara and Yallara were more digestible than Durack.
 - Crude Protein (CP) - Williams had the highest CP and Wintaroo the lowest.
 - WSC - Yallara had the highest WSC, and Koorabup and Williams had the lowest.
 - ADF - Koorabup and Wintaroo had the highest average ADF, and Brusher and Yallara the lowest.
 - NDF - Koorabup and Wintaroo had the highest average NDF, and Yallara had the lowest.
 - NDF digestibility after 30 hours (NDFDom30) - Brusher, Mulgara and Yallara hay had higher levels of rumen digestibility after 30 hours than Carrolup and Durack hay.
- Yallara, a quick dual-purpose variety, was best performing for quality, with the highest WSC and lowest fibre levels, and thin stems. Yallara had comparable hay yield to Brusher and Wintaroo, with lower lodging risk and similar hay colour. Its flag leaf is erect, making it more vulnerable to impact by adverse weather in a dry finish. Yallara can be a bit quick for better seasons in higher rainfall areas.

- New specialist hay variety Koorabup (released for superior Septoria resistance) did not perform well when benchmarked against Brusher, yielding 0.5t/ha lower, with a higher ADF and NDF risk, lower WSC, but had similar hay greenness and stem diameter.

New hay varieties

Intergrain are working hard to breed new oat varieties with improved hay and grain profitability (Allan Rattey, pers. comms. January 2023).

- Wallaby is a mid-late maturity line with market leading quality, suitable for sowing in the last week of April until the third week of May, like Kingbale and Wintaroo, and 7–10 days earlier than Mulgara.
- Kultarr is a tall, mid-maturity line with market leading biomass and export suitable quality for May sowing.
- Archer and Kingbale produce high biomass and export suitable quality. Archer and Kingbale are suitable for IMI residue (IBS) systems.
- 13008-18 is a promising new line, with improved grain yield and grain quality, being slightly taller and earlier to flower than Bannister. Early dual-purpose data for 13008-18 is encouraging.

Cutting growth stage

Watery ripe (Z71) (when grain is formed but only contains clear, greenish liquid and is not drawing heavily on carbohydrate from photosynthesis or storage) is considered the ideal cutting time for optimising hay yield and achieving quality targets. As the industry looks to optimise hay quality, one option available to growers is to cut the crop before it reaches the watery-ripe stage. Choosing the best cutting time is a careful balance between quality, yield, panicle emergence, current and forecast weather.

NHA trials demonstrated the effect of spring growing conditions on delayed cutting and the subsequent effect on hay quality. In 2020, WA trials at Muresk experienced a drier than average spring. Hay quality and quantity was optimised between panicle emergence (Z59) and Z71. During this growth window, traits such as WSC, ADF, NDF and leaf chlorophyll content plateaued, but then deteriorated as the crop growth progressed beyond Z71. Crude protein progressively reduced following Z59. Further yield increase beyond Z71 was outweighed by lower quality, and profitability fell. Victorian trials at Rupanyup experienced a wetter than average spring, and most oat varieties held hay quality from Z59 through to 14 days after Z71. Yield increased significantly as the crop matured.

Cutting in the Z59 to Z71 window helps minimise curing time before quality starts to rapidly decline. Slight delays in cutting can be tolerated when there is adequate spring moisture and mild conditions.

Spikelets ripen down the panicle, so inspect the top florets to make growth stage cutting decisions. Note however, that panicle emergence and watery ripe growth stage aren't always sequential, i.e. genetics and environmental conditions influence the degree of panicle emergence prior to the onset of watery ripe.

Effects of grazing

Southern NSW hay crop production typically achieves high yields which may not meet export quality standards, therefore the focus is on supplying domestic dairy markets. Grazing dual purpose oats is common. In NSW crop defoliation trials sown in 2020 and 2021, both very wet, high yielding years, simulated grazing significantly reduced hay yield compared to the control (from 13.5-15.5 t/ha ungrazed to 10-11

t/ha grazed), however, produced more manageable crop canopies with quality better aligned to the requirements of export hay customers for hay production.

An SA trial at Tarlee in 2020 measured similar responses to grazing on oaten hay crops, reducing hay yield by 2 t/ha, with a reduction in plant height and lodging, and finer stems compared to the ungrazed crop.

Gains achieved from grazing crops and potential hay quality improvements will depend on livestock returns and the export price premium over the domestic market at that time.

Target plant density

Southern NSW growers typically sow fodder crops at grain-crop densities, which can be more than 50% lower than what is beneficial in other states (targeting 320 plants/m²). Research evaluated the effect of plant densities ranging from 160-360 plants/m².

Hay yield responded to the different seasonal conditions.

- In the dry 2019 season, hay yield was maintained across increasing plant density.
- Hay yield increased in the wetter seasons of 2020 and 2021, but only by 1.2 t/ha.
- As plant densities increased, stem diameter decreased, improving physical hay quality in all seasons.
- In a more average season, the cost of higher plant densities positive impact on hay yield should offset the cost of sowing extra seed.

To target higher quality oaten hay, set the crop up at the beginning of the season with higher target plant densities than grain-only crops to reduce stem diameter, and other hay quality traits, while also providing a stronger plant base structure to support cut hay off the ground, reducing potential quality losses from slower drying hay windrows or wet soil.

Lodging management using Moddus Evo

Moddus Evo inhibits the formation of gibberellic acid (GA), which promotes cell elongation. It is sometimes used to reduce height of wheat or barley crops grown in higher rainfall or high fertility situations that are prone to lodging.

Trials on oaten hay varieties showed the label rate of 400 mL/ha of Moddus Evo applied at Z31-Z32, compared to the control:

- improved straw strength and reduced the lodging risk
- reduced yield and height
- did not change stem diameter when cut at 15 cm
- affected panicle emergence for some varieties which could cause curing time issues.

Careful consideration should be given before applying Moddus Evo at the label rate to oats for export hay, as it is hard to predict the likelihood of lodging at Z31 and could cause panicle emergence issues.

A lower (unregistered) trial rate of 200 mL/ha of Moddus Evo at Z31-Z32, compared to the control and higher rate of Moddus Evo:

- maintained the benefit of better straw strength and lowered lodging risk
- reduced the risk of yield loss.

Managing panicle emergence using gibberellic acid

In dry seasons, and in low rainfall environments, the panicles of oats can be slow to emerge from the leaf sheath, often only partially emerging prior to the watery ripe growth stage. This results in growers either delaying cutting until they have fully emerged or cutting at the right growth stage with extended curing time due to the biomass contained within the leaf sheath. Both of these scenarios can result in reduced hay quality due to the decline in water soluble carbohydrates and increase in fibre when cutting occurs at the later growth stages,

or the increased environmental exposure and potential for weather damage as the hay cures over a longer period of time.

Trials showed application of GA as ProGibb SG at 40 g/ha at Z31-Z32, Z37-Z39, or both times, did not improve panicle emergence. Note, ProGibb SG is not registered for use in oaten hay (but is recommended on oats for forage).

- GA elongated the nodes, but it elongated them all, producing taller plants, not just the peduncle.
- There was no adverse effect on hay yield or quality of applying ProGibb SG.
- Later applications (post-flag leaf emergence) of GA may be required, or other growth regulator products, so that effect is only seen on the peduncle.

Plant pathology

Disease surveillance

Disease surveillance conducted across Western Australia and Victoria from 2018 to 2021 showed:

- Septoria avenae blotch was the most common disease in WA (>90% paddocks surveyed)
- RLL is the most common and severe foliar disease in Southeastern Australia
- RLL was detected and confirmed in WA oat crops.

Saprophyte suppression/weather damage trials

Post-cutting hay discoloration due to saprophytes reduces visual quality, suitability for export markets and economic returns. Saprophytes feed on dead and decaying plant tissue, so curing hay provides an ideal environment for colonisation, especially when it coincides with rainfall events.

Late season strobilurin application reduced the visual quantity of saprophytic fungal growth on the exposed/bleached portion of the windrow (the green portion of the

windrow was unaffected), without impacting yield and nutritional quality.

Strobilurin fungicides were more effective at decreasing saprophytic growth than triazole based chemistries. Strobilurin chemistries all had the same level of impact as each other.

Applying strobilurins 4 weeks prior to cutting at Z71, was just as effective as applying 3 weeks prior to cutting and provided a wider cutting window while reducing hay residue risk compared to no application.

Fungicides should be applied to manage the diseases present in-crop, with any additional saprophyte suppression an off-target bonus rather than being for the sole purpose of the application.

What does this mean?

Growing oaten hay that meets export quality standards is achieved by choosing high yielding varieties with favourable quality traits, and by managing the crop for with optimal nutrition and disease protection, coupled with timely cutting and curing that maintains this high quality.

Varieties respond similarly to agronomic levers, but by choosing varieties with genetically higher quality traits, their hay quality response to sowing time, higher

nitrogen rates that drive biomass and seasonal rainfall patterns, growers will be more likely to meet export quality hay standards.

Understand your hay tests for quality and understand your buyer needs to plan agronomic strategies that help improve or continue to produce a consistent quality product.

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Australia. Thank you to the partner organisations; Department of Primary Industries and Regional Development, South Australian Research and Development Institute, Agriculture Victoria, New South Wales Department of Primary Industries, Birchip Cropping Group, Hart Field Site group and Intergrain. <https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2024/02/oaten-hay-yield-and-quality-response-to-agronomic-levers>



Penong Sticky Beak day, 2023.



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Weeds

Improving the management of Group 1 resistant barley grass in Eyre Peninsula farming systems

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¹SARDI; ²The University of Adelaide; ³Sharon Nielsen Statistical Consulting and Training



Location
Mount Cooper

Rainfall
Av. Annual: 411 mm
Av. GSR: 326 mm
2023 Total: 394 mm
2023 GSR: 292 mm

Soil type
Red loam

Paddock history
2023: Barley, cut hay
2022: Wheat
2021: Self-regenerating medic pasture
2020: Wheat

Plot size
12 m x 1.7 m x 3 replicates

Key messages

- **New herbicides will provide future opportunities for grass weed management, but Sakura® is still a good option for barley grass weed control in cereals.**
- **Reducing the weed seed bank in every season is pivotal to managing all grass weeds.**

- **Crop rotation is important for barley grass management to achieve higher yields with wheat/break-crop/wheat rotation and two-year break/wheat rotation producing similar yields in 2023.**
- Shedding seeds well before crop harvest, reducing the effectiveness of harvest weed seed control strategies compared to weeds such as ryegrass.

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 traits include:

- Increased seed dormancy that results in delayed barley grass emergence. This often does not occur until 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 the effectiveness of crop-topping or spray-topping in pastures.

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 also monitored five 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 summarises the findings of the third year of the three-year research program.

How was it done?

New herbicide technologies have been registered and released for grass weed management, such as Luximax®, Mateno Complete® and Overwatch® in cereals, and Ultro® 900 herbicide for grass weeds and Reflex® for broadleaf weed control in pulses. New herbicides were compared against current herbicide options for barley grass weed management in 2021 and 2022.

In 2021, a three-year rotational trial site was established at Mount Cooper, consisted of four replicated trials, aiming to control herbicide resistant barley grass in a cereal, pulse, two year break and IMI crop systems. 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 were 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. For the 2022 trial details and results refer to 'Improving the management of Group 1 resistant barley grass in Eyre Peninsula farming systems', EPFS Summary 2022, p.124. A grass weed herbicide of Clethodim 700 ml/ha and Hasten (1% of spray solution/water volume) was applied to the Butler peas on 17 June 2022, and fungicides and insecticides were applied in September and October.

In the 2023 season, all trials were sown on 3 May with 72 kg/ha of Calibre wheat and 70 kg/ha MAP (10:22:0:0) and 25 kg/

ha urea placed below the seed. A pre-sowing knockdown was applied of 1.5 L/ha Trifluralin, 2L/ha Glyphosate, 118 g/ha Sakura, Estericide Xtra 680 @ 400 ml/ha and LI700 at 400ml/100L. An in-crop broadleaf weed control herbicide of Estericide Xtra 680 @ 800 ml/ha was applied on the 4 July. The site had 50 kg/ha urea spread in early June and another 70 kg/ha urea in mid-July.

A linear mixed model using restricted maximum likelihood was used to analyse this season's data using ASReml-R Butler (2009) and the R Core Team (2016) package Biometry Assist (Nielsen *et al.* 2022). Due to the uneven coverage of barley grass weeds across the site, the level of early barley grass coverage (barley grass plants/m²) in the plot in 2024 was 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. Tukey's multiple comparison test is also used to indicate rankings flagging statistical differences between treatments, where the treatment was found to have a significant value in the model. A 5% significance level was used throughout.

Herbicide efficacy

In this season, barley grass samples were collected from five paddocks on upper Eyre Peninsula. These samples had been sent to a private laboratory to be tested for resistance to Clethodim herbicide at 500 ml/ha, and a Clethodim @ 500 ml/ha and Butoxydim (Factor) @ 100 g/ha mixture.

Dormancy

Barley grass seeds from 30 paddocks across upper EP were sown in shallow trays of soil at MAC in 2021 and were assessed again in 2023 for length of seed dormancy and germination patterns.

What happened?

The 2023 season was an average growing season at Mount Cooper with a decile 5 growing season (292 mm) and a decile 5 total annual rainfall (394 mm).

Trial 1. Controlling grass weeds in cereals - Wheat/Pea/Wheat rotation

The Mount Cooper site was sown into good soil moisture.

There were no differences in plant establishment due to the herbicide treatments used in previous seasons (Table 1). The average plant density in the wheat/pulse/wheat rotation was 82 wheat plant/m². There were no differences in early dry matter with the average across treatments being 2.6 t/ha. There were no differences in NDVI (average, 0.8) measured between treatments.

There were differences in late dry matter (Table 1). The Nil Control treatment had lower dry matter as did Treatment 15, of 2022 Strand medic and wheat with Trifluralin 1.8 L/ha plus Avadex® (500 g/L) 1.6 L/ha IBS in 2021. Despite the lower late dry matter in 2023, Treatment 15 performed well in grain yield and grain protein (Table 1).

The Nil Control treatment performed poorly with lowest grain yield and lowest grain protein levels in 2023. The treatments with a strand medic rotation in 2021 with good weed control had the higher wheat yields and grain protein in 2023 compared to the Nil Control treatment (Table 1).

There were no differences between herbicide treatments for late barley grass density or barley grass weed seed heads at Mount Cooper in 2023 given the different rotational treatments using the predicted models with previous barley grass numbers as a covariate. There was an average of 106 barley grass weed seeds at harvest/m² across the different treatments, with the Nil Control having high numbers compared to other treatments with 738 barley grass weed seeds at harvest/m².

Table 1. Late dry matter, yield and grain quality of wheat at Mount Cooper 2023, and the density of barley grass heads, adjusted for 2023 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 (6 plants/m²).

BLOCK 1 Treatment Number	2022 Break crop Treatment	2021 Chemical Treatment with Scepter wheat	Late dry matter of Wheat (t/ha)	Harvest Barley grass weed seed set/m ²	Grain Yield of wheat (t/ha)	Grain protein (%)
1	Peas with Trifluralin 2 L/ha	Luximax® 500 ml/ha IBS (sown below 3 cm)	13.1 ± 0.9 cd	15	5.6 ± 0.14 b	10.8 ± 0.13 a
2	Peas with Trifluralin 2 L/ha	Sakura® (118 g/ha) IBS	13.4 ± 0.9 cd	5	5.5 ± 0.14 b	10.8 ± 0.13 a
3	Peas with Trifluralin 2 L/ha	Sakura® (118 g/ha) IBS	12.7 ± 0.9 de	191	5.4 ± 0.14 ab	10.8 ± 0.13 a
4	Peas with Trifluralin 2 L/ha	Trifluralin 1.8 L/ha IBS - District Practice	12.8 ± 0.9 de	738	5.3 ± 0.14 ab	10.8 ± 0.13 a
5	Peas with Trifluralin 2 L/ha	Overwatch® (1.25 L/ha)	13.0 ± 0.9 de	6	5.5 ± 0.14 b	10.8 ± 0.13 a
6	Peas with Trifluralin 2 L/ha	Luximax® (500 ml/ha) plus Trifluralin (1.8 L/ha) IBS	14.2 ± 0.9 abc	6	5.5 ± 0.14 b	10.8 ± 0.13 a
7	Peas with Trifluralin 2 L/ha	Luximax® (500 ml/ha) plus Avadex® (500 g/L) 1.6 L/ha IBS	11.7 ± 0.9 f	95	5.1 ± 0.14 ab	10.8 ± 0.13 a
8	Peas with Trifluralin 2 L/ha	Overwatch® 1.25 L/ha plus Trifluralin (1.8 L/ha) IBS	13.5 ± 0.9 bcd	67	5.4 ± 0.14 ab	10.8 ± 0.13 a
9	Peas with Trifluralin 2 L/ha	Overwatch® 1.25 L/ha plus Avadex® (500 g/L) 1.6 L/ha IBS	15.1 ± 0.9 a	179	5.2 ± 0.14 ab	10.8 ± 0.13 a
10	Peas with Trifluralin 2 L/ha	Sakura® (118 g/ha) and Avadex® (500 g/L) 1.6 L/ha IBS 10.43	12.9 ± 0.9 de	8	5.5 ± 0.14 b	10.9 ± 0.13 a
11	Peas with Trifluralin 2 L/ha	Sakura® (118 g/ha) IBS	14.8 ± 0.9 a	149	5.4 ± 0.14 ab	10.9 ± 0.13 a
12	Peas with Trifluralin 2 L/ha	Mateno Complete® 1 L/ha early post emergent (EPE)	14.6 ± 0.9 a	287	5.6 ± 0.14 b	11.0 ± 0.13 ab
13	Peas with Trifluralin 2 L/ha	Mateno Complete® 1 L/ha IBS	13.4 ± 0.9 cd	8	5.4 ± 0.14 ab	10.9 ± 0.13 a
14	Nil Control - Peas	Trifluralin (1.8 L/ha)	11.3 ± 0.9 f	84	4.8 ± 0.14 a	10.7 ± 0.13 a
15	Strand Medic	Trifluralin 1.8 L/ha plus Avadex® (500 g/L) 1.6 L/ha IBS	10.2 ± 0.9 g	28	5.6 ± 0.14 b	11.8 ± 0.13 c
16	Strand Medic	Luximax® (500 ml/ha) with Voraxar® (100 ml/ha) IBS	14.5 ± 0.9 a	8	5.7 ± 0.14 b	11.9 ± 0.13 c
17	Strand Medic	Sakura® (118 g/ha) with Voraxar® (100 ml/ha) IBS	13.3 ± 0.9 cd	47	5.5 ± 0.14 b	11.5 ± 0.13 bc
18	Peas with Trifluralin 2 L/ha	Overwatch® (1.25 L/ha) with Voraxar® (100 ml/ha) IBS	14.4 ± 0.9 ab	110	5.4 ± 0.14 ab	11.0 ± 0.13 ab
19	Peas with Trifluralin 2 L/ha	Boxer® Gold 2.5 L/ha IBS	12.1 ± 0.9 ef	61	5.4 ± 0.14 ab	10.7 ± 0.13 a
20	Peas with Trifluralin 2 L/ha	Trifluralin 1.8 L/ha plus Sakura® (118 g/ha) and Avadex® (500 g/L) 1.6 L/ha IBS	13.4 ± 0.9 cd	38	5.4 ± 0.14 ab	10.7 ± 0.13 a
Standard error of the predicted means			1	ns	1.4	0.6

Trial 2. Break crops

The break crop trial was a pulse, cereal, cereal rotation over the three years of the research trials. In 2023 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/m².

The NDVI (measure of green biomass of plots) was significantly lower compared to other treatments for the rotation which had the 2021 Canola ATR-Stingray treatment.

The grain yield at 1.8 t/ha of the Nil Control treatment was significantly lower than the average yield of 3.4 t/ha of the P/W/W rotation block. All other break and pulse rotation treatments performed similarly in grain yield of Calibre wheat in 2023. The grain protein was also lower and grain screenings were higher. The 2021 Medic (hay freeze) with Weedmaster (1.5 L/ha) had higher grain protein levels in 2023, similar to treatment 5, Vetch with Ultro® (1.1 kg/ha) plus Reflex® 500 gm/ha PSPE.

There were no differences between herbicide treatments for late barley grass density or barley grass weed seed heads at Mount Cooper in 2023 given the previous different rotational treatments using the predicted models with previous barley grass numbers being a covariate. There was an average of 1452 barley grass weed seeds at harvest/m² across the P/W/W rotation block.

Trial 3. Two-year break

The two-year break trial at Mount Cooper averaged 84 plants/m² in 2023. There were differences in Calibre wheat establishment with the Canola ATR-Stingray then Vetch with Ultro® (1.1 kg/ha). Treatment 1 having higher plant establishment with 94

plants/m² compared to treatment 5, the two-year medic using propyzamide, Rustler® 0.7 kg/ha IBS having lower plant numbers than other treatments (Table 3).

Despite having higher plant establishment Treatment 1, 2021 Canola ATR-Stingray and Vetch with Ultro® (1.1 kg/ha) had lower NDVI mid-season than Treatments 3, 4 and 6 (Table 3).

There was an average of 1806 barley grass weed seeds at harvest/m² across the different treatments. There were no differences between treatments for late barley grass density or barley grass weed seed heads at Mount Cooper in 2023 given the different rotational treatments using the predicted models with previous barley grass numbers being a covariate.

There were no differences between any treatment in wheat yield or grain quality due to the previous barley grass weed management treatments.

Trial 4: IMI systems

The IMI management system trial at Mount Cooper had no differences in Calibre wheat establishment in 2023 averaging 79 plants/m² (Table 4). There were differences in Calibre wheat for NDVI with the 2022 Kingbale Oats, Treatment 3 and Maximus CL Barley no herbicide (Treatment 4) having a lower measured level of 'greenness' than other treatments (Table 4).

The Razor CL Wheat with no IMI herbicide in 2022 had higher late dry matter production than the other treatments (Table 4) and the Maximus CL Barley no 2022 IMI herbicide had the lowest late dry matter production.

The early and late barley grass weed numbers and harvest weed seed set were all similar regardless of imidazolinone treatments from the previous seasons.

There were differences in grain yield with the 2022 Kingbale Oats, Treatment 3 having higher grain yield (0.6 t/ha) than the 2022 treatment of Maximus CL Barley with Intercept (500 ml/ha). There were no differences in grain quality measured in 2023 due to the previous herbicide treatments.

The relationship in 2023 between grain yield and harvest barley grass weed seed set of the different rotational treatments is shown in Figure 1. The lowest barley grass numbers and highest grain yields were achieved in the wheat/break/wheat rotation. The two-year break systems with lower barley grass numbers, Treatment 2 (two year medic), Treatment 4 (two year canola) and Treatment 5 (medic followed by vetch brown manure) also achieved higher yields. The break crop/wheat/wheat system and IMI system achieved slightly lower grain yields. Figure 1 shows a general trend of declining grain yield with increasing barley grass weed seed set measured at harvest. The lowest grain yields were in the Nil Control grass weed treatment which had the highest barley grass weed seed numbers.

Table 2. 2021 Break crop chemical treatment effects on crop establishment, barley grass weed numbers and dry matter at Mount Cooper in 2023. 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 (25 plants/m²).

BLOCK 2 Treatment Numbers	2022 Treatment	2021 Break Crop Chemical Treatment	NDVI	Harvest Barley grass weed seed set/m ²	Grain Yield of wheat (t/ha)	Grain protein (%)	Screenings (hL)
1	Mateno Complete® 1 L/ha IBS	Peas with Ultro® (1.1 kg/ha) IBS	0.61 ± 0.02 a	856	3.8 ± 0.19 b	9.0 ± 0.1 ab	33.2 ± 2.2 a
2	Mateno Complete® 1 L/ha IBS	Peas with Ultro® (1.1 kg/ha) IBS plus Reflex® 500 gm/ha PSPE	0.60 ± 0.02 ab	802	3.6 ± 0.2 b	8.9 ± 0.09 ab	32.9 ± 2.1 ab
3	Sakura® (118 g/ha) IBS	Peas with Boxer® Gold (2.5 L/ha)	0.60 ± 0.02 ab	834	3.4 ± 0.19 b	9.0 ± 0.09 ab	32.5 ± 2.0 ab
4	Luximax® 500 ml/ ha IBS	Vetch with Ultro® (1.1 kg/ha)	0.62 ± 0.02 a	1564	3.7 ± 0.19 b	9.1 ± 0.09 ab	29.9 ± 2.0 d
5	Mateno Complete® 1 L/ha IBS	Vetch with Ultro® (1.1 kg/ha) plus Reflex® 500 gm/ha PSPE	0.64 ± 0.02 a	1064	3.7 ± 0.19 b	9.2 ± 0.09 b	30.2 ± 2.0 cd
6	Mateno Complete® 1 L/ha IBS	Brown Manure Vetch (Glyphosate DST 2.5 L/ha)	0.62 ± 0.02 a	1264	3.9 ± 0.2 b	9.1 ± 0.1 ab	33.0 ± 2.2 ab
7	Luximax® 500 ml/ ha IBS	Vetch with Ultro® (1.1 kg/ha) plus Reflex® 500 gm/ha PSPE	0.63 ± 0.02 a	1400	3.3 ± 0.19 b	8.8 ± 0.09 ab	36.1 ± 2.1 a
8	Wheat Nil Control	Vetch Control Trifluralin (1.8 L/ha)	0.64 ± 0.02 a	4384	1.8 ± 0.19 a	8.7 ± 0.2 a	37.5 ± 3.4 a
9	Mateno Complete® 1 L/ha IBS	Vetch plus propyzamide Rustler® 0.7 kg/ha	0.63 ± 0.02 a	889	3.6 ± 0.19 b	9.1 ± 0.09 ab	30.5 ± 2.1 cd
10	Mateno Complete® 1 L/ha IBS	Medic (hay freeze) with Weedmaster (1.5 L/ha)	0.66 ± 0.02 a	1914	3.5 ± 0.19 b	9.2 ± 0.09 b	33.4 ± 2.1 a
11	Mateno Complete® 1 L/ha IBS	Medic with propyzamide, Rustler® 0.7 kg/ha IBS	0.65 ± 0.02 a	1529	3.3 ± 0.19 b	9.0 ± 0.09 ab	30.9 ± 2.1 c
12	Mateno Complete® 1 L/ha IBS	Canola ATR-Stingray Overwatch® 1.25 L/ha	0.58 ± 0.02 b	1938	3.3 ± 0.19 b	9.0 ± 0.1 ab	33.6 ± 2.1 a
13	Mateno Complete® 1 L/ha IBS	Vetch Ultro® (1.1 kg/ha) plus propyzamide Rustler® 0.7 kg/ha	0.63 ± 0.02 a	279	3.7 ± 0.19 b	9.1 ± 0.09 ab	30.1 ± 2.1 cd
14	Mateno Complete® 1 L/ha IBS	Peas Terbyne® 850 ml/ha PSPE	0.60 ± 0.02 ab	453	3.7 ± 0.19 b	8.9 ± 0.1 ab	36.8 ± 2.1 a
15	Mateno Complete® 1 L/ha IBS	Peas 900diuron (500 gm/ha) IBS	0.63 ± 0.02 a	1634	3.6 ± 0.19 b	9.0 ± 0.09 ab	32.3 ± 2.1 b
16	Mateno Complete® 1 L/ha IBS	Peas Simazine (1 kg/ha) IBS	0.62 ± 0.02 a	2432	3.5 ± 0.19 b	9.0 ± 0.09 ab	33.6 ± 2.1 a
Standard error of the predicted means			0.18	ns	0.03	0.03	0.8

Table 3. Wheat establishment, NDVI and grain yield for 2023 depending on 2022 break crop treatment and 2021 chemical treatment effect at Mount Cooper. 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 2022 (13 plants/m²). 2022 and 2023 Knockdown herbicides: Weedmaster 1.5 L/ha and LI700 @ 300 ml/100 L.

Treatment Number	2022 Second year break and Chemical Treatment	2021 Break Crop Chemical Treatment	2023 Wheat establish- ment (plants/m²)	NDVI	Harvest Barley grass weed seed set/m²	Grain Yield (t/ha)
1	Vetch with Ultro® (1.1 kg/ha)	Canola ATR-Stingray	94 ± 5 a	0.59 ± 0.04 a	2054	3.7
2	Strand Medic	Brown Manure Vetch (Glyphosate DST 2.5 L/ha)	81 ± 6 bc	0.71 ± 0.04 ab	914	4.9
3	Trident Canola	Strand Medic	83 ± 7 bc	0.64 ± 0.04 b	2979	3.3
4	Trident Canola	Canola ATR-Stingray with propyzamide, Rustler®	85 ± 5 b	0.74 ± 0.04 b	185	5.1
5	Medic with propyzamide, Rustler® 0.7 kg/ ha IBS	Medic with propyzamide, Rustler® 0.7 kg/ha IBS	78 ± 6 c	0.65 ± 0.04 ab	800	4.7
6	Kingbale oats (haycut)	Strand Medic	84 ± 5 bc	0.74 ± 0.04 b	3909	3.6
Standard error of the predicted means			5.6	0.04	ns	ns

Table 4. NDVI, late dry matter (t/ha) and grain yield of the IMI cereal trial at Mount Cooper in 2023, adjusted for 2022 barley grass populations using average weed numbers of 9 barley grass/m². Letters indicate Tukey's multiple comparison test between predicted model terms.

Treatment number	2022 Imidazolinone (IMI) Treatment	2021 Imidazolinone (IMI) Treatment	NDVI	Late dry matter (t/ha)	Harvest Barley grass weed seed set/m²	Grain Yield of wheat (t/ha)
1	Maximus CL Barley no herbicide	Razor CL Wheat with Intercept (500 ml/ha)	0.58 ± 0.02 b	7.45 ± 0.61 c	90	3.5 ± 0.3 ab
2	Razor CL Wheat no herbicide	Spartacus CL Barley with Intercept (500 ml/ ha)	0.59 ± 0.02 b	9.23 ± 0.61 a	651	3.5 ± 0.3 ab
3	Kingbale oats (haycut on residues)	Razor CL Wheat with Intercept (500 ml/ha)	0.63 ± 0.02 a	8.46 ± 0.6 b	0	3.9 ± 0.3 a
4	Maximus CL Barley with Intercept (500 ml/ha)	Scepter Wheat with Trifluralin 1.8 L/ha plus Sakura® (118 g/ha) IBS	0.59 ± 0.02 b	8.01 ± 0.6 bc	935	3.3 ± 0.3 b
Standard error of the predicted means			0.02	0.61	ns	0.34



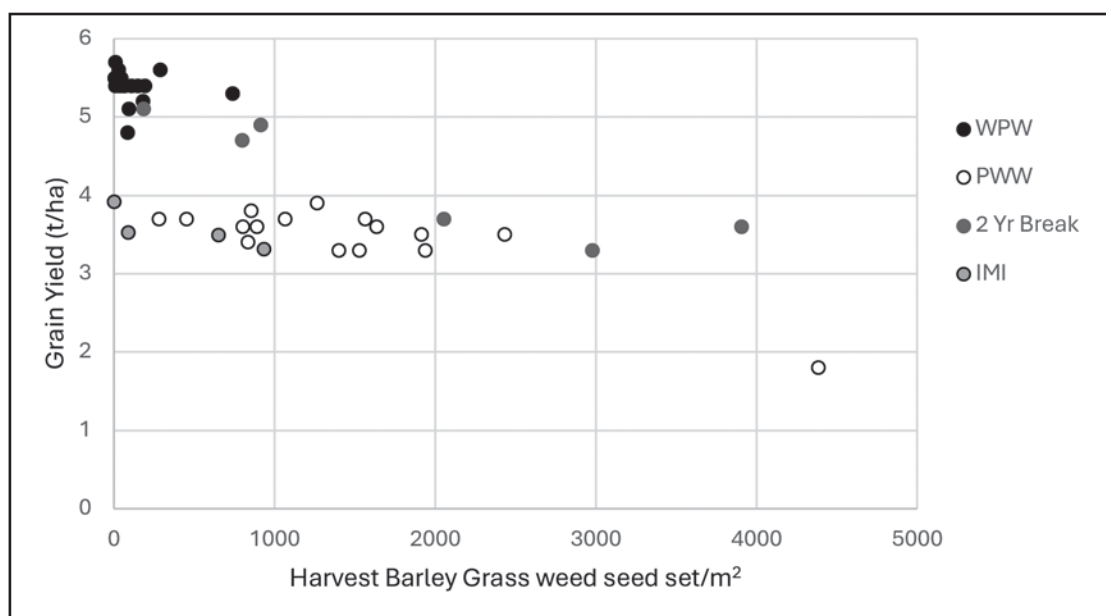


Figure 1. Grain yield (t/ha) and Harvest barley grass weed seed set/m² of different rotational systems at Mount Cooper in 2023.

What does this mean?

In 2023, the lowest barley grass numbers and highest grain yields were achieved in the wheat/break crop/wheat rotation compared to the break crop/wheat/wheat and cereal dominated IMI systems despite 55 units of N, 120 kg/ha of urea, being added across all systems in season to maximise yields.

There was a decline in grain yield with increasing barley grass weed seed set measured at harvest. The lowest grain yields were in the Nil grass weed control treatments which had the highest barley grass weed seed numbers.

The new chemistries from different herbicide groups will provide future opportunities for grass weed management. All herbicides included reduced barley grass compared to the untreated control (nil herbicide). Generally, over the three seasons, herbicides, or herbicide mixes with more than one active ingredient provided better weed management. Continued evaluation of these herbicides in lower rainfall regions will determine their best management practices and potential herbicide residue carry over issues, particularly for the lower rainfall environments with alkaline soils.

The 2023 grower paddocks monitoring for herbicide efficacy are still being tested. Previous seasons results showed there will be some paddocks on the upper EP where management results in herbicide applications not being as effective as expected. 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 need 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.

Reduced effectiveness of Group 1 herbicides within current low rainfall farming systems may result in high barley grass seed bank carry over. The use of Group 1 herbicide at higher rates and in combination with other herbicides will continue to be critical for barley grass management. Reducing the weed seed bank in every season

is pivotal to managing all grass weeds. If barley grass herbicide resistance is suspected, it is essential 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.

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Management of broadleaf weeds in lentils on different soil types

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Key messages

- Reflex[®] applied alone as incorporated by sowing (IBS), or in combination with metribuzin, showed higher stunting in GIA Metro^P compared to IMI lentils, though the severity of herbicide damage was dependent on soil type, with alkaline sandy loam to clayey sand soils reducing plant height than near neutral loam/clay soils.
- Reflex[®] provided control of warden weed, common sowthistle, wild turnip and Indian hedge mustard, however, it was in-effective for controlling medic. Including Group 5 herbicides applied as post-sowing pre-emergent (PSPE), and Group 2 and 12 herbicides as post-emergence at 5-6 crop-node stage (POST) improved broadleaf weed control compared to IBS herbicides only.
- Metribuzin applied POST in GIA Metro^P gave more flexibility and improved medic control compared to its post-sowing pre-emergent application.
- Sub-lethal rates of Group 5 herbicides were not as

effective as the label rates for controlling broad-leaf weeds. Furthermore, previous studies have found recurrent selection with exposure to reduced herbicides rates results in rapid evolution of herbicide resistance in weeds.

- GIA Metro^P was lower yielding compared to PBA Highland XT^P and GIA Thunder^P, where weeds were effectively controlled. However, this yield gap was reduced in the situations of unsatisfactory weed control in IMI lentils.

Why do the trial?

With their potential for impressive economic returns, some pulse crops are becoming increasingly popular among South Australian (SA) growers. As a break crop, pulses can contribute to soil health through nitrogen fixation and can help to reduce the impact of carryover cereal diseases.

The adoption of new herbicide tolerant pulse crops - such as Group 2 Imidazolinone (IMI) tolerant lentil and faba bean - has helped growers to control broadleaf weeds more effectively in the pulse phase of their crop rotation. However, the availability of multiple IMI-tolerant varieties across cereals, pulses and canola has helped to create over-reliance on herbicides with this mode of action (MOA). This in turn has increased the prevalence and risk of IMI herbicide-resistant weeds developing. Accordingly, relying on IMI herbicides alone is not an effective long-term strategy for broadleaf weed management in pulses.

Growers in some SA regions, particularly the Yorke Peninsula and Eyre Peninsula, are expanding lentils into more acidic or highly alkaline sandy soils. The research work carried out in these regions (SAGIT funded TC121 and GRDC funded UOA2105-013RTX) highlighted that lentil crop safety from herbicide damage and effective weed control can be an even greater challenge on such soil types (Bruce *et al*, 2022; EPFS 2022, p. 132). This research work was extended into highly alkaline soils at Kimba, Minnipa and Mudamuckla in the 2023 season to develop improved strategies for better weed control and herbicide resistance management of broadleaf weeds in lentil grown on the upper Eyre Peninsula, with funding support from GRDC (UOA2303-007RTX and UOA2105-013RTX).

How it was done

The site details including soil type, varieties grown, and sowing and harvest dates of three research experimental trials are summarised in Tables 1 and 2. A pre-seeding spray of glyphosate at 1200 g/ha and carfentrazone at 30 g/ha was applied to control existing weeds in the field. Lentil was sown at a depth of 4-5 cm with a target plant density of 120 plants/m² by using a no-till plot seeder fitted with knife-point tines and press wheels. Plots were 10 m long and contained six crop rows spaced 22.5 cm apart. Fertilizer rate was consistent with the local grower practice of 80 kg/ha of monoammonium phosphate banded below the seed at sowing. The experiments were laid out in a randomized complete-block design with three replications.

Table 1. The range of soil pH (in H₂O), organic carbon % and soil texture of the experimental sites in 2023.

Location	pH H ₂ O		OC %		Texture	
	0-10 cm	10-20 cm	0-10 cm	10-20 cm	0-10 cm	10-20 cm
Minnipa	8.8	8.9	0.98	0.70	Sandy clay loam	Sandy clay loam
Mudamuckla	8.8	8.9	0.96	0.93	Sandy loam	Clayey sand
Kimba	7.7	9.5*	0.65	0.24*	Loam/Clay	Clay

*sample represented 10-30 cm soil depth

Table 2. Target weed species, lentil variety and sowing and harvest dates of three upper EP trial sites in 2023.

Location	Target weed species	Variety	Sowing date	Harvest date
Minnipa	Medics	GIA Metro ^P and PBA Highland XT ^P	28 April	16 October
Mudamuckla	Medics and wards weed	GIA Metro ^P and PBA Highland XT ^P	27 April	30 October
Kimba	Common sowthistle and brassica weeds	GIA Metro ^P and GIA Thunder ^P	10 May	2 November

Table 3. Solubility and adsorption coefficient values of herbicides used in three experiments on the UEP in 2023 (source: GRDC pre-emergent herbicide fact sheet).

Herbicide (Group)	Application timing in the experiments	Active ingredient	Solubility (mg/L @ 20°C)		Adsorption coefficient, Koc value	
Diuron (5)	IBS*/PSPE**	900 g/kg diuron	36	Low solubility	813	Slightly mobile
Metribuzin (5)	IBS/PSPE	750 g/kg metribuzin	1165	High solubility	60	Mobile
Reflex® (14)	IBS	240 g/L fomesafen	50	Moderate solubility	228	Moderately mobile
Terbyne® (5)	IBS	750 g/kg terbutylazine	7	Low solubility	230	Moderately mobile
Terrain® (14)	IBS	500 g/kg flumioxazin	0.8	Low solubility	889	Slightly mobile

*IBS: Incorporated by sowing, **PSPE: Post-sowing pre-emergence

The solubility and adsorption coefficient values of the herbicides used as incorporated by sowing (IBS) or post-sowing pre-emergent (PSPE) in the study are summarised in Table 3. All herbicide rates used in the experiments are mentioned in terms of the commercial product (Tables 4-8). Broadleaf weed pod/seed set was assessed near crop harvest from three randomly selected spots within a plot using a 50 cm × 50 cm quadrant. The statistical analysis was done with ANOVA, GENSTAT version 23.

Rainfall conditions

All three experimental sites received lower than average growing season rainfall (GSR) (Figure 1). Minnipa site received 83% of the average GSR rainfall, while the corresponding values for Mudamuckla and Kimba were 50% and 56%, respectively. No significant rainfall event occurred within the first and second weeks after seeding at any of the experimental sites that could carry the risk of washing of pre-emergent herbicides applied either IBS or PSPE on to the crop rows.

What happened?

Crop safety

Crop damage in lentil was assessed using plant emergence counts, and visual assessments for chlorosis, necrosis and stunting. The level of crop damage in lentil from the use of Group 14 herbicides, Reflex® and Terrain®, and Group 5 herbicides, diuron and metribuzin varied across the different sites and is summarised below.

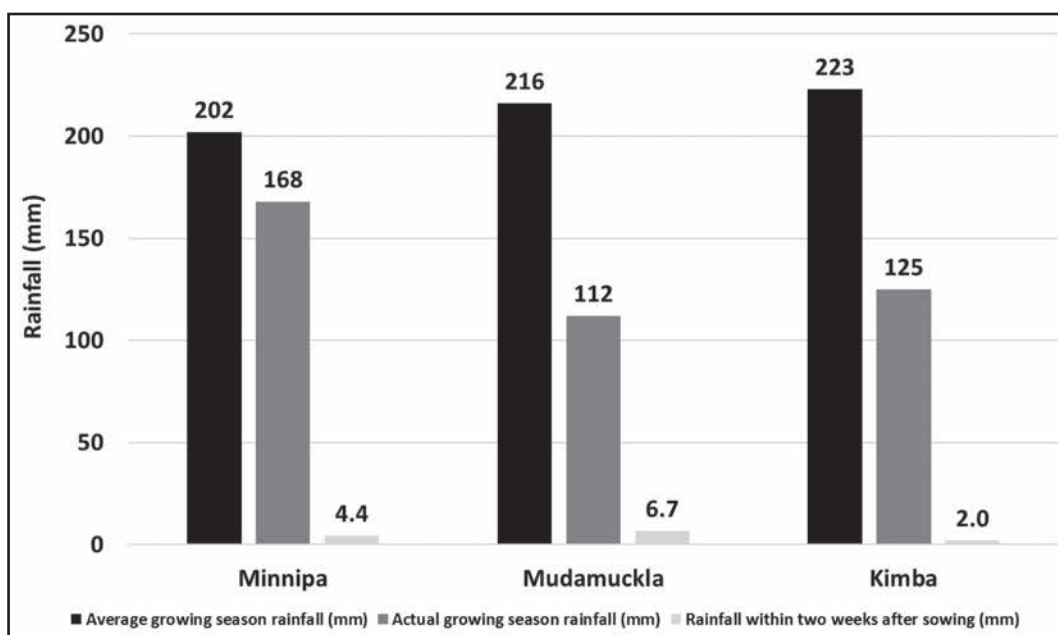


Figure 1. Long term, 2023 and two-weeks post sowing rainfall totals for three sites on the upper Eyre Peninsula in 2023.

Plant establishment

There was no reduction in plant establishment observed from the application of any herbicide treatment compared with the untreated control at all the three experimental sites in 2023 (Tables 4, 6 and 8). Metribuzin applied as post-sowing pre-emergence (PSPE) at 380 g/ha in GIA Metro^P proved safe, and the plant establishment was similar to off-label industry practices of using sub-lethal rates of Group 5 metribuzin at 120 g/ha, Terbyne[®] at 500 g/ha and diuron at 200 g/ha as IBS in imidazolinone tolerant lentils.

Reduction in plant biomass (stunting)

Plant stunting is recognised as a symptom of crop phytotoxicity from the application of Group 14 herbicides. Plant stunting visual scores at 12 weeks post-sowing were generally higher in GIA Metro than PBA Highland XT^P in the Reflex[®] and Reflex + metribuzin treatments (Tables 4 and 6). These visual stunting symptoms in GIA Metro^P were present at the more alkaline sites of Minnipa and Mudamuckla within the first twelve weeks post-seeding, however, plant height measurements at sixteen weeks post-seeding showed no

reduction in plant height between the treated and untreated plots of GIA Metro^P, suggesting a level of plant recovery had occurred. Minnipa and Mudamuckla sites received 43 mm and 28 mm rainfall, respectively, distributed over more than 20 days during a six-week period prior to the plant height measurements carried out in mid to late August. The resultant favourable growing condition after this rainfall is thought to be responsible for plant recovery from the herbicide. At the Kimba site, with near-neutral soil pH, plant height measurements indicated no difference between treated and untreated plots of both GIA Metro^P and GIA Thunder^P. These results are consistent with previous findings of Bruce, *et al.* (2022), where lentils grown on alkaline sandy soils recorded higher stunting from Group 14 herbicides compared to medium textured soils with near-neutral soil pH.

Chlorosis and necrosis

Metribuzin applied post-sowing pre-emergent (PSPE) or post-emergent at 5-6 crop node stage (POST) did not cause chlorosis or necrosis in GIA Metro^P at 180 and 380 g/ha (Tables 4 and 6). Furthermore, off-label industry practices including a combination of Reflex[®] and metribuzin applied

at the sub-lethal rate of 120 g/ha (IBS) caused higher levels of chlorosis in PBA Highland XT^P compared to GIA Metro^P sprayed at highest label rate of 380 g/ha. Reflex[®] at 500 mL/ha (IBS) followed by (f.b.) Brodal[®] at 150 mL/ha at 3-4 node growth stage in PBA Highland^P caused a higher level of chlorosis and necrosis than Reflex[®] at 500 mL/ha (IBS) f.b. Intercept[®] at 500 mL/ha (POST) in PBA Highland, and Reflex[®] at 500 mL/ha (IBS) f.b. metribuzin at 380 g/ha (POST) in GIA Metro^P (Table 4).

Grain yield

The average lentil yields were low at Minnipa (average 0.35 t/ha), very low at Mudamuckla (average 0.17 t/ha), but yields were higher at Kimba (2.02 t/ha) in 2023. Highly alkaline soils at Mudamuckla (Table 3) coupled with 48% lesser rainfall received in the growing season compared to the average GSR (Figure 1) might have resulted in very low yields. Overall, the yields of the GIA Metro^P averaged 19-42% lower in untreated plots than the best herbicide strategy. Similarly, GIA Thunder^P and PBA Highland XT^P yielded up to 35% and 15% lesser yields, respectively, in untreated plots than the best herbicide strategy in these varieties.

Reflex at 500[®] mL/ha (IBS) f.b. Intercept[®] at 500 mL/ha (POST) recorded the highest yield of PBA Highland XT^P at Minnipa (Table 5). It was 25% higher than GIA Metro^P sprayed with Reflex[®] at 500 (IBS) f.b. metribuzin 380 g/ha (POST), though both the treatments recorded similar level of weed control. NVT evaluation of GIA Metro^P in SA, Victoria, Western Australia and New South Wales in 2021 and 2022 suggested it is 20 to 30% lower yielding than PBA Hurricane XT^P where weeds are controlled effectively and in the absence of herbicide damage (Fact sheet Metro, Grains Innovation Australia, 2023). However, there was no yield gap between two varieties in the absence of effective weed control in PBA Highland XT^P when relied either on Reflex (IBS) alone, off-label industry practices of Group 5 herbicides at sub-lethal rates applied alone as IBS or their combinations with Reflex.

Further, GIA Thunder^P recorded up to 28% higher grain yield in the plots treated with Reflex[®] at 750 mL/ha (IBS) f.b. diuron 550 g/ha (PSPE) f.b. Intercept[®] at 750 mL/ha (POST) compared to GIA Metro^P sprayed with Reflex[®] at 750 mL/ha (IBS) f.b. metribuzin at 380 g/ha (PSPE) at Kimba, though both the herbicide strategies recorded similar level of weed control (Table 8). However, this yield gap between two varieties was reduced up to 16% in the absence of effective weed control in GIA Thunder^P while relying on Reflex 500-750 mL/ha (IBS) only.

Broadleaf weed control

Medics were the dominant broadleaf weed species at the Minnipa and Mudamuckla experimental sites. The Mudamuckla site also had additional background population of wards weed. Common sowthistle, and brassica weeds including Indian hedge mustard and wild turnip were the dominant broadleaf weed species at the Kimba site.

The dose and timing of metribuzin application had a significant impact on its efficacy on medics. Metribuzin applied at 180 g/ha either as PSPE or POST did not improve medic control compared to the unsprayed control in GIA Metro^P (Table 7). Further, metribuzin applied at 380 g/ha (POST) was more effective in reducing medic pod set (28 pods/m² compared to 225 pods/m²) when applied at the PSPE timing at Minnipa (Table 5). Similarly, POST application of metribuzin at 380 g/ha (POST) reduced medic pod set by 92% compared to the PSPE application at Mudamuckla.

Group 14 herbicides Reflex[®] and Terrain[®] applied IBS alone did not provide control of medics (Tables 5 and 7). A follow up application of metribuzin (POST) in GIA Metro^P, and Intercept[®] (POST) in PBA Highland XT^P was needed after Reflex[®] IBS to achieve some level of control of medic (7-27 pod/m² at Minnipa, 5-9 at pod/m² Mudamuckla). Off-label industry practices of using sub-lethal rates of Group 5 herbicides metribuzin (120 g/ha), diuron (200 g/ha), Terbyne[®] (500 g/ha) IBS proved in-effective for medic control. Previous studies have revealed that recurrent selection with exposure to reduced herbicides rates resulted in rapid evolution of herbicide resistance in some weeds and should be avoided (Neve and Powles, 2005; Gressel 2011).

Reflex[®] (IBS) at 500-750 mL/ha reduced plant numbers of wards weed to 1.5-2.5 plants/m² compared to 27.5 plants/m² in the unsprayed control plots (Table 7). A follow up application of metribuzin (POST) in GIA Metro^P, and Intercept[®] (POST) in PBA Highland XT^P provided control of ward weed plants that survived in intra-row spaces. Metribuzin on its own applied at both 180 g/ha and 380 g/ha, either PSPE or POST, proved effective for wards weeds control. Terrain[®] did not prove

effective for wards weed control (17.2 plants/m²).

Common sowthistle control improved with increased rates of Reflex[®] from 500 mL/ha to 1000 mL/ha (Table 8). Most of the surviving plants of common sowthistle in Reflex[®] treated plots were found in the intra-row spaces, from where the applied herbicide was likely moved out by the seeding operation. Where Reflex[®] was applied IBS and f.b. Group 5 herbicides metribuzin applied as PSPE/ POST, or diuron PSPE, the surviving weeds in the intra-row area were mostly controlled. Further, metribuzin at 380 g/ha applied POST proved more effective in reducing common sowthistle pod set (0.3 pods/m²) compared to its PSPE application (27.6 pods/m²).

Reflex[®] applied IBS alone or in combinations with Group 5 herbicide metribuzin/diuron PSPE, plus a follow up application of Group 2 herbicide Intercept[®] or Group 12 herbicide Brodal[®] post-emergent provided effective control of brassica weeds such as Indian hedge mustard and wild turnip (<1 pod/m²) compared to unsprayed control plots (Table 8).

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. The Group 14 herbicide Reflex® applied in combination with other registered Group 2, 5 and 12 herbicides has increased the options for broadleaf weed control in lentil. However, consideration should be given to the associated risks of crop damage when applied alone or with Group 5 herbicides, depending on the soil type and herbicide rates. Furthermore, results in these experiments showed the limitations of weed control with IBS applications of various chemistries compared to PSPE or POST applications where available.

New dual metribuzin and IMI tolerant lentil, GIA Metro^P has provided new opportunities to control multiple broadleaf weeds, including improved medic control in lentil. The increased adoption of this variety will potentially help to reduce selection pressure and delay resistance build up to the IMI herbicides. Grain yield of GIA Metro^P is significantly lower than existing lentil varieties in the absence of weeds, or where weeds are controlled effectively without crop damage from Group 5 herbicides due to a fitness penalty associated with the metribuzin tolerance. GIA Metro^P is an option for lentil growers where weed competition and/or current herbicide options (e.g. IMI-resistant broadleaf weeds) prohibit economical and sustainable lentil production. The strategic use of GIA Metro^P in some cropping rotations may assist in improved weed control in lentil and reduced weed seed bank burdens of Group 2 resistant weeds allowing for a return to other lentil varieties in subsequent seasons. Growers must refer to the new permit for metribuzin use

in GIA Metro^P in varying soil and weather conditions, as granted by the Australian Pesticides and Veterinary Medicines Authority (PER92810, 2022).

More research work is needed to understand the safest and most efficient way of controlling weeds in lentil in low rainfall areas, including the effective and judicious use of GIA Metro^P. More studies in low rainfall areas with growers' preferences of lower cost herbicide options, means metribuzin POST could be a cost-effective strategy compared to other strategies with IBS and PSPE herbicides, but needs further investigation. It will enable growers to make more informed and confident decisions about adopting these new tools for managing broadleaf weeds in lentil, especially in the regions where they have not been grown in the past.

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Table 4. Measures of crop phytotoxicity in two varieties of lentil to various herbicides and herbicides mixtures on alkaline sandy clay loam soils at Minnipa in 2023. Plant stunting score (1 = no stunting, 9 = plant death), chlorosis score (1 = no chlorosis, 9 = plant death), stunting score (1 = no stunting, 9 = plant death). Data labelled with the same letters within a column are not significantly different (P<0.05).

	Variety	Herbicide treatment (dose in terms of commercial product)	Emergence (plants/m²)	Chlorosis	Necrosis	Stunting	Plant height (cm) 16 WAS
				12 WAS**			
1	GIA Metro ^P	Metribuzin 380 g/ha (POST)	115 a	1.0 b	1.2 de	1.5 cde	13.4 c
2		Metribuzin 380 g/ha (PSPE)	105 a	1.0 b	1.0 e	1.2 de	13.5 c
3		Reflex® 500 mL/ha (IBS)	107 a	1.3 b	1.5 bcd	3.0 a	13.0 c
4		Reflex® 500 mL/ha (IBS) f.b. Intercept® 500 mL/ha (POST)	99 a	1.3 b	1.3 cde	2.8 a	13.1 c
5		Reflex® 500 mL/ha (IBS) f.b. metribuzin 380 g/ha (POST)	99 a	1.3 b	1.7 bc	2.7 ab	12.9 c
6		Reflex® 500 mL/ha (IBS) f.b. metribuzin 380 g/ha (PSPE)	97 a	1.3 b	1.8 b	3.3 a	12.9 c
7		Unsprayed control	108 a	1.0 cb	1.0 e	1.0 e	13.8 bc
8		Reflex® 500 mL/ha (IBS)	117 a	1.2 b	1.2 de	1.8 cd	18.5 a
9		Reflex® 750 mL/ha (IBS)	90 a	1.3 b	1.5 bcd	2.0 bc	18.7 a
10		Reflex® 500 mL/ha (IBS) f.b. Brodal® 150 mL/ha at 3-4 crop node stage	110 a	2.0 a	3.5 a	2.8 a	15.4 b
11		Reflex® 500 (IBS) f.b. Intercept® 500 mL/ha (POST)	80 a	1.2 b	1.3 cde	2.0 bc	18.5 a
12	PBA Highland ^P XT	Reflex® 500 mL/ha (IBS) + diuron 200 g/ha (IBS)*	97 a	1.2 b	1.5 bcd	1.5 cde	18.5 a
13		Reflex® 500 mL/ha (IBS) + diuron 200 g/ha (IBS)* f.b. Intercept® 500 mL/ha (POST)	96 a	1.2 b	1.3 cde	1.8 cd	18.7 a
14		Reflex® 500 mL/ha (IBS) + metribuzin 120 g/ha (IBS)*	93 a	1.8 b	1.5 bcd	2.0 bc	17.1 a
15		Terbyne® 500 g/ha (IBS)*	97 a	1.0 b	1.2 de	1.3 cde	18.3 a
16	Unsprayed control	103 a	1.0 b	1.0 e	1.3 cde	18.3 a	

*off-label industry practice, **weeks after sowing
 IBS: Incorporated by sowing, PSPE: Post-sowing pre-emergence, POST: Post-emergent at 5-6 crop node stage, f.b.: Followed by.

Table 5. Efficacy of various herbicides and herbicide mixtures on medic density and pod set and the associated grain yield of two lentil varieties on alkaline sandy clay loam soils at Minnipa in 2023. Data labelled with the same letters within a column are not significantly different ($P<0.05$). Data labelled with the same letters within a column are not significantly different ($P<0.05$).

	Variety	Herbicide treatment (dose in terms of commercial product)	Seed bearing medics/m ²	Medic pods/m ²	Yield (kg/ha)
1	GIA Metro ^P	Metribuzin 380 g/ha (POST)	6.3 efg	28 d	349 cde
2		Metribuzin 380 g/ha (PSPE)	31.4 ab	225 bc	286 def
3		Reflex [®] 500 mL/ha (IBS)	13.7 cdef	182 bc	254 ef
4		Reflex [®] 500 mL/ha (IBS) f.b. Intercept [®] 500 mL/ha (POST)	4.4 gh	26 d	290 cdef
5		Reflex [®] 500 mL/ha (IBS) f.b. metribuzin 380 g/ha (POST)	0.8 hi	7 de	364 cde
6		Reflex [®] 500 mL/ha (IBS) f.b. metribuzin 380 g/ha (PSPE)	16.0 bcde	125 c	288 cdef
7		Unsprayed control	49.0 a	433 a	209 f
8	PBA Highland ^P XT	Reflex [®] 500 mL/ha (IBS)	22.1 bc	188 bc	367 cde
9		Reflex [®] 750 mL/ha (IBS)	18.5 bcd	154 c	369 bcde
10		Reflex [®] 500 mL/ha (IBS) f.b. Brodal [®] 150 mL/ha at 3-4 crop node stage	6.3 efg	29 d	357 cde
11		Reflex [®] 500 (IBS) f.b. Intercept [®] 500 mL/ha (POST)	5.8 efgh	27 d	486 ab
12		Reflex [®] 500 mL/ha (IBS) + diuron 200 g/ha (IBS)*	25.0 bc	196 bc	394 abcd
13		Reflex [®] 500 mL/ha (IBS) + diuron 200 g/ha (IBS)* f.b. Intercept [®] 500 mL/ha (POST)	5.3 fgh	34 d	496 a
14		Reflex [®] 500 mL/ha (IBS) + metribuzin 120 g/ha (IBS)*	9.0 defg	139 c	405 abc
15		Terbyne [®] 500 g/ha (IBS)*	25.0 bc	161 c	385 abcd
16		Unsprayed control	49.0 a	296 ab	315 cdef

*Off-label industry practice
 IBS: Incorporated by sowing, PSPE: Post-sowing pre-emergence, POST: Post-emergent at 5-6 crop node stage, f.b.: Followed by.

Table 6. Measures of crop phytotoxicity in two varieties of lentil to various herbicides and herbicides mixtures on alkaline sandy loam (0-10 cm) to clayey sand (10-20 cm) soil at Mudamuckla 2023. Plant stunting score (1 = no stunting, 9 = plant death), chlorosis score (1 = no chlorosis, 9 = plant death), stunting score (1 = no stunting, 9 = plant death). Data labelled with the same letters within a column are not significantly different (P<0.05).

	Variety	Herbicide treatment (dose in terms of commercial product)	Emergence (plants/m ²)	Chlorosis on 20/7/23	Necrosis	Stunting	Plant height (cm) 16 WAS
				12 WAS**			
1	GIA Metro ^P	Metribuzin 180 g/ha (POST)	106 a	1.0 d	1.0 a	1.3 b	17.5 b
2		Metribuzin 180 g/ha (PSPE)	118 a	1.0 d	1.0 a	1.3 b	16.9 bc
3		Metribuzin 380 g/ha (POST)	119 a	1.2 cd	1.0 a	1.0 b	17.2 bc
4		Metribuzin 380 g/ha (PSPE)	113 a	1.0 d	1.0 a	1.2 b	17.9 b
5		Reflex® 500 mL/ha (IBS) f.b. metribuzin 380 g/ha (PSPE)	121 a	1.0 d	1.0 a	2.3 a	15.3 c
6		Reflex® 500 mL/ha (IBS) f.b. metribuzin 380 g/ha (POST)	121 a	1.0 d	1.0 a	2.0 a	16.1 bc
7		Unsprayed control	126 a	1.0 d	1.0 a	1.2 b	16.1 bc
8	PBA Highland ^P XT	Reflex® 500 mL/ha (IBS)	121 a	1.2 cd	1.0 a	1.0 b	24.1 a
9		Reflex® 750 mL/ha (IBS)	119 a	1.3 bcd	1.0 a	1.2 b	24.1 a
10		Reflex® 500 mL/ha (IBS) f.b. Intercept® 500 mL/ha (POST)	100 a	1.5 abc	1.2 a	1.0 b	24.9 a
11		Terrain® 120 mL/ha (IBS)	104 a	1.8 a	1.3 a	1.0 b	24.9 a
12		Reflex® 500 mL/ha (IBS) + metribuzin 120 g/ha (IBS)*	100 a	1.7 ab	1.2 a	1.0 b	24.0 a
13		Reflex® 500 mL/ha (IBS) + diuron 200 g/ha (IBS)*	112 a	1.2 cd	1.0 a	1.2 b	25.3 a
14		Reflex® 500 mL/ha (IBS) + diuron 200 g/ha (IBS)* f.b. Intercept® 500 mL/ha (POST)	124 a	1.0 d	1.0 a	1.0 b	25.7 a
15		Brodal® 80 mL/ha (IBS)* + diuron 200 g/ha (IBS)* f.b. Intercept® 500 mL/ha (POST)	105 a	1.7 ab	1.0 a	1.0 b	24.9 a
16		Unsprayed control	118 a	1.3 bcd	1.0 a	1.0 b	24.5 a

*Off-label industry practice, **Weeks after sowing

IBS: Incorporated by sowing, PSPE: Post-sowing pre-emergence, POST: Post-emergent at 5-6 crop node stage, f.b.: Followed by.

Table 7. Efficacy of herbicides on medic and wards weed density, and medic pod set on alkaline sandy loam (0-10 cm) to clayey sand (10-20 cm) soil at Mudamuckla in 2023. Data labelled with the same letters within a column are not significantly different ($P \leq 0.05$).

	Variety	Herbicide treatment (dose in terms of commercial product)	Medic pods/plot	Wards weed/ plot	Yield (kg/ha)
1	GIA Metro ^P	Metribuzin 180 g/ha (POST)	71.4 a	0.1 de	148 cde
2		Metribuzin 180 g/ha (PSPE)	97.8 a	1.5 cd	120 e
3		Metribuzin 380 g/ha (POST)	7.8 bc	0 e	123 e
4		Metribuzin 380 g/ha (PSPE)	98.2 a	0.1 de	150 cde
5		Reflex [®] 500 mL/ha (IBS) f.b. metribuzin 380 g/ha (PSPE)	77.1 a	0 e	136 de
6		Reflex [®] 500 mL/ha (IBS) f.b. metribuzin 380 g/ha (POST)	9.4 bc	0 e	131 de
7		Unsprayed control	85.2 a	14.3 b	122 e
8	PBA Highland ^P XT	Reflex [®] 500 mL/ha (IBS)	52.1 a	1.5 cd	202 ab
9		Reflex [®] 750 mL/ha (IBS)	67.1 a	2.5 c	201 ab
10		Reflex [®] 500 mL/ha (IBS) f.b. Intercept [®] 500 mL/ha (POST)	4.5 bc	0 e	216 ab
11		Terrain [®] 120 mL/ha (IBS)	81.5 a	17.2 ab	181 bcd
12		Reflex [®] 500 mL/ha (IBS) + metribuzin 120 g/ha (IBS)*	68.4 a	1.3 cde	194 abc
13		Reflex [®] 500 mL/ha (IBS) + diuron 200 g/ha (IBS)*	65.8 a	2.7 c	210 ab
14		Reflex [®] 500 mL/ha (IBS) + diuron 200 g/ha (IBS)* f.b. Intercept [®] 500 mL/ha (POST)	0 c	0 e	243 a
15		Brodal [®] 80 mL/ha (IBS)* + diuron 200 g/ha (IBS)* f.b. Intercept [®] 500 mL/ha (POST)	3.5 bc	0 e	212 ab
16		Unsprayed control	70.6 a	27.5 a	189 bc

*Off-label industry practice
IBS: Incorporated by sowing, PSPE: Post-sowing pre-emergence, POST: post-emergent at 5-6 crop node stage, f.b.: Followed by.

Table 8. Crop growth and weed efficacy response to different herbicides on loamy clay (at 0-10 cm with near-neutral soil pH) to clayey soil (at 10-30 cm and alkaline reaction) at Kimba 2023.

	Variety	Herbicide treatment (dose in terms of commercial product)	Emergence (plants/m ²)	Plant height (cm) 10 WAS*	Common sowthistle pods/m ²	WT pods/m ²	IHM pods/m ²	Yield (t/ha)
1		Reflex® 750 mL/ha (IBS)	112 a	10.5 cde	6.3 cde	0 c	1.0 b	1.76 c
2		Metribuzin 380 g/ha (PSPE)	104 a	9.6 def	27.6 b	0.5 c	0 b	1.75 c
3		Metribuzin 380 g/ha (POST)	105 a	8.9 f	0.3 def	0 c	0 b	1.87 c
4		Metribuzin 380 g/ha (PSPE) f.b. Intercept® 750 mL/ha (POST)	119 a	9.3 ef	7.3 cd	0 c	0 b	1.64 c
5	GIA Metro ^P	Reflex® 750 mL/ha (IBS) f.b. metribuzin 380 g/ha (PSPE)	108 a	9.1 ef	0.6 def	0 c	0 b	1.94 c
6		Reflex® 750 mL/ha (IBS) f.b. metribuzin 380 g/ha (PSPE) + Brodal® 200 mL/ha (POST)	102 a	9.0 ef	0.6 def	0 c	0 b	1.84 c
7		Reflex 750 mL/ha (IBS) f.b. metribuzin 380 g/ha (PSPE) f.b. Intercept® 750 mL/ha (POST)	111 a	9.9 def	0.1 ef	0 c	0 b	1.80 c
8		Reflex 750 mL/ha (IBS) f.b. metribuzin 380 g/ha (POST)	110 a	8.7 f	0 f	0 c	0 b	1.87 c
9	GIA Thunder ^P	Reflex 750 mL/ha (IBS) f.b. metribuzin 380 g/ha (POST) + Intercept® 750 mL/ha (POST)	101 a	9.9 def	0 f	0 c	0 b	1.92 c
10		Unsprayed control	119 a	9.3 ef	124.3 a	37.2 b	11.8 a	1.26 d
11		Reflex® 500 mL/ha (IBS)	102 a	11.9 abc	26.8 b	0.3 c	0.9 b	2.45 ab
12		Reflex® 750 mL/ha (IBS)	103 a	12.3 ab	17.0 bc	0 c	0 b	2.32 b
13		Reflex® 1000 mL/ha (IBS)	107 a	12.9 a	7.5 cd	0 c	0 b	2.68 a
14		Reflex 750 mL/ha (IBS) f.b. diuron 550 g/ha (PSPE) f.b. Brodal® 200 mL/ha (POST)	108 a	12.0 abc	2.7 def	0.6 c	0 b	2.69 a
15		Reflex® 750 mL/ha (IBS) f.b. diuron 550 g/ha (PSPE) f.b. Intercept® 750 mL/ha (POST)	98 a	11.1 bcd	0.1 ef	0 c	0 b	2.66 a
16		Unsprayed control	104 a	12.4 ab	130.0 a	57.8 a	11.5 a	2.30 b

*Weeks after sowing, IBS: Incorporated by sowing, PSPE: Post-sowing pre-emergence, POST: Post-emergent at 5-6 crop node stage, f.b.: Followed by.

Pastures

Harvesting and use of annual medic pods on farm

David Peck^{1,2} and Jeff Hill¹
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Location
Palmer - Murray Plains
Craig Paech

Rainfall
Av. Annual: 394 mm
Av. GSR: 227 mm
2022 Total: 348 mm

Plot Size
10 m x 1.2 m

Location
Rosedale - Mid North
SARDI Turretfield Research Centre

Rainfall
Av. Annual: 469 mm
Av. GSR: 358 mm
2022 Total: 322 mm

Plot Size
10 m x 1.2 m

Key points

- With early desiccation, 790-1080 kg/ha of medic pods were harvested at Kingsford but none at Palmer due to low late-winter and early spring rainfall.
- Broadcasting medic pods in early Autumn failed to successfully establish medic pasture.

- In four of six attempts we have successfully harvested medic pods, but further research is required on using medic pods to successfully establish medic pasture. Further research is needed before growers adopt this practice.

Why do the trial?

Annual medic pasture systems are widely used in low rainfall areas of South Australia, provide feed to livestock and fix nitrogen for the benefit of following grain crops (e.g. 0.7-2.9 t/ha increased grain yield EPFS Summary 2020, p. 205; EPFS Summary 2020, p. 213). Legume pastures reduce input costs and risk in low rainfall areas. 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 seed and the ability to broadcast seed early prior to season break to increase early dry matter and seed set may encourage more sowing of medics and thus benefits to subsequent grain crops. 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 grain harvester; 2) medic pods can be broadcast to provide a relatively

cheap way of establishing medic pastures. It follows on from preliminary work in the Dryland Legume Pastures Systems (DLPS) project that found medic pastures can be desiccated and pods successfully harvested at one of two sites (EPFS Summary 2021, p. 220) and sown in late summer to successfully establish medic pastures (EPFS Summary 2021, p. 189). In 2022 this project confirmed that medic pods can be harvested (EPFS Summary 2022, p. 148). In 2023, we set up two trials to further study harvesting of medic pods and two trials to determine if we can broadcast medic pods to establish medic pastures.

How was it done?

Broadcasting medic pods

The broadcasting trial was set up to determine if strand (cv. Seraph) and barrel medic (cv. Sultan-SU) pods that were stored for 1 or 2 summers could be broadcast in early March to successfully establish annual medic pastures. The medic pods were harvested in 2021 (EPFS Summary 2021, p. 220) and 2022 (EPFS Summary 2022, p. 148) with a grain harvester after desiccation. Pods stored for one summer were broadcast at 80 and 120 kg/ha, and pods stored for two summers were sown at 40 and 80 kg/ha.

Controls were scarified seed sown at 5 and 10 kg/ha when pods were broadcast in early March 2023 and soon after the break. Hardseed studies were conducted whereby 40 pods were placed inside envelopes made from flywire and placed on the soil surface the day we broadcast the medic pods. The hardseed study was collected at the break in the season, wet up for one week to allow soft seed to germinate, dried, threshed and number of hard seed counted. On a separate sample prior to placing pods in the field we determined the number of seeds per pod and per g of pod. The hardseed studies were conducted in pods as the pods may impact seed softening and the threshing of pods can put minute scratches on seed which may result in faster softening than seeds without scratches.

Harvest of medic pods

A medic pod harvesting trial was established at Palmer and at SARDI’s Kingsford Research farm near Gawler, South Australia in 2023 in a similar way as previously reported (EPFS Summary 2021, p. 221 and EPFS Summary 2022, p. 148). The strand medic cultivar Seraph and the barrel medic cultivar were used. Adjacent to the pod harvesting trial an equivalent trial was sown and allowed to naturally senesce to determine total seed yield.

Prior EPFS articles provide details on medic seed development and targeted desiccation day. In brief, the targeted desiccation day is when maximum number of pods are between 400-900 growing degree days (GDD). In practice, this is when many of the pods have turned from green to grey and a week after some of the first pods have fallen to the ground. Actual desiccation day requires a forecast of four fine days with light winds. Medic pods were harvested with a small plot harvester four days after desiccating. The naturally senesced area had pods vacuumed from two 0.1 m² areas.

What happened?

Pod harvest

Both sites had low growing season rainfall particularly from July to October, followed by high rainfall in November and December after the medics had senesced. The low rainfall in late winter and early spring resulted in low plant growth and pod set at the low rainfall site Palmer, pod harvest was not attempted. At Kingsford, many pods stayed attached to the medic plants and were able to be harvested with a small plot harvester (Figure 1). Table 1 presents pod yield harvested with plot harvester from desiccated area, total pod in naturally senesced area, percent pod harvested with grain harvester, and

seed to pod ratio for desiccated area and naturally senesced area. The plot harvester achieved a pod yield of 790 kg/ha for Sultan-SU and 1080 kg/ha for Seraph. For Sultan-SU we harvested 31% of total pods and for Seraph 57% of total pods. The seed to pod ratio in desiccated pods is lower than naturally senesced pods. This is due to some of the harvested pods containing immature seeds. By comparing the seed/pod ratio we calculated that 75% of Seraph pods had viable seeds and 90% of Sultan-SU pods had viable seeds. The bulk density of harvested pods of Seraph was 420 kg/m³ and for Sultan-SU was 200 kg/m³.

Broadcasting medic pods

Broadcasting medic pods failed to establish medic pastures with plants counts indicating less than a sowing rate of 1 kg/ha was achieved. The failure of seeds to establish can be due to seeds failing to soften or due to how long the pods stayed wet and how well pods contacted the soil. Hardseed studies failed to provide an estimate of seed softening as we frequently retrieved more seeds from the field than we estimated. The error was attributed to 10-25% immature pods without seeds. Hardseed studies have previously been done, but seeds in intact seed pods need further work.

Table 1. Pod yield (kg/ha) harvested with grain harvester from desiccated trial, total pod yield from naturally senesced trial, percent of pod harvested, and seed to pod ratio of pods harvested with grain harvester from desiccated trial and vacuum harvester from naturally senesced trial. 2022.

Cultivar	Pods (kg/ha)			Seed/pod ratio	
	Dessiccated	Senesced	% harvested	Dessiccated	Senesced
Seraph	1080	1890	57	0.27	0.36
Sultan-SU	790	2570	31	0.29	0.32



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).

What does it mean?

For harvest of medic pods to be successful we need to achieve two objectives: 1) easily harvest medic pods; 2) sow/broadcast medic pods and achieve enough seed softening to establish medic pastures. Both these objectives are readily achieved in French serradella and bladder clover. This lowers the cost and risk of failure of pasture establishment and enable farmers to sow pasture without interfering with their cropping operation (Loi and Yates 2020). Over three consecutive years medic pods being easily harvested has been regularly achieved. This was the first year that we tried to sow/broadcast medic pods and concluded that pods need to be stored more than two summers to be successful.

Harvest medic pods

In six trials over three years, desiccating medic plants have allowed a successfully harvest, with greater than 800 kg/ha of medic pods on four occasions but less than 100 kg/ha of pods on two occasions. The failures were at low

rainfall sites (Minnipa, Palmer) in years with low spring rainfall. In conclusion, in medium and low rainfall areas in years without a dry spring harvesting medics pods is successful. Medic pods fall to the ground more readily than pulses and to be successful in harvesting medic this must be a high priority, as is regularly inspecting the senescence and pod fall of the medics. It is suggested that desiccation be in one week after the first pods fall and when a forecast of four fine days with light winds exists.

This research focused on planting a current cultivar after a knockdown of the first germination of weeds and background medic. This minimises background medic contribution to the pod harvested. However, in a dry spring, this increases the chance of low seed set. To increase seed set in a year with a dry spring you can sow early but to maximise percentage of desired cultivar you need to select a paddock with low background medic. If farmers are happy with their current medic cultivars, they

can harvest from a regenerating paddock. Regenerating paddocks typically have higher plant numbers than sown pastures and have higher early dry matter production. Seed industry studies show that seed set is reduced (in ungrazed pastures) when sowing rates exceed 20 kg/ha. The seed set reduction is due to high early dry matter reducing soil water and also light penetration into the canopy. In order to deal with high plant numbers in regenerating medics it is recommended to graze until the first flower. This can be practiced in years with wet springs as it will increase the pod yield and will be able to spare some pasture paddocks from grazing.

Destocking some medic paddocks in wet springs can be done to boost soil seed reserves. Annual medic pastures increase overall farm profitability with much of the profit increase due to lower nitrogen requirements during the cropping phase. It is worth managing medic pastures for increased production including higher seed set in wet springs.

Pod storage

The bulk density of Seraph pods was 420 kg/m³ which is a similar bulk density as oats. The bulk density of Sultan-SU was 200 kg/m³ and is due to its spines not allowing the pods to pack tightly. To achieve enough seed softening the pods need to be stored for several years and the cost of storage needs to be considered when talking with farmers about the prospect of harvesting and using medics on farm. Some see the long-term storage as a barrier, but others in low rainfall areas chose to grow late season vetch due to the benefit of extended green feed and nitrogen fixation in a wet spring. They expect to harvest late season vetch seed approximately every 5-7 years and store until the next time they can harvest late season vetch.

Pod broadcasting

Hardseeds of French serradella and bladder clover can be sown at 15-30 kg/ha in late summer to early Autumn at 1-2 cm, and will soften in autumn and establish with the opening rains (Loi and Yates 2020). This is possible as these two species have an unusual seed softening process whereby seed softens readily in the dark (e.g. sown at 1-2 cm). By contrast, hardseeds of medics do not soften in the dark but in fact soften slightly less when buried as they are exposed to lower temperatures and experience lower temperature fluctuations which are the two major drivers of seed softening. Broadcast medic pod softening will be maximised and this is a cheaper operation than sowing. However despite using 40 and 80 kg pods/ha for pods stored for two summers and 80 and 120 kg/pods of pods stored for one summer we failed to establish medic pastures. Opening rains at Palmer were light (e.g. maximum daily rainfall in April was 4.8 mm) and it is likely that medic pods did not fully wet through to the seeds and/or dried

out before the seeds germinated, pushed through the pod and into the soil.

If the pods were sown into the soil at Palmer, the 18.7 mm of rain recorded over 11 days would be expected to wet the soft seeds inside the pods and allow them to germinate and establish. For this reason future research should focus on sowing medic pods instead of broadcasting.

Pod sowing rate can be calculated by $(SR/0.25) \times 100/S$ where SR is your desired sowing rate of soft seed (sowing rates of 5-10 kg/ha are common), and S is the percent softening expected. It is expected that S will be influenced by length of time pods are stored. However researchers are currently unable to provide guidance on the expected percent softening rates.

Seed softening is a two-stage process with stage 1 being exposure to heat and stage 2 being temperature fluctuations. In laboratory studies stage 1 signal can be increased by hotter temperature and/or longer storage times. In the field, hotter summers provide a higher stage 1 signal and hence higher subsequent softening. Fluctuations in autumn (warm days and cool nights) provide the signal for stage 2. Harrison *et al.* (2021) showed that hardseeds stored for the long term in a laboratory soften much more when placed in the field in late summer than seeds stored for only 1 summer. The results from this research indicate that pod storage needs to be greater than two summers to achieve high softening rates.

Conclusion

With attention to detail and early desiccation, medic pods can be harvested from medic nursery paddocks or regenerating paddocks grazed up until the first flower. However in 2023 broadcasting pods stored for one

summer at rate of 120 kg/ha and two summers at 80 kg/ha failed to establish a medic pasture. In order to have relatively low sowing rates and high multiplication factor (how many ha of pasture can be sown per ha of medic harvested) pods need to be stored for more than two summers. Further research is required on pod storage and seed softening, before the harvest and sowing of medic pods can be recommended to growers.

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Acknowledgments

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Early autumn sowing demonstration of hardseeded pods segments of French serradella on sandy soils

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¹The University of Adelaide; ²SARDI; ³AIR EP

Locations
Lowbank (LB), Woolpunda (WO), Solomon (SO), Warrambo (WA), Wudinna (WU), Mt Springton (MS)

Farmers
Tim Paschke, Warren May, Leon Vietch, Chris Lymn, Chris Tapscott

Groups
AIR EP & Lowbank Ag Bureau

Rainfall
Av Annual/Av. GSR (mm)
2023 Total/2023 GSR (mm)

Solomon
346/246
213/167

Warrambo
310/224
172/134

Wudinna
275/191
218/169

Soil Type
Sandy Soils, pH ranging from 6.4 to 8.1 (CaCl₂), organic carbon 0.6 - 0.7 %

Plot size
Large scale demonstrations 10ha at each of the studies

Key messages

- French serradella, an annual pasture legume, is widely grown in Western Australia (WA) and its adoption is increasing in New South Wales (NSW). Preliminary assessment in South Australia (SA) showed promising potential for growth, particularly on sandy hills.

- In 2023, a comprehensive evaluation on early autumn sowing of hardseeded serradella pod segments across low to mid-rainfall regions of SA was conducted. The results revealed that autumn sowing could successfully establish serradella plants.
- The nodulation of serradellas sown from pods exhibited a reliance on paddocks with a lupin history, whereas sites devoid of prior lupin cultivation gave suboptimal nodulation.
- To obtain the full benefits of autumn sowing of hardseeded pod segments, further investigation is imperative to explore the successful introduction of serradella rhizobia and to enhance effective nodulation.

Why do the trial?

Hardseeded French Serradella cultivars are widely grown on deep acidic sands in WA and is increasingly being grown on acidic loams in NSW. Recent research in SA and VIC has found that it has the potential to lift pasture production on sandy soils with mildly acidic to mild alkaline pH (EPFS Summary 2016, p. 155; EPFS Summary 2019, p. 230; EPFS Summary 2020, p. 211 and EPFS Summary 2021, p. 197). French serradella pod segments are readily harvested with conventional grain harvesters. However, it is difficult and expensive for the seed industry to remove seeds from the

Pods, hence making scarified seed expensive relative to other annual pasture legume seed. Hardseeded French serradella cultivars have an unusual seed softening process whereby buried pod segments (i.e. in dark) has much higher rates of seed softening than pods segments on the soil surface (i.e. sunlight inhibits seed softening). This process allows pod segments to be sown at 1-2 cm in late summer to early autumn (ahead of the main sowing time), which is widely practiced by growers in WA and NSW. The seeds will be softened by the fluctuating temperatures in autumn and emerge following the break in the season, which allows for early feed and greater seed set in years with a spring drought. Additionally, the readily harvestable seeds enable farmers to harvest their own low-cost seeds for future use.

South Australia’s low rainfall regions frequently have extensive dune-swale systems, which may provide an opportunity for serradella pastures on large sand dunes. Dunes and interdunal swales can have substantial variations in soil textures and pH levels, where soil textures can range from sandy soils on the dunes to loams/clays on the swales, and pH levels can range from neutral to slightly acidic on the dunes to higher alkalinity in the swales. Soil texture and pH have large effects on the performance of pasture legume species. Matching species to parts of the landscape can increase overall pasture production.

Field trials in the Victorian Mallee under the DLPS project demonstrated that serradella could produce 1 to 1.5 t/ha extra biomass compared with vetch on sandy dunes (EPFS Summary 2021, p. 197) and 1 to 1.5 t/ha less biomass in the swale. In 2022, this project sowed 10 ha to a mixture of barrel medic, strand medic and French serradella in paddocks with dune/swale landscape with the serradella outperforming the medics in terms of plant dry matter biomass on the dunes and extending the growing season. Based on this result, we targeted large sandy dunes in 2023 and carried out autumn sowing of serradella pod segments to achieve adequate plant establishment and optimum levels of nodulation.

Successful nodulation - a key factor in nitrogen fixation presents unique challenges when dry-sown in late summer to early autumn as serradella pod segments would remain in dry soil for too long and may compromise rhizobia survival. While serradella has its own rhizobia group (S), it is fully compatible with lupin rhizobia (G). Evidence from trials in Victorian mallee sands had suggested that serradella pasture establishments were more successful on sites where lupins had been grown (EPFS Summary 2020, p. 211). In WA, late summer sown French

serradella crops usually nodulate well in soils with a previous history of lupin (Loi and Revell 2021), although it is still recommended to inoculate seeds. A deeper understanding of the rhizobium history and dynamics is required for serradella adaptation in SA, where lupin production is relatively limited. This is because sowing serradella pod segments at sites without prior lupin production will need to depend solely on the effective inoculation of pod segments at sowing to obtain optimum nodulation. To bridge this knowledge gap, we conducted extensive field trials targeting sandy dunes with and without a history of lupin cultivation in SA's low to mid-rainfall regions. Lupin history in the paddock was determined by asking host farmers and by using the newly available Predicata rNod test for presence or absence of S/G rhizobia. This study aims to determine if hardseeded pods segments of serradella could be sown in early autumn to achieve high plants numbers that are well nodulated.

How was it done?

In collaboration with local farm managers, farming systems groups AIR EP, Lowbank Ag Bureau, and Barossa Improved Farming Group, we established seven 10 ha pasture demonstration sites in low rainfall areas, including Lowbank and Woolpunda in Murray Mallee

(2 sites), Solomon, Warrambo and Wudinna on Eyre Peninsula (3 sites), and Mt. Springton in the Adelaide Hills (2 sites), which falls under medium rainfall region. At each of these sites, 300 kg of serradella pods (@ 30 kg/ha) and 100 kg/ha of Alosca dry granular inoculant (@ 10 kg/ha) were sown together by host farmers using their seeding equipment on sand dunes from March to April 2023 (Table 1). Soil samples prior to sowing were tested for presence of S/G rhizobia using Predicta rNod. Plant emergence counts were conducted in May 2023. Root nodulation inspections were conducted 10 to 12 weeks after emergence and continued throughout the growing season.

What happened?

Summer sown serradella pods emerged after opening rains which occurred within 1 to 1.5 months after sowing at all sites. Pods sown at the two Mt. Springton sites emerged within a week due to 6 mm of rain that fell immediately after sowing. Plant emergence varied from 58 to 102 plants/m² in low rainfall areas and 261 to 295 plants/m² in high rainfall area (Table 1).

Table 2 presents Predicta rNod tests results, lupin history and the percentage of plants nodulated. Two out of the seven sites had lupin/serradella rhizobia present.

Table 1. Demonstration sites established across SA showing their location, region with sowing date and plant emergence counts.

Region	Location	Sowing date	Plant emergence plants/m ² (mean ± SD)
Murray Mallee	Lowbank	11/04/2023	91.1 ± 6.9
	Woolpunda	24/03/2023	84.4 ± 49.1
Eyre Peninsula	Solomon	27/04/2023	57.8 ± 40.8
	Warrambo	27/03/2023	63 ± 21.7
	Wudinna	23/04/2023	101.8 ± 42.3
Mt Springton, Adelaide Hills	Upper paddock	24/03/2023	294.5 ± 148.7
	Lower paddock	24/03/2023	261 ± 87

Mt Springton had a rhizobia level of 3 and Solomon had a level of 1 (Table 2). Both sites with a lupin history had 100% of plants nodulated with a mean of 10.3 ± 1.0 nodules per plant (Figure 1). The remaining five paddocks without a lupin history had mean plant nodulation rate of 41%

ranging from 5% to 81% (Table 2) and a mean of 0.7 ± 0.2 nodules per plant (Figure 1).

Other plant biophysical measurements showed significantly higher shoot growth and shoot and root dry weight biomass in lupin history sites than

non-lupin sites. Root length did not differ between the two groups.

Plant observation 3-4 months after emergence identified yellowing and less biomass production in non-nodulated plants compared with nodulated plants (Figure 2).

Table 2. rNod test on soils prior to sowing showing rhizobia levels and report interpretation. Paddock’s lupin-growing history were collected from farm owners and root nodulation status observed in the field.

Region	Location	Last Lupin crop	Log10 Rhizobia G/S levels	Nodulation status	% of plants nodulated
Murray Mallee	Lowbank	None	0	poor	5
	Woolpunda	None	0	poor	46.4
Eyre Peninsula	Solomon	>12 yrs	1	good	100
	Warrambo	None	0	poor	61.5
	Wudinna	None	0	poor	11
Mt Springton, Barossa	Upper paddock	2021	3	good	100
	Lower paddock	None	NA	average	81.2

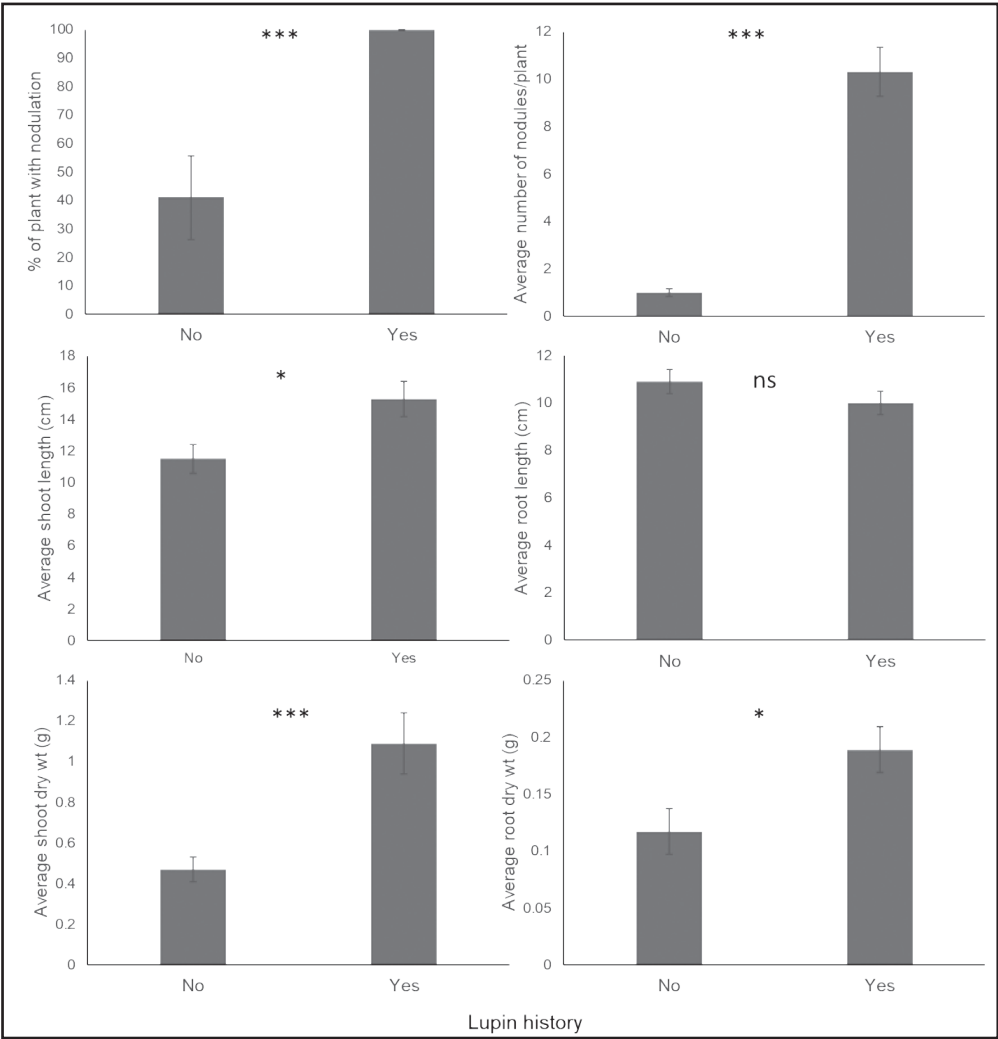


Figure 1. Comparison of root nodulation and other biophysical measurements (percent of plant nodulation, shoot length, root length, shoot dry weight and root dry weight) between sites with and without lupin history. No are sites without a lupin history and Yes are sites with a lupin history. Bar represents standard error of the mean. *, * and ns are statistical significance levels ($p \leq 0.05$, $p \leq 0.001$ and not significant) of group comparison using ANOVA test.**





Figure 2. Comparison of nodulated and non-nodulated *Serradella* plants.

What does this mean?

French serradella is a promising species for neutral sandy soils of SA. Hardseeded pod segments can be sown in early autumn in SA as plants are able to quickly establish following the opening rains. For the seeds to soften, they need to be sown at 1-2 cm deep into the soil for the correct diurnal temperature fluctuation to occur. Plant emergence counts were adequate in all trial sites, despite some sites were sown in late April (Table 1). The currently recommended sowing time of hardseeded pod segments is in February to early March (EPFS Summary 2021, p. 200). More trials are required on yearly climatic variations before April sowing can be widely recommended.

In this project, the pod segments were inoculated with 10 kg/ha of clay granules at all sites. Even though autumn sowing achieved adequate plant numbers, the root nodulation of plants at sites without

a lupin history was sub-optimal, indicated by the percentage of plants nodulated and number of nodules per plant. This means that the inoculum might have assisted the Solomon site (low rNod scores) to achieve good nodulation levels, but it did not assist sites without a lupin history to achieve a good nodulation status. The serradella plants without nodulation were yellow and produced less biomass, which resulted from a lack of nitrogen in the system due to no nodulation. Further research is still required on how to inoculate autumn sown pods segments on paddocks without a lupin history, also on determining if other forms (peat, freeze dried) can achieve high nodulation with late summer - early autumn sowing. It is also of industry importance to investigate inoculating the last cereal crop with serradella/lupin rhizobia to introduce rhizobia into the soil in the future.

In WA and NSW, farmers grow a nursery paddock and harvest pod segments which they utilize with a late summer/early autumn sowing program to provide increased early feed and higher seed set in years with low spring rainfall. Like pulse and canola crops, serradella is susceptible to budworm attacks, which needs to be managed for successful seed set. French serradella has the potential to increase pasture production on sandy soils without high pH values. Furthermore, serradella growth is indeterminate, which allows it to extend the growing season in wet years. In conclusion, harvesting pod segments and sowing early autumn can achieve adequate plant numbers, but to achieve good nodulation, rhizobia inoculated lupins need to have been grown previously.

Therefore, if growers would like to adapt French serradella into their local farming systems, they should incorporate lupins into the crop rotation, where profitable, to achieve the required rhizobial level for French Serradella plants to successfully nodulate in soil and contribute to long-term agricultural sustainability. Alternatively, they can sow inoculated (Farquharson *et al.*, 2022) soft seed at the break of the season. Otherwise, growers are advised to wait for more research results to become available prior to sowing hardseeded pod segments into soils without a prior lupin cultivation. For the assessments of presence of group G/S rhizobia levels in soil, rNod is a rapid and useful tool that can be used by growers and consultants.

We recommend initially trialling serradella on relatively small areas for growers who are interested. A good overview of using serradella in WA is provided by Loi and Revell (2021). Cultivars can be soft or hard, with currently available hardseeded cultivars being margurita and frano (~ten days

earlier). Both soft-scarified seeds, suitable for sowing near or after the break, as well as hardseed pod segments, ideal for late summer or early autumn sowing, are available for commercial purchase. When cultivating serradella, it is crucial to understand the type of seeds acquired and when to sow them.

Acknowledgements

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Livestock

Assessing an automated virtual fencing system in sheep with wool

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Key messages

- **Virtual fencing is not yet commercialised for sheep in Australia, with further research and development required prior to use on farm.**
- **A modified commercial virtual fencing system contained sheep with clipped wool and sheep with 6 months of wool for a nine-day period.**
- **Sheep with 6 months wool had 75.5 % more pulses administered by the collars than clipped sheep. This suggests that a low proportion of pulses made adequate contact through the wool and mob dynamics may have accounted for some level of compliance with the virtual fence.**
- **Sheep that breach the virtual fence and enter the exclusion zone can return to the inclusion zone without physical assistance.**
- **Collars are likely not a long-term virtual fencing solution for sheep with wool but may be a viable option in shedding breeds.**

Why do the trial?

Virtual fencing technology is gaining popularity with commercial and research activity increasing throughout Australia in recent years. Virtual fencing is a GPS enabled technology that uses cues administered by neckbands to communicate a virtual boundary to livestock. The technology poses many benefits including reduced infrastructure and labour associated with managing grazing livestock and strategic management of livestock location for increased production and environmental preservation.

Virtual fencing is well established in cattle with the containment and exclusion capabilities of the technology proven in a range of systems. There are multiple commercially available devices for cattle within Australia and their use is allowed in some states. Currently all forms of virtual fencing for livestock are prohibited in South Australia. Virtual fencing for sheep is less developed and with no commercial activity in sheep currently occurring within Australia. Recent research has used modified cattle devices to determine that sheep without wool

can be contained using virtual fencing. However, this research has been limited to small sample sizes and short durations.

This trial aimed to expand upon previous research and determine if a modified commercial device could contain larger mobs of sheep. An additional aim was to assess virtual fencing collars as a viable option for virtually fencing sheep with wool.

How was it done?

The trial took place over nine days in April/May 2023 at the SARDI, Struan Research Centre in Naracoorte. One hundred and eight crossbred ewes were drafted and fitted with virtual fencing collars. The ewes were split into six mobs of 18:

- Control (2 replicates): contained with electric fencing, 6 months of wool growth.
- Treatment One (2 replicates): contained using virtual fencing, 6 months of wool growth.
- Treatment Two (2 replicates): contained using virtual fencing, wool clipped from head to top of shoulders.

The trial took place in six 2.2 ha trial paddocks at the Struan Research Centre. The ewes were restricted from approximately one third of their paddock using their respective fencing type. The available pasture was predominantly a phalaris/clover mix with no supplementary feeding provided during the trial period.

All sheep wore a virtual fencing collar to facilitate GPS tracking and account for collar effect, however virtual fencing cues were disabled for the control groups.

What happened?

The virtual fencing system was successful in containing both the clipped sheep and sheep with wool for nine days. The trial was ceased after nine days due to collar fit limitations with no fault in the technology itself. A heat map

of GPS locations throughout the trial (Figure 1) visually displays the effectiveness of the virtual fencing across the trial period. Some breaches of the virtual fence did occur as is seen with all virtual fencing scenarios. The least effective containment occurred in one of the virtually fenced replicates with 6 months wool growth (far right paddock, Figure 1). The two control groups experienced slightly worse containment than the three best virtually fenced groups due to faults in the electric fence that needed repairing throughout the trial. Overall, the level of containment observed within the virtually fenced groups far exceeded what was expected.

When comparing the number of signals administered to each group it was observed that sheep with wool were administered 75.5 % more signals than clipped

sheep. This suggests that a low proportion of pulses made adequate contact through the wool and a higher number of signals were required to enforce the virtual fence. This is important to note when considering the viability of virtual fencing collars for commercial application in sheep with wool. Mob dynamics were not measured during this trial but should be considered when assessing the effectiveness of virtual fencing in sheep.

All sheep that breached the virtual fence returned to the inclusion zone with their peers without physical assistance. Prior to the trial it was unknown whether sheep would be capable of responding to the virtual fencing system to return to the inclusion zone unassisted. This finding is significant when considering use of this technology at a commercial scale.

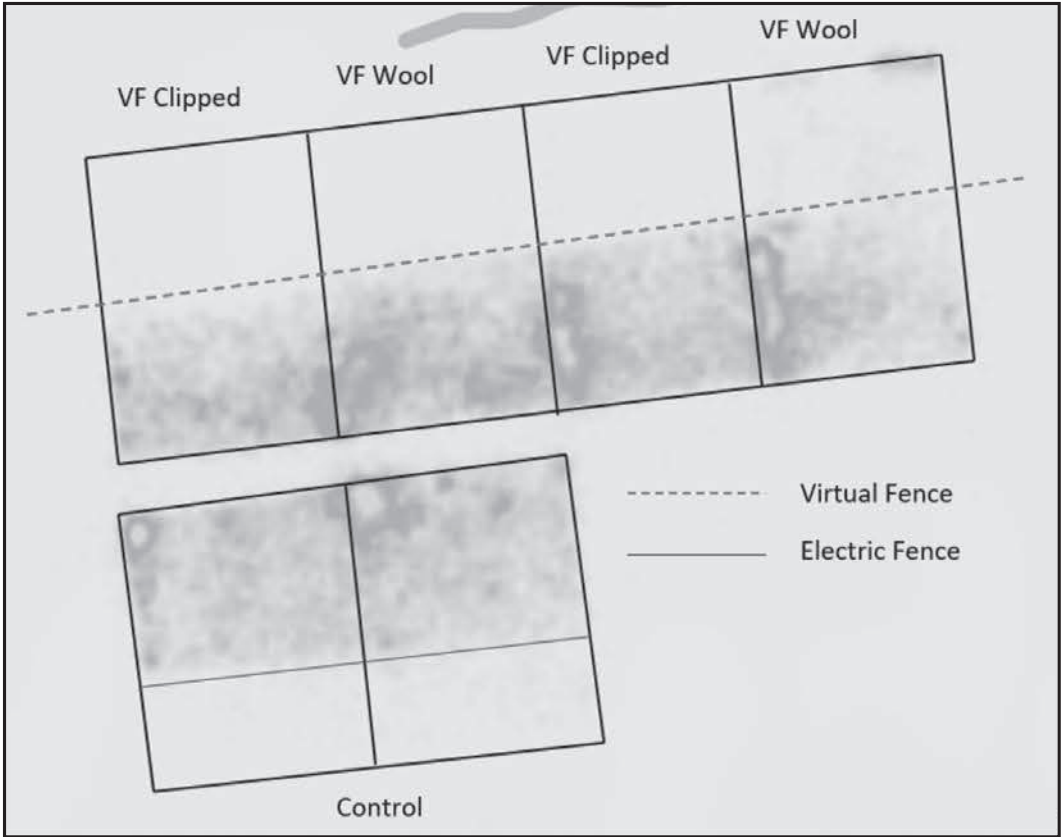


Figure 1. A heat map displaying the GPS locations of sheep within their trial paddocks, highlighting the ability of the virtual fencing to contain sheep. Darker areas indicate more frequent incidence of sheep in that area than lighter areas.

What does this mean?

The results of this trial represented a significant development for virtual fencing in sheep. Establishing that sheep can be contained using a modified commercial device opens up many opportunities for future research into potential applications of this technology.

Despite the fact that sheep with wool were contained, the higher level of signals administered to facilitate this compared to clipped sheep is a major consideration for future use. This may reduce precision, controllability by the user, and the ability for sheep to successfully learn the virtual fencing algorithm. Therefore, virtual fencing collars may not be

suitable as a long-term solution for sheep with wool and alternative devices such as ear tags should be prioritised. Virtual fencing collars may be a viable option for use in shedding breeds where interruptions to signal delivery by wool is not an issue. Even in this case, specialised sheep collars will need to be developed with hardware and algorithm improvements.

The findings of the above trial have provided an opportunity to further assess virtual fencing in sheep and brings us one step closer to commercial implementation. Trial work undertaken by SARDI in 2024 will focus on excluding sheep

from erodible areas within a crop stubble at the Minnipa Agricultural Centre. This upcoming trial will demonstrate just one of many potential commercial applications of virtual fencing in sheep.

Acknowledgements:

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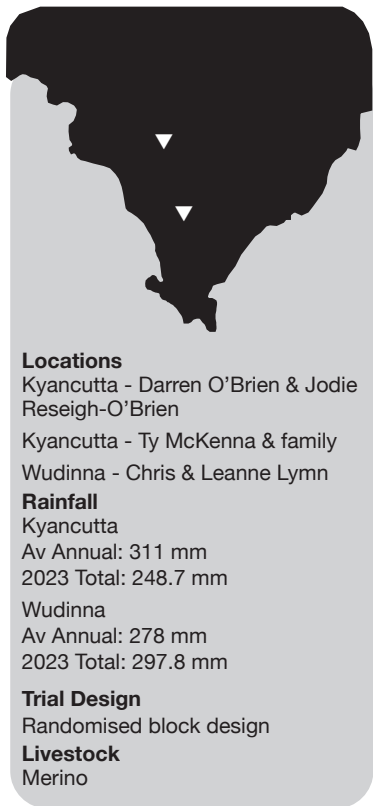


Yarwondutta Rock taken from MAC N3.

Improving the productivity and climate resilience of the Australian Sheep Industry

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Key messages

- **High ambient temperatures during mating and pregnancy can cause heat stress in sheep which impair reproductive outputs, costing the Australian sheep industry approximately \$168 million each year.**
- **Alleviation strategies such as the antioxidants melatonin and vitamin ADE, have previously been linked to reducing the negative impact of heat stress in other species.**
- **Ewe supplementation just prior to joining with melatonin and/or ADE drench increased the number of potential lambs at pregnancy scanning.**

- **Two prototype calculators were developed; first, to predict the impact of Melatonin and Vitamin ADE on productivity and profitability of flocks, and the second, to use climate data for a particular location to predict the impact of heat events during joining on their lambing rates to then make decisions around adoption of heat alleviating management strategies.**

Why do the trial?

The aim of this trial was to determine the impacts of melatonin implants (Regulin®) and a vitamin ADE drench on the fertility and fecundity, and thermoregulation of sheep across South Australia. High ambient temperatures during mating and pregnancy impair health, reproduction and welfare of sheep. Each day in excess of 32°C during the week of mating reduces the number of lambs born per 100 ewes mated by 3.5%, with high temperatures during pregnancy retarding fetal growth and, thus, reducing lamb survival and weaning rates.

Strategies which increase the capacity of sheep to tolerate heat and mitigate the negative impacts on reproduction are essential to maintain flock productivity and sustainability. Both melatonin and vitamin ADE have potent antioxidant properties which can act by reducing free radicals within the body that are produced during heat stress. Determining their capability in reducing the negative effects of heat stress in

sheep will also provide the sheep industry with the ability to predict the impact of heat events on flock productivity and make informed decisions around the adoption of amelioration strategies.

How was it done?

This trial work ran from the 20 November 2022 until July of 2023 at 21 producer sites, across South Australia. The producer sites were obtained through collaborations with multiple farming systems group including; South Australian Research and Development Institute (SARDI), MacKillop Farm Management Group (MFMG), Barossa Improved Grazing Group (BIGG), Upper North Farming Systems Group (UNFS), Northern and Yorke Landscape Board (NYLB), Mallee Sustainable Farming Systems Group (MSF), Murray Plains Farming Systems Group (MPF), and Agricultural Innovation and Research Eyre Peninsula (AIR EP).

The trial consisted of three treatments; control (no supplementation), melatonin and ADE; across 21 producer sites, each site acting as a replicate. Just prior to joining, ewes were randomly allocated into three treatments consisting of Melatonin, Vitamin ADE and Control. The melatonin ewes received an 18 mg melatonin capsule (Regulin®) via a subcutaneous injection behind the ear, the Vitamin ADE ewes received a 10 ml oral drench of Maxivit Vitamin A, D & E Oral (Compass Feeds), and the Control ewes did not receive any treatment.

Following administration of the treatment the ewes were returned as one mob through till pregnancy scanning and managed according to standard husbandry for that particular farming site. All ewes were individually identified using either visual or electronic ear tags, or the use of branding paint. Pregnancy status and the number of fetuses carried by each ewe were determined by an experienced commercial operator using ultrasound. These data were used to calculate the following outcomes for each flock and each treatment: percentage of ewes pregnant, and the percentage of ewes carrying 1, 2, 3 or 4 fetuses, which in turn was used to calculate potential lambing rate (expressed as fetuses as a percentage of ewes joined and fetuses as a percentage of pregnant ewes).

In addition, on each producer site, at least one temperature device (tiny tag; Hastings Data Loggers) was placed in the paddock in which joining occurred, and was moved with the flock as required. The tiny tag was set to record ambient temperature and humidity at hourly intervals during the joining period. These data were

used to understand the potential impact of climate on potential lambing rates, with each day over 32°C during the week of joining. The original objective was to use the climate data collected for each producer site to develop a prototype calculator for use by sheep producers to make informed decisions around implementation of heat alleviating strategies, which will hereon be referred to as the “Sheep_Heat_Economics_HotDays” calculator. However, due to the milder than normal climate experienced during summer of 2022/2023, it was decided to use historical climate data obtained from the Bureau of Meteorology (BoM) to develop this calculator. The additional benefit of using the BoM data is that it is a more robust data set, with data being available for the past 65 years, and is also available over a wider range of locations and is, thus, more relevant to a wider range of producers. The underlying premise for this calculator is that producers can insert their location, and receive outputs predicting the extent to which lambing rate is likely to be decreased by heat events (days > 32°C) in their location and for their chosen joining period, with each

day > 32°C during joining (the average per week for the joining period) multiplied by 3.5 to give the expected reduction in lambing rate (fetuses per 100 ewes joined; as per Lindsay *et al.*, 1975; Kleemann and Walker, 2005; van Wettere *et al.*, 2021).

In addition, a second prototype calculator (the “SheepHeat_Economics_Supplement” calculator) was developed to provide sheep producers with the ability to determine the effect of using either melatonin or ADE on productivity and profitability of their flock. This calculator incorporates the cost of production values provided in the PIRSA Gross Margin Guide, and allows a range of scenarios to be modelled, whereby flock size, DSE rating, lambing rate, treatment type and efficacy (improvement in lambing rate), cost of production and lamb sale price can be altered to test the financial outcome.

Statistical analysis was conducted using SPSS (IBM). A general linear mixed model, with region, breed and age included in the model, was run to determine the impact of treatment on all parameters measured.

Table 1. Effect of treating ewes in flocks at three properties on Eyre Peninsula with Regulin® and Vitamin ADE at joining on pregnancy rate and fetal number at pregnancy scanning.

Treatment	Ewe No.	Lamb No.	% Preg	% Single	% Twin	% Triplets	Lambs, % ewes joined
Control	622	791	81a	34	46 a	<1	127.2 a
Vitamin ADE	798	1114	86 b	32	52 b	1	139.6 b
Regulin®	702	1134	97 c	32	64 c	<1	161.5 c

^{ab} Within column indicate differences between means; *P* < 0.05

Table 2. Effect of treating ewes in flocks across South Australia with Regulin® and Vitamin ADE at joining on pregnancy rate and fetal number at pregnancy scanning.

Treatment	Ewe No.	Lamb No.	% Preg	% Single	% Twin	% Triplets	Lambs, % ewes joined
Control	4075	5013	84 a	46 a	36 a	1	123 a
Vitamin ADE	3005	4194	90 b	42 ab	47 b	1	140 b
Regulin®	3343	4653	87 b	37 b	48 b	2	139 b

^{ab} Within column indicate differences between means; *P* < 0.05

What happened?

Across the three producer sites situated in the Eyre Peninsula the use of melatonin and ADE supplementation increased the ewe fertility and fecundity (Table 1). For every 100 ewes joined, melatonin increased pregnancy rates by 16 ewes, and ADE drench increased pregnancy rates by 5 ewes. Additionally, where potential lambing rate is based on the number of fetuses present at scanning, the supplementation of melatonin prior to joining increased this by 34.3 %, and ADE by 12.4 %. Similar results are observed when the data from all 21 producer sites across South Australia is combined with both melatonin and ADE increasing the number of pregnant ewes, and potential lambing rate by 16 % and 17 % respectively (Table 2).

Using the data obtained from the tiny tags on each of the producer sites, the number of days $\geq 32^{\circ}\text{C}$ was calculated for the period of joining, this was then divided by the duration of joining to calculate the mean number of days $\geq 32^{\circ}\text{C}$ during each week of joining. Using the equations developed by Lindsay *et al.* (1975) and Kleemann

and Walker (2005), the number of days per week $\geq 32^{\circ}\text{C}$ were multiplied by 3.5 to generate the impact on potential lambing rates (Table 3).

Using historical BoM data (1957 to 2023), and five sites across South Australia chosen as representative of climate, the incidence of days $\geq 32^{\circ}\text{C}$ during typical joining periods (late December through to end of January) was calculated, and used to calculate the loss of potential lambs. This was done for an average joining period, as well as the hottest joining period since 1957. These data are presented in Figure 1, and in Figure 2 the financial impost of these losses are presented, based on a flock of 100 ewes.

What does this mean?

This project has demonstrated two easy to implement, highly adoptable and effective strategies to improve the fertility and, thus, productivity of sheep flocks which mate their ewes during late spring to early autumn. These strategies, Melatonin implants (Regulin® and Vitamin ADE oral

drench), when given just prior to joining increased potential lambing rates and the percentage of ewes pregnant. Considering their mode of action, which relates to improved thermoregulation, as well as improved development and survival of embryos (eg Bouroutzika *et al.*, 2020 and 2022; Contreras-Correa *et al.*, 2023; Viola *et al.*, 2023), adoption of these supplements is likely to improve the climate resilience of the South Australian sheep flock, and help to ensure its sustainability and productivity in the face of climate change.

Overall, Regulin® and Vitamin ADE treatment of ewes to increase lambing rate appears a robust, profitable management practice. Treatment efficacy and lamb sale price will impact the return on investment of Regulin® and Vitamin ADE treatments and should be considered when deciding to implement these practices. Further confirmation of the true heat-mitigating effects of these treatments on sheep flock fertility will then allow complex predictions of financial return across different production environments.

Table 3. Days per week of joining $\geq 32^{\circ}\text{C}$ and potential decrease in lambing rate for an average joining week on a subset of producer sites.

Trial Site	Region	Days per week of joining $\geq 32^{\circ}\text{C}$	Potential decrease in lambing rates for an average joining week (%)
7	Barossa	3	10.5
19	Eyre Peninsula	4.6	16.1
5	Eyre Peninsula	3	10.5
17	Mallee	2.4	8.4
6	Upper North	3.8	13.3
16	Upper North	5.4	18.9
2	Upper North	4.2	14.7
3	Upper North	3.6	12.6
9	Murray Plains	1.4	4.9
10	Murray Plains	1.6	5.6
12	South East	2.4	8.4
1	South East	1.4	4.9
4	South East	0.6	2.1

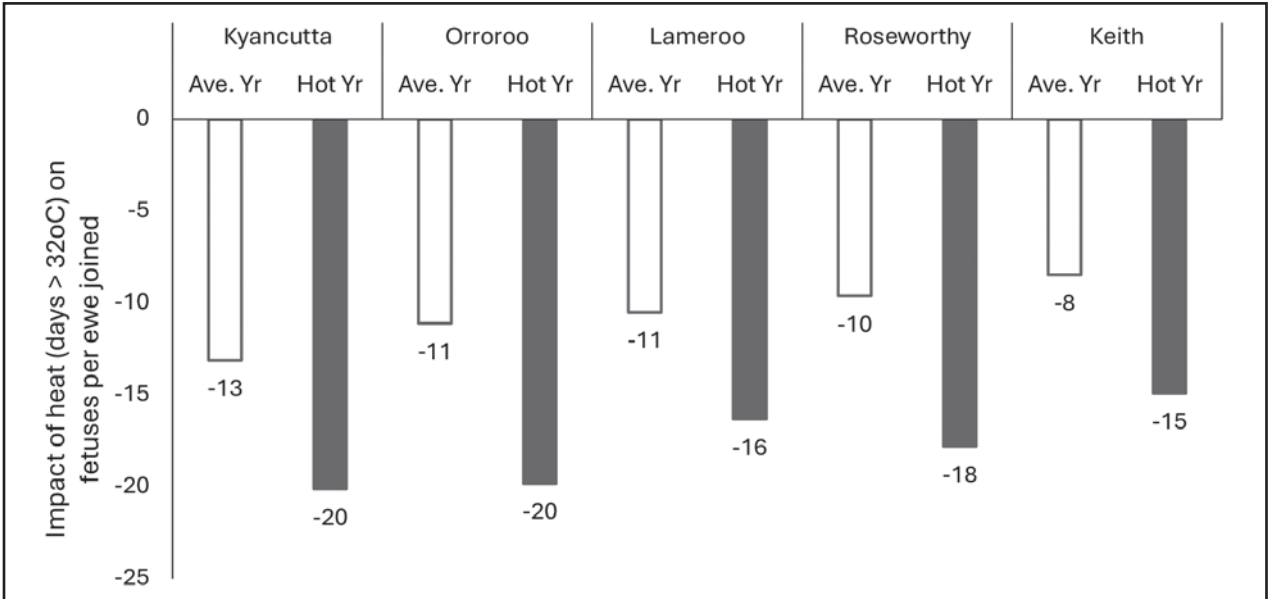


Figure 1. Impact of days $\geq 32^{\circ}\text{C}$ during joining on potential lambing rate (fetuses per ewe joined) in an average summer joining period and the hottest summer period since 1957.

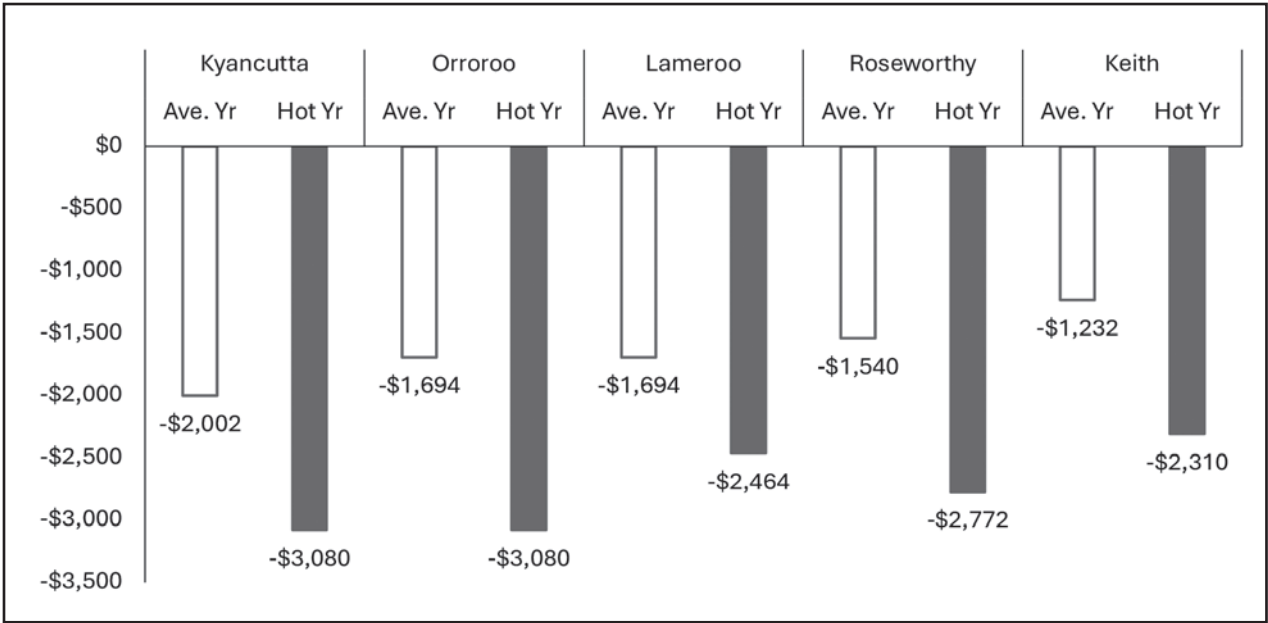


Figure 2. Financial loss due to the reduction in lambing rates that occur when 100 ewes are exposed to days $\geq 32^{\circ}\text{C}$ during the week of joining. Calculated for an average summer joining period and the hottest summer joining period since 1957. Assumptions: lamb price of \$130 / head minus \$21 COP / head and a base line lambing rate of 140 %.

Acknowledgements

We wish to acknowledge the 21 producers who took part in the trial and were willing to be involved and the farming systems groups, to Compass Feeds for the Maxifit ADE Drench, and to CEVA for the Regulin®. Further acknowledgements go to the funding bodies for this trial including the Davies Research Centre University of Adelaide, SARDI, SA Sheep Industry Fund, and the South Australian Drought Resilience Adoption and Innovation Hub.

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Disease

Effect of deep ripping and fungicide application on rhizoctonia

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Location
Poochera
Gosling Family

Rainfall
Av. Annual: 326 mm
Av. GSR: 247 mm
2023 Total: 207 mm
2023 GSR: 120 mm

Paddock history
2023: Volunteer pasture
2022: Wheat
2021: Barley

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

- **Rhizoctonia infection on field pea roots was reduced by deep ripping undertaken 3 years previously, but amendments incorporated with the ripping had no further impact on rhizoctonia.**
- **Uniform® fungicide in furrow at seeding did not reduce rhizoctonia in the 2023 crop but did in 2022 in a decile 9 season.**
- **Despite using peat inoculant at seeding, nodulation for N fixation was poor.**

Why do the trial?

Rhizoctonia (*Rhizoctonia solani*) remains a significant constraint to crop 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. Previous GRDC investments evaluated the efficacy of fungicidal 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 are 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 different soil management strategies used to investigate the effects of soil amelioration and fungicide application at seeding on rhizoctonia.

Key messages

- **Kastar peas performed poorly in a decile 2 season at Poochera with an average yield of only 0.26 t/ha.**

How was it done?

“Producing more profitable crops on highly calcareous soils by improving early vigour and overcoming soil constraints” was a project funded for three years by the CRC for High Performance Soils with support by the GRDC. In 2020, a three-year rotational trial 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). The biochar product is now referred to as Carbon Coated Mineral (CCM).

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 CCM (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 in 2020 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, Spartacus CL barley was seeded in all plots at 60 kg/ha with a DBS seeder using ribbon seeding boots on 19 May. 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®, at 400 mL/ha with 85 L/ha of water, was applied as a split application (on top of the seed rows and banded under the seed rows) to one of the seeding passes in each plot. The trial was sown with a DBS seeder using ribbon seeding boots on 13 May into good moisture conditions with DAP @ 50 kg/ha and Maximus CL barley @ 60 kg/ha to all plots.

In 2023, the trial was sown with a DBS seeder using ribbon seeding boots on 16 May into a drier seed bed with MAP @ 50 kg/ha and Kastar peas (IMI herbicide tolerant) @ 100 kg/ha to all plots. The fungicide Uniform® was re-applied in the same way and to the same seeding passes used in 2022. The trial was treated with a knockdown and soil-active herbicides immediately before seeding.

Crop establishment and grain yield were assessed in 2023. In addition, at eight weeks after seeding, plant roots were scored for number of nodules, root score and rhizoctonia infection. Rhizoctonia infection was assessed using a score (0-10) developed by the project team. The ratings are: 0=no disease, 2-3=<25% roots damaged, 4-5=25-50% roots damaged, 6-7=50-75% roots damaged, 8-9>75% roots damaged, 10=all roots highly diseased and truncated.

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 fungicide treatments.

What happened?

The 2023 season on upper Eyre Peninsula was poor despite stored summer soil moisture from November 2022 rainfall events. Minnipa (35 km from the trial site) had a decile 2 growing season (April to October), and a decile 4 season for total rainfall in 2023.

Kastar pea establishment was similar across all treatments and averaged 48 plants/m².

Uniform® fungicide did not reduce rhizoctonia infection on pea roots eight weeks after seeding in 2023. However, there were differences in root disease scores between the 2020 management and deep ripping treatments.

Rhizoctonia infection was higher in the Control and Fertiliser toxicity treatments than in the Deep - CCM, Deep AM and the Deep rip only treatments (Figure 1). Anti-Rhizoctonia, which was only applied in 2020, had similar disease to the Control, Fertiliser toxicity and Deep rip treatments.

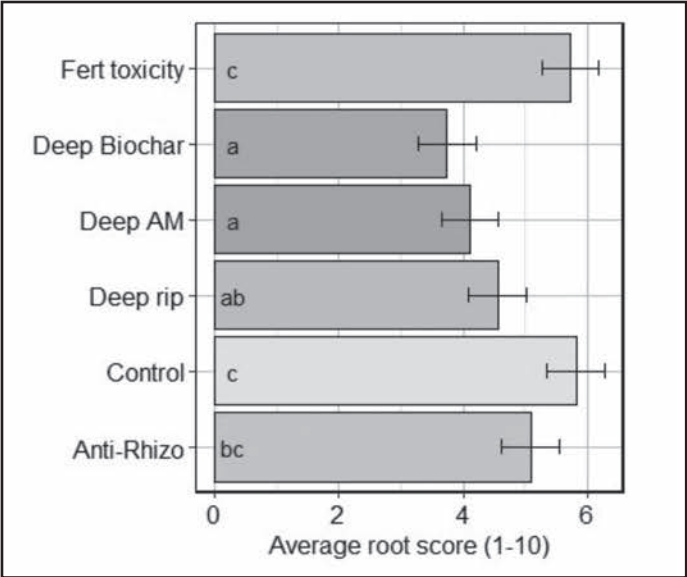


Figure 1. Average Rhizoctonia score on field pea roots in the Poochera rhizoctonia management trial with 2020 applied management treatments (0= no Rhizoctonia infection and 10= roots highly diseased and truncated), 2023. The letters within the graph represent the LSD of treatments which are significantly different at LSD ($P=0.05$).

Table 1. Average Grain yield (t/ha) of Kastar peas in the Poochera rhizoctonia management trial, 2023.

2020 Treatment	Nil	Uniform
Anti-Rhizo	0.32	0.31
Deep Biochar	0.29	0.27
Deep rip	0.28	0.28
Control	0.24	0.24
Fert toxicity	0.21	0.29
Deep AM	0.18	0.19
LSD ($P=0.05$)	ns	ns

Nodulation for N fixation was very poor despite being inoculated with peat, with an average of only one nodule per plant.

Just prior to harvest in October, the Deep CCM treatment appeared to have better and more even crop growth than the other treatments (data not shown).

Grain yield of Kastar peas in 2023 was similar across all treatments, averaging only 0.26 t/ha across the whole trial (Table 1).

What does this mean?

The 2023 season was very dry (decile 2) and Kastar peas performed poorly with an average yield of only 0.26 t/ha. Despite being inoculated at seeding with peat inoculant, nodulation for N fixation was poor with one nodule per plant.

Despite management treatments being imposed three years previously, they still had some effect on rhizoctonia infection on field peas in 2023. All treatments deep ripped in 2020 had lower rhizoctonia infection than the Control but the incorporation of organic amendments with ripping in 2020 had no further effect on rhizoctonia in 2023. Uniform® fungicide in furrow at seeding did reduce rhizoctonia in the 2022 barley crop in a decile 9 season.

Uniform® fungicide applied as a split application at seeding did not reduce rhizoctonia infection on pea roots in the dry season of 2023. However, in 2022, in a decile 9 rainfall year with cool mild grain filling conditions, despite having no reduction in rhizoctonia disease at eight weeks, the application of Uniform® fungicide

at seeding increased barley grain yield by 0.26 t/ha (EPFS Summary 2022, p.165). This was possibly due to lower foliar disease or by protecting the crown roots from rhizoctonia later in the season. The lack of benefit from Uniform on rhizoctonia has been common 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 any other strategies to reduce grass weeds, are still the “go to” management options so that rhizoctonia inoculum levels are low prior to the cereal crop.

The ‘Epidemiology and management of rhizoctonia in low and medium rainfall zones’ research has one more season to run. In 2024, crop performance and rhizoctonia infection will be monitored in a trial which was established in 2023 and is examining innovative

management strategies for rhizoctonia such as deep ripping with and without amendments and the use of long coleoptile varieties. 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.

Acknowledgements

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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, Rebecca Tomney and Cate Scholz for field work and processing samples and Karyn Reeves for undertaking the statistical analysis.

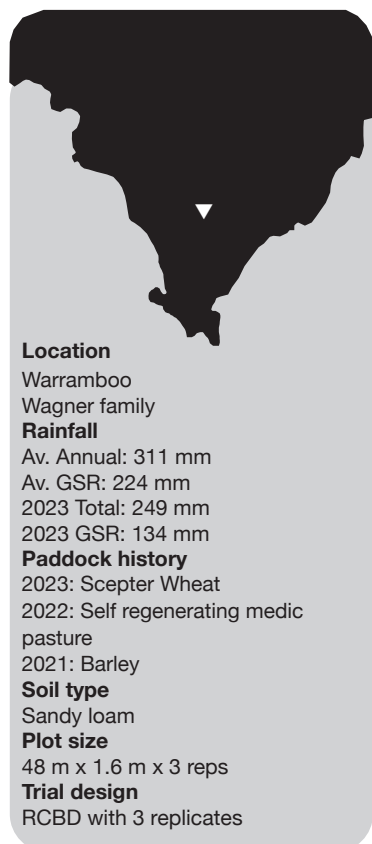


GRDC Lentil Check Grower Group meeting at Minnipa, 2023.

Demonstrating deep ripping and fungicide application on rhizoctonia management

Amanda Cook^{1,2}, Karyn Reeves³, Ian Richter¹, Craig Standley¹ and Marina Mudge¹

¹SARDI; ²The University of Adelaide; ³DPIRD, Western Australia and AIR EP



Key messages

- **Uniform in-furrow fungicide did not reduce rhizoctonia root disease in Calibre wheat in 2023.**
- **Neither ripping nor uniform fungicide altered grain yield of wheat compared to the control in 2023.**
- **Calibre outyielded Scepter by 0.4 t/ha in the control treatment.**

Why do the trial?

Rhizoctonia (*Rhizoctonia solani*) remains a significant constraint to crop production in the low and medium rainfall zones of the Southern and Western regions, especially on the calcareous soils of upper Eyre Peninsula (EP).

The aim of the current GRDC investment 'Epidemiology and management of Rhizoctonia in low and medium rainfall zones' (DAW2206-006RTX) is to examine innovative management strategies for rhizoctonia management 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 (e.g. soil amelioration and deeper sowing with long coleoptile varieties, and plant fumigants) to reduce the impact of rhizoctonia. The AIR EP Warramboo grower demonstration was implemented in 2023 to investigate the effects of soil amelioration, fungicide application and a long coleoptile wheat variety on rhizoctonia.

Newer long coleoptile varieties like Calibre may offer opportunities to sow below the highest Rhizoctonia inoculum level in the soil (0-5 cm) and to also allow better crop establishment from depth after deep ripping.

How was it done?

A grower at Warramboo implemented three deep ripping and Nil control blocks pre-sowing in mid-April 2023. The deep ripping treatments (6 m wide per pass) were imposed to 40 cm using a Bednar ripper, then rolled. Three seeding treatments were implemented; either Scepter, Calibre (long coleoptile wheat) or Calibre + Uniform[®] fungicide @ 400 ml/ha applied with a split application on plots 48 m long by 1.6 m wide.

The replicated trial was sown using a small plot seeder with Harrington knife points and press wheels on 31 May into a moist seed bed. A pre-sowing knockdown consisted of 2 L/ha Glyphosate, 80 L/ha Hammer and LI700 at 400ml/100L. Scepter and Calibre were sown @ 72 kg/ha with MAP fertiliser @ 70 kg/ha placed below the seed. The fungicide Uniform[®] (active ingredients, azoxystrobin & mefenoxam) was applied at 400 mL/ha with 80 L/ha of water as a split application (on top of the seed rows and banded under the seed rows). 50 kg/ha of urea was spread post crop emergence on 6 July.

Crop establishment was measured on 6 July 2023. At eight weeks after seeding 15 plants were sampled per treatment and scored for number of tillers, number of crown roots, and rhizoctonia infection of crown roots, seminal roots and overall. Internode root length, plant weight and root weight were also measured. Rhizoctonia infection was assessed using a score (0-10) developed by the project team. The ratings are: 0=no disease, 2-3=<25% roots damaged, 4-5=25-50% roots damaged, 6-7=50-75% roots damaged, 8-9>75% roots damaged, 10=all roots highly diseased and truncated. Crop vigour was estimated by NDVI on 26 August. Grain yield using a Zurn plot harvester was sampled on 10 November and grain quality traits were assessed.

Data from quantitative assessments were analysed using an ANOVA with three replicates sown in a single range using GENSTAT.

What happened?

The 2023 season on upper Eyre Peninsula had below average winter and spring rainfall, but there was some stored soil moisture from November 2022 summer rainfall events. Mid-April rains allowed seeding to occur in adequate to drier moisture, however, follow up

rainfall events greater than 10 mm over two days didn't occur until late June-early July.

The total rainfall for Kyancutta in 2023 (16 km from trial site) was 249 mm, and the 2023 growing season rainfall was 134 mm.

Wheat establishment across all treatments averaged 111

plants/m², however shallower sown Scepter wheat had better establishment (126 plants/m²) than the Calibre Nil treatments (Figure 1). The Scepter wheat had similar to plant establishment to the Calibre unripped with Uniform fungicide applied treatment (Figure 1).

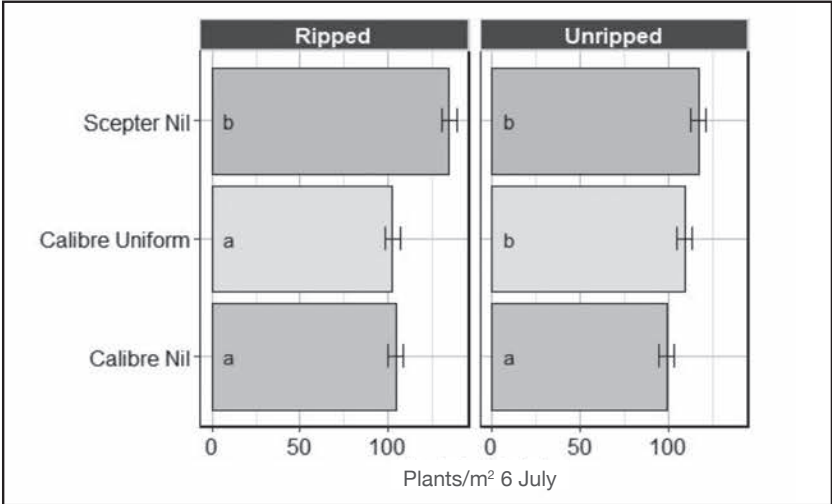


Figure 1. Wheat establishment in the Warramboo rhizoctonia management trial, 2023. The letters within the graph represent the LSD of treatments which are significantly different at LSD (P=0.05).

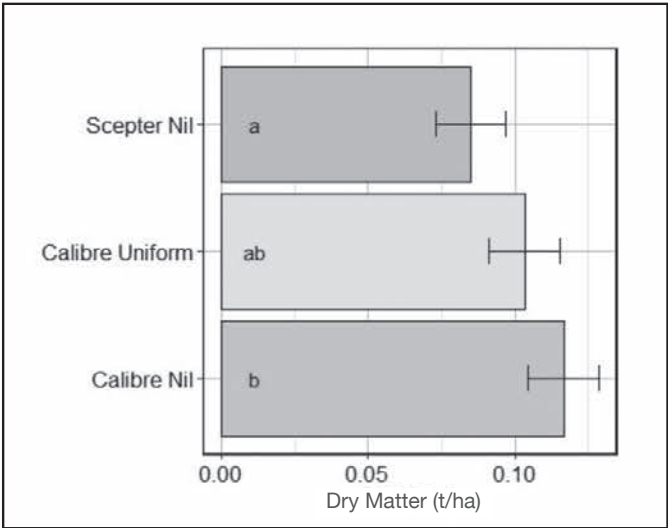


Figure 2. Average wheat dry matter (t/ha), averaged over soil amelioration treatments, eight weeks after seeding in the Warramboo rhizoctonia management trial, 2023. The letters within the graph represent the LSD of treatments which are significantly different at LSD (P=0.05).

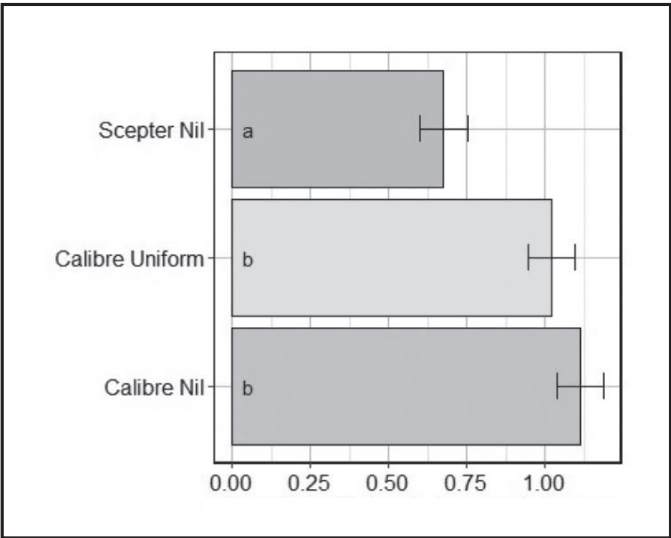


Figure 3. Average Grain yield (t/ha) of wheat in the Warramboo rhizoctonia management trial, 2023.

Table 1. Grain protein (%) of wheat in the Warramboo rhizoctonia management trial, 2023.

Management treatment	Grain protein (%)
Calibre Nil	12.6 a
Calibre Uniform	13.0 a
Scepter Nil	13.8 b
LSD (<i>F prob</i> =0.05)	0.7

Soil amelioration did not impact on plant biomass or NDVI. The Calibre Nil (without fungicide) treatment had greater biomass than Scepter without fungicide (Figure 2).

The management treatments of soil amelioration, variety or fungicide did not change rhizoctonia infection (average rating of 5.6), number of tillers (3), internode root length (3 cm) or number of crown roots (11) or % crown root infection (46%) eight weeks after seeding in 2023.

The only treatment which affected grain yield was variety choice; Calibre yielded 0.39 t/ha than Scepter (Figure 3), with average yield across the trial being 0.94 t/ha.

Scepter had higher protein than Calibre (Table 1). There were no other differences in grain quality.

What does this mean?

Scepter wheat and Calibre Nil in unripped plots had higher plant establishment than Calibre after deep ripping. Calibre had greater plant biomass than Scepter during the season.

Soil amelioration in a deep white sand at Warramboo did not affect plant biomass, rhizoctonia disease levels or root growth, grain yield or quality in a decile 2 season.

Uniform® fungicide applied in a split fluid application did not improve plant root growth or reduce Rhizoctonia disease impacts on seminal or crown roots on in either ripped or unripped soil.

The plant dry matter taken in August was greater with the Calibre unripped treatment compared to the Scepter unripped treatment, and the gains in dry matter followed through to differences in grain yield at harvest. Scepter wheat had higher grain protein levels than Calibre.

The lack of benefit from Uniform® on rhizoctonia has been common in previous upper EP research with earlier and drier finishes to the seasons. Using canola or legume break crops which are grass free in the rotation, and any other strategies to reduce grass weed numbers, are still the “go to” management options to reduce rhizoctonia inoculum levels before the cereal crop. Rhizoctonia

inoculum levels will increase during the season with a cereal crop.

The ‘Epidemiology and management of rhizoctonia in low and medium rainfall zones’ research has one more season to run. In 2024, crop performance and rhizoctonia infection will be monitored again to investigate management strategies for rhizoctonia such as deep ripping and the use of long coleoptile varieties.

Acknowledgements

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Management of foliar disease in lentils on the upper Eyre Peninsula

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Location
Mount Cooper - Angus Gunn

Rainfall
Av. Annual: 421 mm
Av. GSR: 332 mm
2023 Total: 394 mm
2023 GSR: 292 mm

Soil type
Red clay loam

Paddock history
2023: Wheat
2022: Lentil
2021: Barley

Plot size
10 m x 1.76 m

Trial design
Fungicide trial: Randomised complete block design
Variety trial: Split plot design

Location
Mount Damper - AJ Michael

Rainfall
Av. Annual: 317 mm
Av. GSR: 206 mm
2023 Total: 216 mm
2023 GSR: 135 mm

Soil type
Calcareous sandy loam over calcrete

Paddock history
2023: Wheat
2022: Lentil
2021: Wheat

Plot size
12 m x 1.76 m

Trial design
Fungicide trial: Randomised complete block design
Variety trial: Split plot design

Key messages

- **Conditions in the 2023 growing season were not conducive for lentil foliar fungal diseases Ascochyta blight (AB) or Botrytis grey mould (BGM).**
- **Fungicide sprays were not needed in a decade 1-2**

rainfall season for maximum gross margin in lentils on upper Eyre Peninsula (UEP) when there was low disease pressure.

- **No lentil varieties consistently out-performed others in terms of yield or quality.**
- **Foliar disease level in lentil did not influence grain grades at delivery in a below average rainfall year (2023).**

Why do the trial?

The upper Eyre Peninsula (UEP) has been gradually incorporating more lentils into the farming system for both agronomic and economic benefits as a legume break crop. The UEP farming system is characterised by its warm, low rainfall climate with short, mild winters. Therefore, determining which existing lentil variety performs best under those conditions while being resistant to major pulse diseases, such as Botrytis grey mould (BGM) and Ascochyta blight (AB), is important in the UEP farming system. Due to the water-limiting environment, BGM and AB are less likely to impact yield in comparison to other higher rainfall regions but can still cause major financial loss if managed ineffectively, especially in a wet season like 2022.

Effective disease management requires implementing integrated disease management (IDM). This includes observing 3-4 years rotations between crops of the same type in the same paddock, sowing clean seed, and choosing disease resistant varieties that are compatible with the disease risk profile, paddock history, local climate, soil type, and agronomic management. Use of foliar

fungicides should follow strategies to mitigate against development of fungicide resistance, so choosing the most suitable fungicide(s) for the situation and application at the optimum time ahead of a rain front is critical. Planning a fungicide strategy early in the season will better prepare for effective control of foliar diseases and this can reduce production losses while maximising the gross margin at the end of the season.

Due to the unique climate of the UEP and lentils being a relatively new crop in the system, more information is needed to determine if one fungicide spray is sufficient to provide disease control in most seasons or whether multiple fungicide sprays provide any additional benefit.

A number of current GRDC investments aim to develop economic frameworks around decision making for disease management in pulses across mid and high rainfall regions in SA. However, a gap exists in this investigation for the low rainfall region of the UEP region. Hence, this project aimed to:

1. Investigate if only one fungicide spray is sufficient for controlling AB and BGM in a low rainfall region in a moderately disease resistant lentil variety (GIA Thunder IMI).
2. Determine the effectiveness of various fungicide strategies in only one spray application.
3. Determine which fungicide strategies result in the highest gross margin by the end of the season.
4. Determine which lentil variety can produce the highest yield in a low rainfall region.

Location
Minnipa Agricultural Centre

Rainfall
Av. Annual: 325 mm
Av. GSR: 241 mm
2023 Total: 280 mm
2023 GSR: 169 mm

Soil type
Red loam

Paddock history
2023: Field pea
2022: Wheat
2021: Field pea

Plot size
12 m x 1.76 m

Trial design
Variety trial: Split plot design

How was it done?

This project consisted of five trials located at three trial sites, Mount Cooper (2), Mount Damper (2) and Minnipa Agricultural Centre (MAC) (1). Both Mount Cooper and Mount Damper sites had a fungicide (Table 1) and a variety trial (Table 2), whereas MAC only had a variety trial (Table 3). The trial site information is listed in Table 4. The assessments conducted at each site during growing season were

plant emergence, early and late normalized difference vegetation index (NDVI), late dry matter, percent plot disease, and weather data collection. The grain was harvested and weighed using the Zurn small plot harvester. Grain quality assessments of the lentil grain harvested from two sites were compared post-harvest.

Table 1. 2023 Fungicide treatments for Mount Cooper and Mount Damper trials sown to the lentil variety GIA Thunder IMI. *Fungicides are applied at early/mid flowering at Mount Damper since canopy closure is not fully achieved.

Treatment No.	Fungicide Treatment
1	Untreated control
2	Treated control - Echo® 900WDG (Chlorothalonil) at 1 L/ha + Spin Flo (Carbendazim) at 500 mL/ha every 2 weeks. First treatment at 5 weeks after sowing
3	Veritas® Opti at 400 mL/ha at canopy closure*
4	Miravis® Star at 500 mL/ha at canopy closure
5	Aviator® Xpro® at 400 mL/ha at canopy closure
6	Echo® 900WDG at 1 L/ha + Spin Flo 500 at mL/ha at canopy closure
7	Mancozeb 750 WG at 1.5 kg/ha at canopy closure
8	Seasonal variation spray - First application: Ahead of first rain front at or after canopy closure (Echo® 900WDG at 1 L/ha + Spin Flo at 500 mL/ha). Second application: Ahead of second rain front after canopy closure, at least 14 days after first spray (Veritas® Opti at 400 mL/ha). Third application: Ahead of third rain front after canopy closure, at least 14 days after second spray (Echo® 900WDG at 1 L/ha + Spin Flo at 500 mL/ha)

Table 2. Variety trial treatment information for Mount Cooper and Mount Damper, 2023.

Whole-plot treatment (fungicide application)	Sub-plot treatment (variety)
1 Full Disease - No fungicide sprays	1 GIA Thunder IMI
	2 PBA Hallmark XT
	3 PBA Hurricane XT
	4 PBA Highland XT
	5 PBA Jumbo2
2 No Disease - Fungicide sprays every 2 weeks	1 GIA Thunder IMI
	2 PBA Hallmark XT
	3 PBA Hurricane XT
	4 PBA Highland XT
	5 PBA Jumbo2

Table 3. Variety trial treatment information for Minnipa, 2023.

Treatment	Variety
1	GIA Thunder IMI
2	PBA Hallmark XT
3	PBA Hurricane XT
4	PBA Highland XT
5	PBA Jumbo2
6	GIA Lightning IMI (coated with P-Pickel T)

Table 4. Trial site information for Minnipa, Mount Cooper and Mount Damper sites, 2023.

Site location	MAC	Mount Cooper	Mount Damper
Sowing date	8 May 2023	9 May 2023	9 May 2023
Sowing depth	60 mm	60 mm	70 mm
Fertiliser rate	MAP - 50 kg/ha	MAP - 50 kg/ha	MAP - 50 kg/ha
Inoculum	Peat in seed envelopes	Peat in seed envelopes	Peat in seed envelopes
Plant density	150 plants/m ²	150 plants/m ²	150 plants/m ²
Sowing method	Direct drilling	Direct drilling	Direct drilling
Row spacing	25.4 cm (10 inches)	25.4 cm (10 inches)	25.4 cm (10 inches)
Plot centre	2 m	2 m	2 m
Pre sowing herbicide	Glyphosate 1.5 L/ha + Hammer (50 mL/ha) + Propyzamide (700 mL/ha) + Reflex (700 mL/ha)	Glyphosate 1.5 L/ha + Hammer (50 mL/ha) + Propyzamide (700 mL/ha) + Reflex (700 mL/ha)	Glyphosate 1.2 L/ha + Hammer (30 mL/ha) + Propyzamide (600 mL/ha) + Reflex (500 mL/ha)
PSPE herbicide	Clethodim 360 330 mL/ha + Hasten 1% + Ammonium sulphate 8kg/1000L	Glyphosate 1.5 L/ha + Hammer (50 mL/ha) + Propyzamide (700 mL/ha) + Reflex (700 mL/ha)	Glyphosate 1.2 L/ha + Hammer (30 mL/ha) + Propyzamide (600 mL/ha) + Reflex (500 mL/ha)
Harvest date	16 October 2023	27 October 2023	18 October 2023

What happened?

Fungicide trials

In this low disease and low rainfall year, there were no significant difference between fungicide treatments at either Mount Damper or Mount Cooper for disease level, NDVI, grain yield or grain quality.

Disease levels, rated as percentage of the plot with AB symptoms, were very low (<8%) throughout the growing season at both trial sites (Figure 1). AB is a seed and stubble borne disease that is promoted by rain-splash in winter, whilst BGM is usually associated with mild temperatures (15-25°C) and high relative humidity (>70%) in spring. The low disease scores in both trials reflects the dry conditions in late winter and spring at the sites.

NDVI was used as a non-destructive biomass sampling method to indicate the level of biomass from each treatment. However, there was no significant difference in late NDVI values (27 September) between treatments at both sites.

Mount Damper had a higher average yield (1.59 t/ha) than Mount Cooper (1.22 t/ha) but there were no significant difference between each treatment. Due to low disease levels, only 300 grain weights were measured for quality assessment but no significant difference between treatments was observed. Lentils at Mount Damper had higher 300 grain weights on average than Mount Cooper, even though Mount Cooper had higher late NDVI values on average than Mount Damper.

Variety trials:

AB disease levels in the variety trial at both sites were also very low (Figure 2 and 3) and there was no significant difference between the Full Disease (no fungicides applied) and No Disease (fungicides applied) treatments. PBA Hallmark XT, rated MRMS to AB pathotype 2, had the highest disease scores throughout the season overall, while PBA Jumbo2, rated RMR(p) to AB pathotype 2, had the lowest disease scores, but the difference between each variety was not significant.

A positive linear correction was observed between biomass and estimated yield at Minnipa and Mount Damper (Figure 4). The Minnipa site showed the stronger biomass-yield correlation than Mount Damper. The Mount Cooper site showed no correlation.

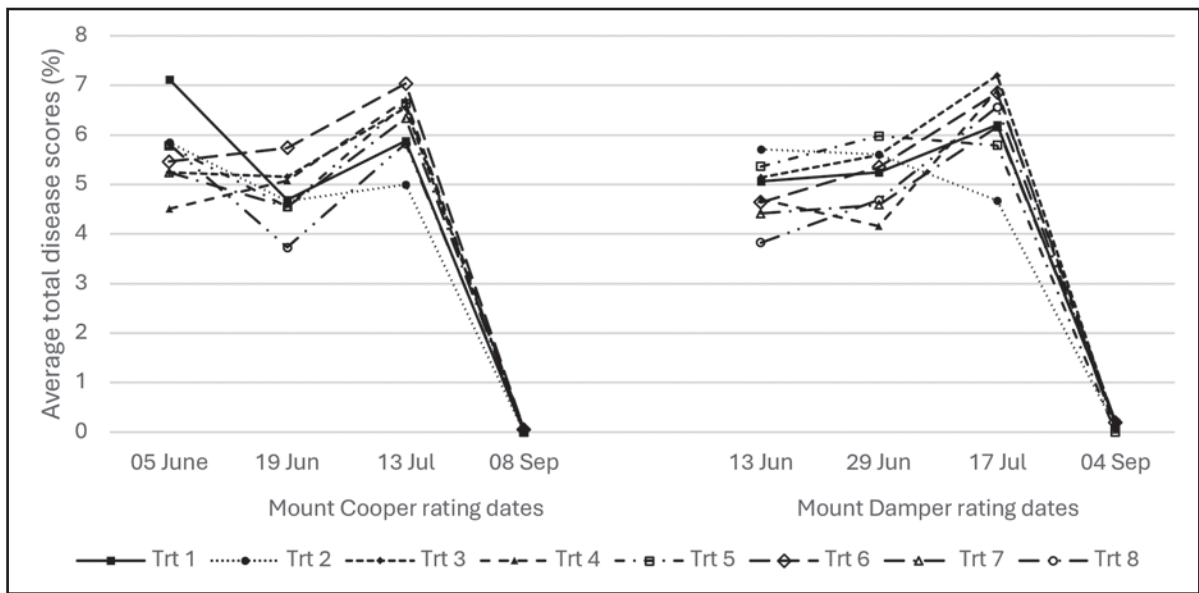


Figure 1. Average total disease scores in 2023 of the eight fungicide treatments on GIA Thunder IMI lentils rated on four occasions at Mount Cooper (5 June, 19 June, 13 July and 8 September) and Mount Dampier (13 June, 29 June, 17 July and 4 September).

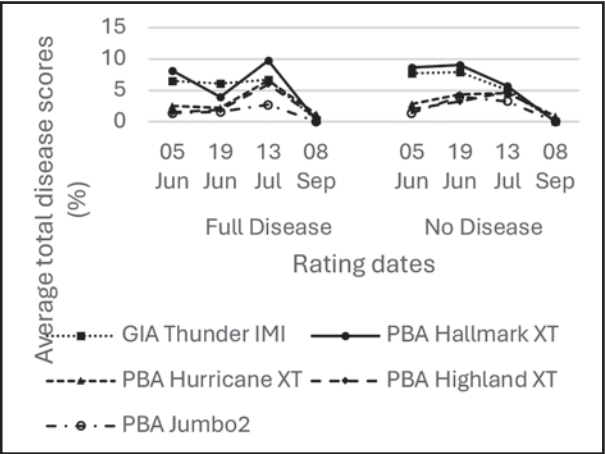


Figure 2. Average total disease scores of each of the five lentil varieties in the both the Full Disease and No Disease whole-plot treatments combined as rated on four occasions at Mount Cooper in 2023.

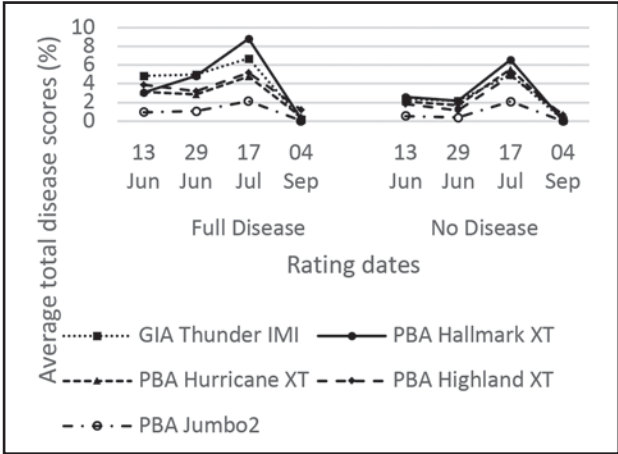


Figure 3. Average total disease scores of each of the five lentil varieties in the Full Disease and No Disease whole-plot treatments combined as rated on four occasions at Mount Dampier in 2023.

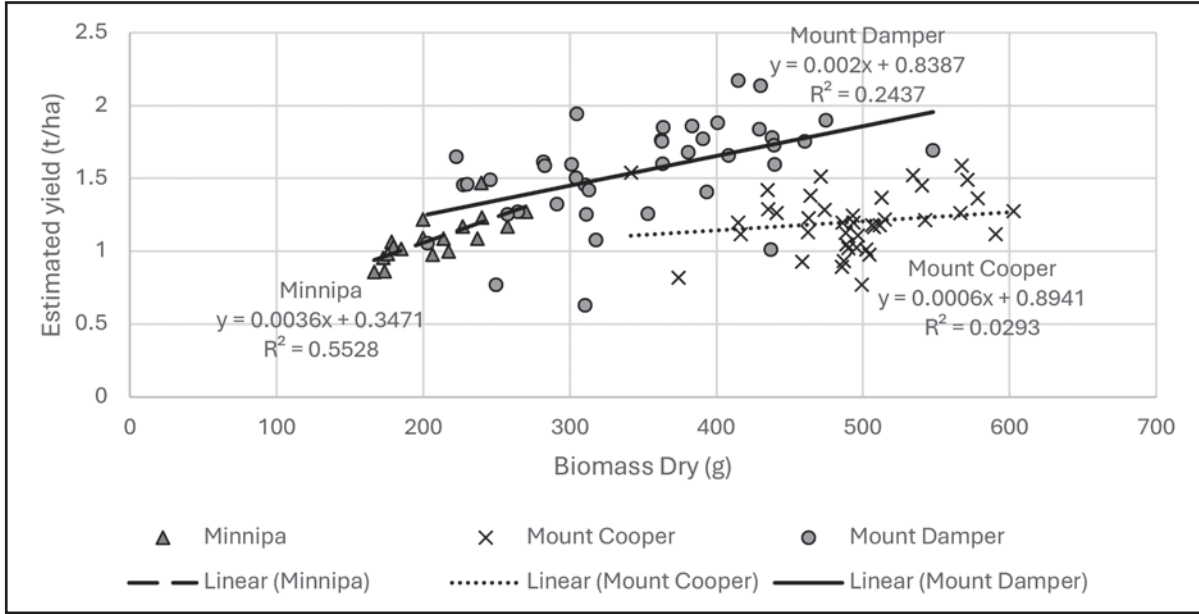


Figure 4. The relationship between biomass and estimated lentil yield at Minnipa, Mount Cooper, and Mount Dampier lentil variety trials in 2023.

Trials were harvested and estimated yield calculated (Table 5). At Minnipa, GIA Thunder IMI was the highest yielding variety, and this was significantly higher than PBA Hallmark XT. At Mount Cooper, there was a significant effect of variety in the Full Disease (no fungicides applied) treatment only where PBA Highland XT recorded the highest yield, but this was statistically similar to yields for PBA Hurricane XT, GIA Thunder IMI and Jumbo2.

At Mount Damper, lentil harvestability issues were encountered during harvesting

which were scored and accounted for in the statistical analysis. The harvestability issues did not appear to influence the general trend in yields after yield adjustments. No multiple comparisons were done on Mount Damper yields.

Varietal results for total defective grains varied across each site. At Minnipa, GIA Thunder IMI and GIA Lightning IMI had the least number of total defective grains, though not statistically different from PBA Hallmark XT, PBA Hurricane XT and PBA Highland XT, whereas PBA Jumbo2 had the most total defective grains (Table

6). At Mount Cooper and Mount Damper, significant differences between varieties were detected only in the Full Disease treatment. At Mount Cooper, PBA Hallmark XT had the least total defective grains and PBA Highland XT had the most total defective grains (Table 6), while in Mount Damper, GIA Thunder had the least total defective grains, and PBA Hurricane XT, PBA Highland XT and PBA Jumbo2 had the most total defective grains. There was no significant interaction between fungicide treatment and variety.

Table 5. The estimated lentil yields (t/ha) harvested from variety trials in Minnipa, Mount Cooper and Mount Damper 2023 (*Mount Damper trial encountered harvest issues. The mean yield data displayed for Mount Damper in this table was the adjusted mean. Therefore, no multiple comparisons were done between varieties either fungicide treatment) (ns* meaning no significant difference between treatments).

Variety	Minnipa	Mount Cooper		Mount Damper* (Adjusted for harvest loss)	
		Full Disease	No Disease	Full disease	No Disease
GIA Thunder IMI	1.25 a	1.18 ab	1.24	1.87	1.15
PBA Hallmark XT	1.05 b	0.96 b	1.13	1.75	1.27
PBA Hurricane XT	1.11 ab	1.22 ab	1.42	1.76	1.59
PBA Highland XT	1.07 ab	1.27 a	1.27	1.84	1.36
PBA Jumbo2	1.04 ab	1.05 ab	1.30	1.63	1.49
GIA Lightning IMI	1.06 ab	N/A		N/A	
F prob (Variety)	<0.05	<0.05	ns	ns	ns
LSD (Variety) (F Prob=>0.05)	0.28	0.20	ns	0.2	ns
F prob (Fungicide*Variety)	N/A	ns*		ns	

Table 6. The mean weight of total defective grains (g) (defective + poor colour) of lentils harvested from variety trials at Minnipa, Mount Damper and Mount Cooper in 2023.

Variety	Minnipa	Mount Cooper		Mount Damper	
		Full Disease	No Disease	Full Disease	No Disease
GIA Thunder IMI	4.46 b	3.52 ab	3.478	2.26 b	2.09
PBA Hallmark XT	6.11 ab	3.38 b	3.670	2.65 ab	2.54
PBA Hurricane XT	7.35 ab	4.39 ab	4.275	3.25 a	3.34
PBA Highland XT	6.62 ab	4.56 a	4.293	3.07 a	3.13
PBA Jumbo2	7.59 a	3.64 ab	4.290	3.09 a	3.11
GIA Lightning IMI	4.48 b	N/A		N/A	
F prob (Variety)	<0.05	<0.05	ns	<0.05	ns
LSD (Variety) (F prob=>0.05)	1.96	0.78	ns	0.45	ns
F prob (Fungicide*Variety)	N/A	ns		ns	

What does this mean?

Fungicide trials

Fungicide applications for control of lentil foliar disease were unnecessary on the UEP in 2023. The fungal foliar diseases, AB and BGM of lentils, were at very low levels likely due in part to the decile 1-2 growing season rainfall in that region. These diseases require sufficient moisture either as frequent rainfall or high humidity present in the crop as dew, fog, or high soil moisture. The retail prices (Table 7) and the cost of implementing each treatment (Table 8) suggest that UEP growers who did not put out a fungicide would have saved between \$13-56 /ha. Thus, in this one-year study, it suggests that on the UEP there was no benefit from applying foliar fungicides in a below average rainfall season and in a below average disease year.

Variety trials

Aiming to maximise crop biomass to suit rainfall levels to achieve high

yield is important. A positive, linear correlation between biomass and final yield (Figure 4) was revealed across low (Minnipa) and medium (Mount Damper) rainfall areas on the UEP but not higher rainfall areas (Mount Cooper).

No fungicide application was necessary at Minnipa (Decile 2-3 rainfall), Mount Cooper (Decile 5 rainfall) or Mount Damper (Decile 2-3 rainfall) in the 2023 season with the disease pressure present at these sites, and varietal differences was dependent on the site. Therefore, in a below average rainfall year like 2023, no fungicide application was required on UEP regardless of the lentil variety grown in this one-year study with little disease pressure.

The yield and quality of all varieties varied across different sites. In a season like 2023, poor colour would not play a significant role in lentil grades determination due to a lack of diseases to stain the seeds during podding. Most of the

poor colour grains found in this year's trial was most likely due to the heat and drought stress crops experienced during podding.

Table 9 demonstrated the average possibility of grades for each variety tested in the trials in 2023 at Minnipa, Mount Cooper and Mount Damper. At Minnipa, GIA Lightning IMI and GIA Thunder IMI were more likely to receive NIPT1 grade with a probability of 66% and 33% respectively, with relatively low deduction if they had received NIPTB grade. At Mount Cooper, GIA Thunder IMI (87.5%) and PBA Hallmark (75%) were more likely to receive NIPT1 grade. At Mount Damper, PBA Hurricane and PBA Jumbo2 were less likely to receive top grade than other varieties. However, due to the minimal foliar disease levels observed, it is not possible to make conclusive claims about grain grades, thus more research is required to investigate the profitability of lentil varieties on the UEP.

Table 7. The retail price (\$/kg or L) of each fungicide product used in 2023.

Fungicide product	Retail price (\$/kg or L)
Mancozeb	\$8.75
Carbendazim (Spin Flo®)	\$11.50
Chlorothalonil (Echo® 900 WDG)	\$14.00
Veritas® Opti	\$42.00
Miravis® Star	\$68.15
Aviator® Xpro®	\$59.70

Table 8. The cost per hectare of each fungicide treatment in the 2023 season (machinery and labour costs excluded).

Treatment	Description	Cost/ha (\$)
1	Untreated control	0
2	Treated control (Chlorothalonil 1 L/ha + Carbendazim 500 mL/ha every 2 weeks)	119
3	Veritas Opti 400 mL/ha before canopy closure	17
4	Miravis Star 500 mL/ha before canopy closure	34
5	Aviator Xpro 400mL/ha before canopy closure	24
6	Chlorothalonil 1 L/ha + Carbendazim 500 mL/ha before canopy closure	20
7	Mancozeb 1.5 kg/ha before canopy closure	13
8	Seasonal variation spray	56

Table 9. The probability of each lentil variety harvested from the Minnipa, Mount Cooper and Mount Damper in 2023 entering each grade and their average deduction per tonne if they make it into NIPTB grade (*There is no deduction for PBA Jumbo2 as it would be rejected).

Variety	Minnipa				Mount Cooper				Mount Damper			
	NIPT1 /LR1 (%)	NIPTA /LRA (%)	NIPTB /Reject (%)	NIPTB Deduction /t (%)	NIPT1 /LR1 (%)	NIPA /LRA (%)	NIPTB /Reject (%)	NIPTB Deduction /t (%)	NIPT1 /LR1 (%)	NIPA /LRA (%)	NIPTB/Reject (%)	NIPTB Deduction /t (%)
GIA Thunder IMI	33	0	66	0.5	87.5	12.5	0	0	100	0	0	0
PBA Hallmark XT	0	0	100	1.83	75	25	0	0	100	0	0	0
PBA Hurricane XT	0	0	100	3	25	37.5	37.5	0.5	87.5	12.5	0	0
PBA Highland XT	0	0	100	2.17	0	75	25	0.25	100	0	0	0
PBA Jumbo2	0	0	100	N/A	37.5	50	12.5	N/A	87.5	0	12.5	N/A
GIA Lightning IMI	66	0	33	1.5	N/A				N/A			

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Root Diseases in Lentils

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Key messages

- *Fusarium avenaceum* (F. Ave) reduced lentil yield by between 60-77% compared with the uninoculated control.
- *Rhizoctonia solani* AG8 reduced lentil yield by 50% under a high inoculum load, compared with the uninoculated control.
- *Didymella* (syn. *Phoma*) *pinodella* did not reduce lentil yield compared to the uninoculated control.

Why do the trials?

A series of yield loss trials are currently being conducted as part of a 3-year SAGIT investment (SUA421) and a 3-year GRDC National Project lead by SARDI, to:

1. identify the key soilborne pathogens of various pulse species, including lentil,
2. quantify the range of yield loss potential and
3. determine the potential value of management options such as fungicides and crop rotation.

Soil borne diseases cost the Australian grains industry hundreds of millions of dollars per annum. In wheat alone, diseases such as Crown Rot (*Fusarium* spp.) and Root Lesion Nematode (*Pratylenchus* spp.) have been estimated to cause losses of \$79 million and \$134 million annually (Murray and Brennan, 2009). However, because soilborne diseases are less obvious than foliar diseases, their impacts often go unnoticed. Furthermore, because pulses are a comparatively new addition to Australian farming systems, the soilborne diseases affecting these crops are under-researched and

poorly understood. Consequently, the yield impacts of soilborne pathogens on lentil yields are not well known.

However, previous surveys of poor performing pulse crops across Australia have demonstrated that root diseases are common, and further work has led to the identification of key soilborne pathogens likely reducing pulse yields. *Fusarium* spp., *Rhizoctonia solani* AG8, and *Didymella pinodella* spp. are commonly found in soil/root DNA tests on the Eyre Peninsula (EP), as well as in other Australian growing regions. These pathogens have long been known to affect pasture legumes such as medic and clover, but their effect on lentil yield is not well established. These trials aim to quantify yield loss in lentil caused by these pathogens and explore management options.

How was it done?

Overview

In 2023, four field trials were conducted to investigate the effect of *Fusarium* spp., *R. solani* AG8 and *D. pinodella* on lentil (cv Hallmark) root health and yield. Two trials were conducted at Loxton Research Centre (-34.438722, 140.596356) and two at Roseworthy Agricultural College (-34.539789, 138.688897). Trials were cultivated and fumigated before sowing to reduce (as much as possible) any background pathogens. Loxton was sown using a plot seeder on the 29 June and Roseworthy sown on the 21 July. Lentil was sown at 51 kg/ha to target a plant density of 120 plants/m², with the disease inoculum (sterile millet seeds colonised by the pathogen in the laboratory) incorporated at sowing

down the same cone. All trials included uninoculated controls and were sown in a 5-range design with five replicates.

Fusarium trial

One trial was sown at Roseworthy. The trial had 11 treatments (Table 1). Treatments were isolates or isolate mixes of *Fusarium* species which had been collected during previous surveys and had demonstrated some pathogenicity toward pulse species in the controlled environment room (CER) at Waite. As well as millet inoculum, seeds were coated in a spore solution prior to sowing.

Rhizoctonia solani AG8 trial

One trial was sown at Loxton. The *R. solani* trial had six treatments (Table 2).

Didymella pinodella trials

One trial was sown at Loxton and one trial at Roseworthy. The trials had a split plot design, with irrigation as the main plot and inoculum as the sub plot. Irrigation had two levels, while inoculum had five levels, making for a total of 10 treatments (Table 3). Additional water (330 mm at Loxton and 215 mm at Roseworthy) was applied to the irrigated plots using a dripper line system over four irrigation events. Irrigation was first applied at the early vegetative stage of the lentil (26 July at Loxton, 11 August at Loxton) and ended at lentil flowering (25 September at Loxton, 26 September at Roseworthy). The aim of irrigation was to see if additional soil water increased soilborne disease. To stop cross-contamination of the irrigated plots into the unirrigated plots, there was a buffer row between each treatment row.

Table 1. Treatment details of 2023 Fusarium trial at Roseworthy.

Treatment	Pathogen	Mix	Isolate Origin	CER pathogenicity
F. solani 1	<i>F. solani</i>	Single	SA chickpea	Low-moderate
F. solani 2	<i>F. solani</i>	Mix	SA faba	Nil
F. ave 1	<i>F. avenaceum</i>	Single	SA faba	High
F. ave 2	<i>F. avenaceum</i>	Single	SA faba	High
F. ave 3	<i>F. avenaceum</i>	Single	NSW faba	High
F. acu 1	<i>F. acuminatum/tricinctum</i>	Mix	NSW field pea	High-moderate
F. acu 2	<i>F. acuminatum/tricinctum</i>	Mix	SA faba + chickpea	Low-moderate
F. oxy 1	<i>F. oxysporum</i>	Mix	SA faba + lentil	Low-moderate
F. oxy 2	<i>F. oxysporum</i>	Mix	VIC isolate mix	Low-moderate
F. red 1	<i>F. redolens</i>	single	SA field pea	moderate
Control	Uninoculated control	-	-	-

Table 2. Treatment details of 2023 Rhizoctonia solani AG8 trial at Loxton.

Treatment	Details
Uninoculated Control (CC)	Sown without colonised millet.
High Rate (HR)	High rate of inoculum; 168g plot-1; 4g m-1
Medium Rate (MR)	Medium rate of inoculum; 42g plot-1; 2g m-1
MR + Liquid Fungicide (ML)	Medium rate of inoculum + typical in-furrow liquid fungicide for Rhizoctonia in cereals
MR + Seed treatment (MST)	Medium rate of inoculum + typical fungicide seed treatment for Rhizoctonia in cereals
MR + P-pickle T (MP)	Medium rate of inoculum + typical fungicide seed treatment for lentils and other pulses

Table 3. Treatment details of 2023 Didymella pinodella trials at Loxton and Roseworthy.

Irrigation (main plot)	Inoculum (sub-plot)	Details
Irrigated	Uninoculated Control (CC)	
	High Rate (HR)	126g plot ⁻¹ , 3g m ⁻¹
	Medium Rate (MR)	42g plot ⁻¹ , 1g m ⁻¹
	Medium Rate + Spore Suspension applied to seed (MS)	11 spores/cm ³ soil, applied early vegetative stage of lentil
	Medium Rate + Seed Treatment (TM)	P-pickle T, 2ml/kg seed
Non-irrigated	Uninoculated Control (CC)	
	High Rate (HR)	126g plot ⁻¹ , 3g m ⁻¹
	Medium Rate (MR)	42g plot ⁻¹ , 1g m ⁻¹
	Medium Rate + Spore Suspension applied to seed (MS)	11 spores/cm ³ soil, applied early vegetative stage of lentil
	Medium Rate + Seed Treatment (TM)	P-pickle T, 2ml/kg seed

What happened

Fusarium trial

Lentil yield was reduced by up to 77% in the *F. avenaceum* (F Ave.) treatments compared with the uninoculated control. The F. ave 1, F. ave 3, and F. ave 2 treatments

yielded 0.23 t/ha, 0.36 t/ha, and 0.40 t/ha, respectively, compared with 1.01 t/ha in the uninoculated control (Figure 1). Lentil in the *F. avenaceum* treatments had increased visual root disease scores up to 4 times greater than lentil in the uninoculated control

(Figure 2). While some of the other *Fusarium* treatments had increased root disease scores compared with the control (F. solani 1 & 2, F. oxy 1, and F. red 1), this did not translate to a difference in yield or aboveground biomass.

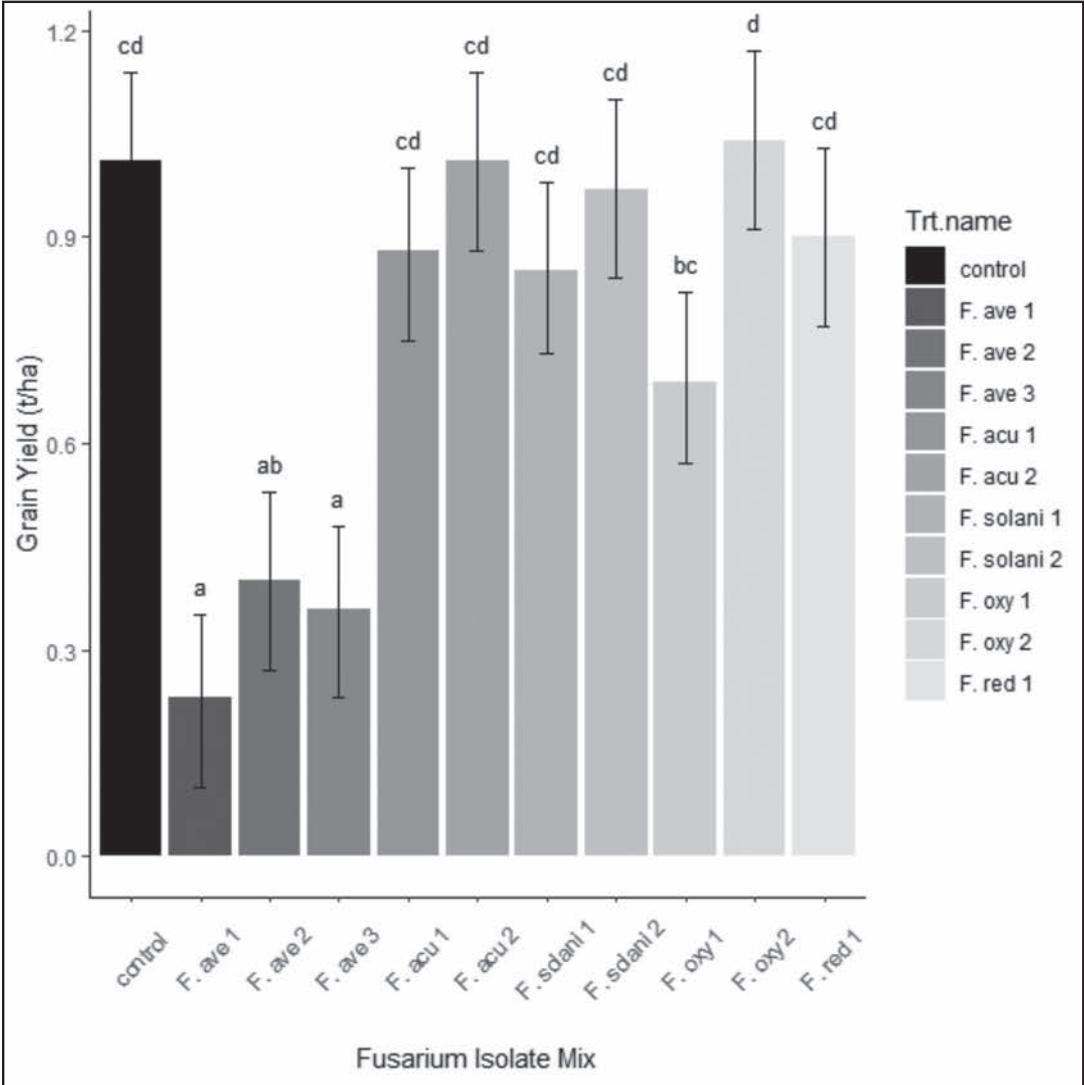


Figure 1. Grain yield (t/ha) by isolate mix in lentil at the Roseworthy Fusarium trial, 2023. Error bars indicate ± 1 95% confidence interval.

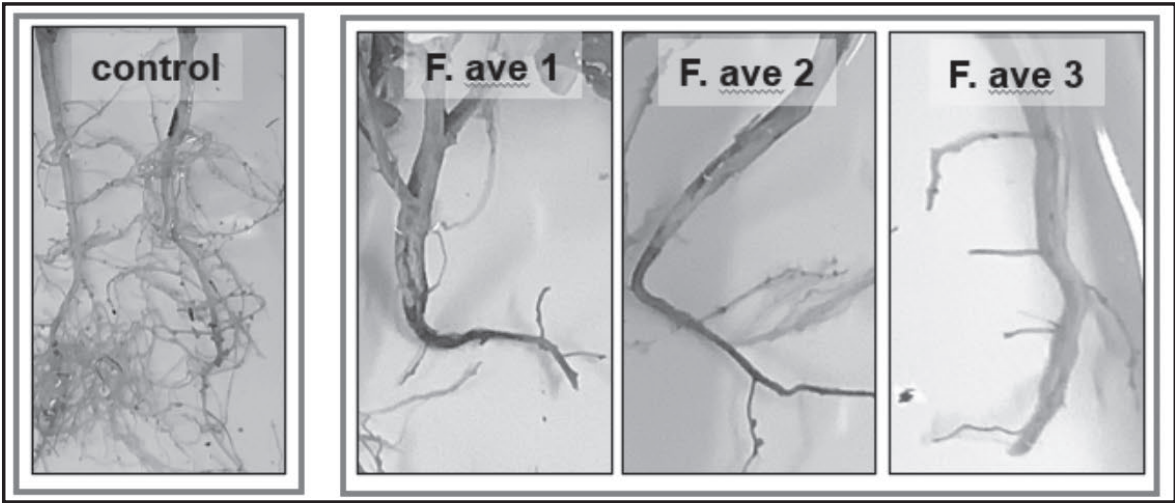


Figure 2. Visual signs of disease on lentil root from the uninoculated control compared with the *F. avenaceum* treatments at the Roseworthy Fusarium trial, 2023.

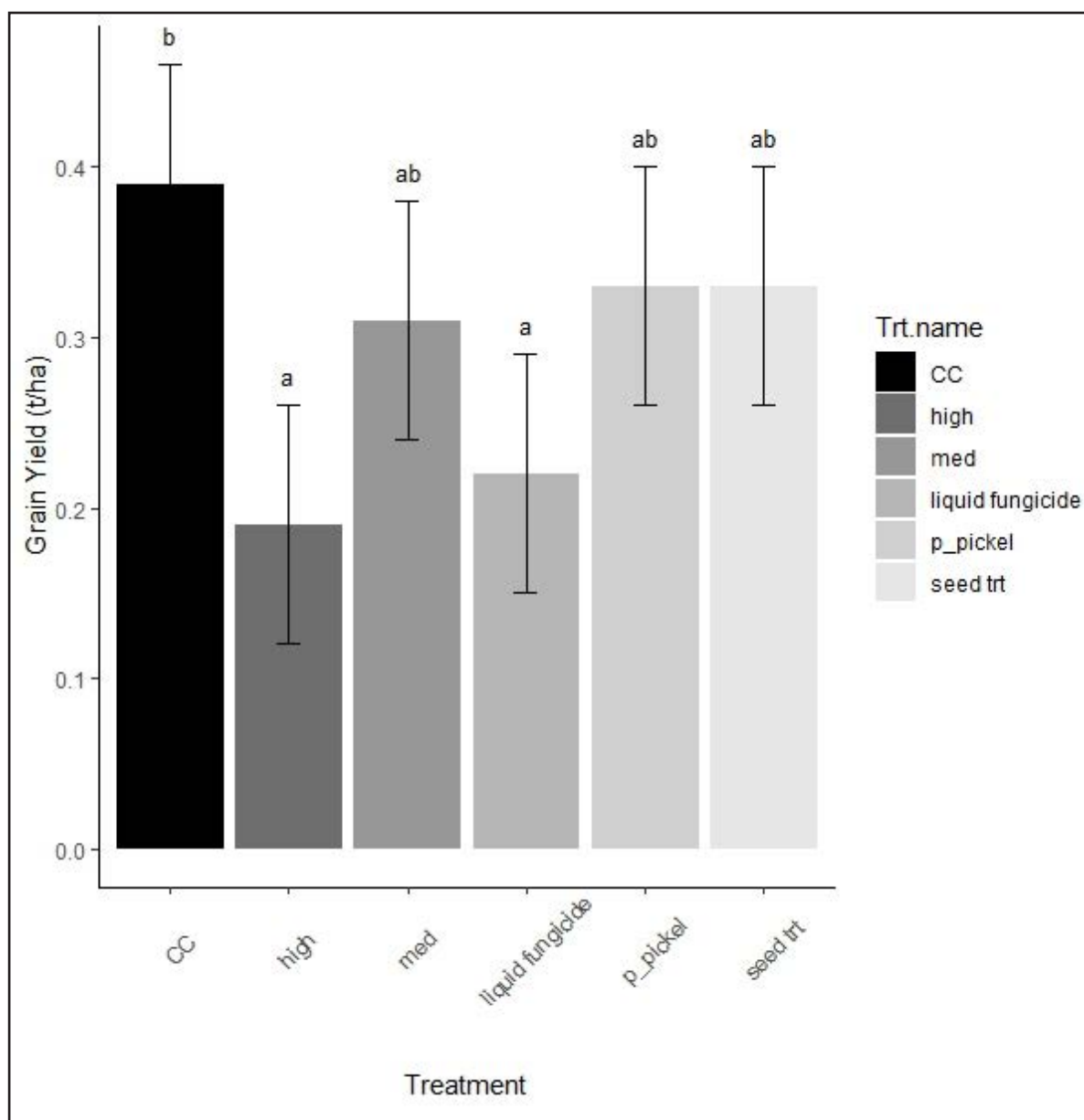


Figure 3. Grain yield (t/ha) by treatment in lentil at the Loxton *Rhizoctonia* trial, 2023. Error bars indicate ± 1 95% confidence interval.

***Rhizoctonia solani* AG8 trial**

Lentil grain yield was reduced in the high inoculum (HR) and liquid fungicide (ML) treatments compared with the uninoculated control. Lentil in the HR and ML treatments had yields of 0.19 t/ha and 0.22 t/ha, respectively, while lentil in the uninoculated control had a yield of 0.39 t/ha. All other treatments yielded similarly to the uninoculated control (Figure 3).

Over the course of the season, the efficacy of the seed treatment (MST) appeared to lessen. While MST plots had greater establishment than the other inoculated plots earlier in the

season (Figure 4), by harvest there was no difference in yield. This could be due to the lower seed weight in the MST plots, which had the lowest hundred seed weight (HSW) of all treatments (4.14g). Although this was not significantly different to the HSW of the other treatments when compared individually (HSW 4.37g for CC), across the six treatments there was a significant difference in HSW overall ($p < 0.05$; data not shown).

***Didymella pinodella* trials**

Inoculation with *Didymella pinodella* did not affect lentil grain yield, with all treatments at both

sites having a similar yield to the uninoculated control. At Loxton the irrigated plots sown with a fungicide seed treatment had increased yield compared to the other irrigated inoculated plots, but not to the uninoculated control (Figure 5). Although the trial area was fumigated prior to sowing, post-harvest Predicta B soil testing revealed the presence of *Pythium* spp., *Rhizoctonia solani* AG2.1 and AG8 and *Macrophomina phaseolina* at low levels in the Loxton trial area. These pathogens would have built up over the season, as a fumigated plot of land adjacent to the trial area had almost no detection of background pathogens post-harvest.

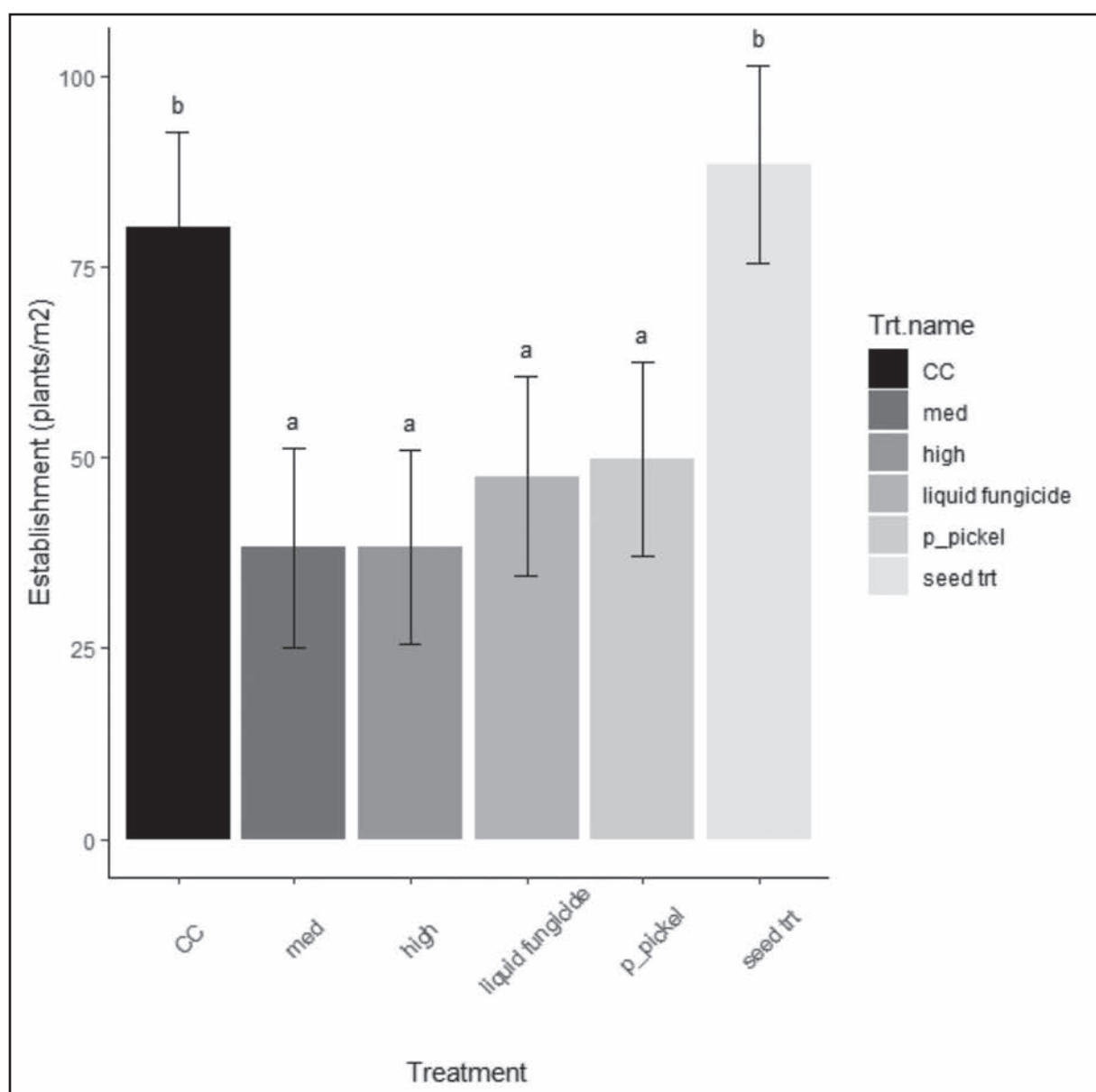


Figure 4. Plant establishment (plants/m²) by treatment in lentil at the Loxton Rhizoctonia trial. Error bars indicate ± 1 95% confidence interval.

At both sites, visual root disease severity was higher in the untreated inoculated treatments compared with the uninoculated control and the inoculated seed-treated treatment (Figure 6). The inoculated untreated treatments had disease affecting between ~ 13-30% of the root biomass, whereas the uninoculated control and the seed-treated treatment had visible disease symptoms on <5% of roots. The yield nil difference between the inoculated treatments and the uninoculated control suggests that mild *Didymella* symptoms alone (<30%) do not affect lentil productivity.

At Roseworthy there was no difference in yield between the irrigated and unirrigated plots. Conversely, at Loxton irrigated plots had greater yield than the unirrigated plots (Figure 5).

What does this mean?

***Fusarium* trial**

Fusarium avenaceum significantly reduced lentil yield, highlighting that in paddocks where *F. avenaceum* inoculum is present, there is a high potential for lentil yield loss. Previous soil surveys suggest that the pathogen is present in around 20% of paddocks, but that it is not evenly distributed across the

whole paddock. Future research should investigate the factors that influence the distribution of *F. avenaceum* across a paddock, including its preferred ecological range (soil type and temperature, moisture requirements) and main method of reproduction in the field. Further, our trial was sown late, in cold and wet conditions. In these conditions *F. avenaceum* caused significantly reduced establishment compared with the uninoculated control. Trials in 2024 will be established to investigate potential seed treatment options when late sowing is unavoidable.

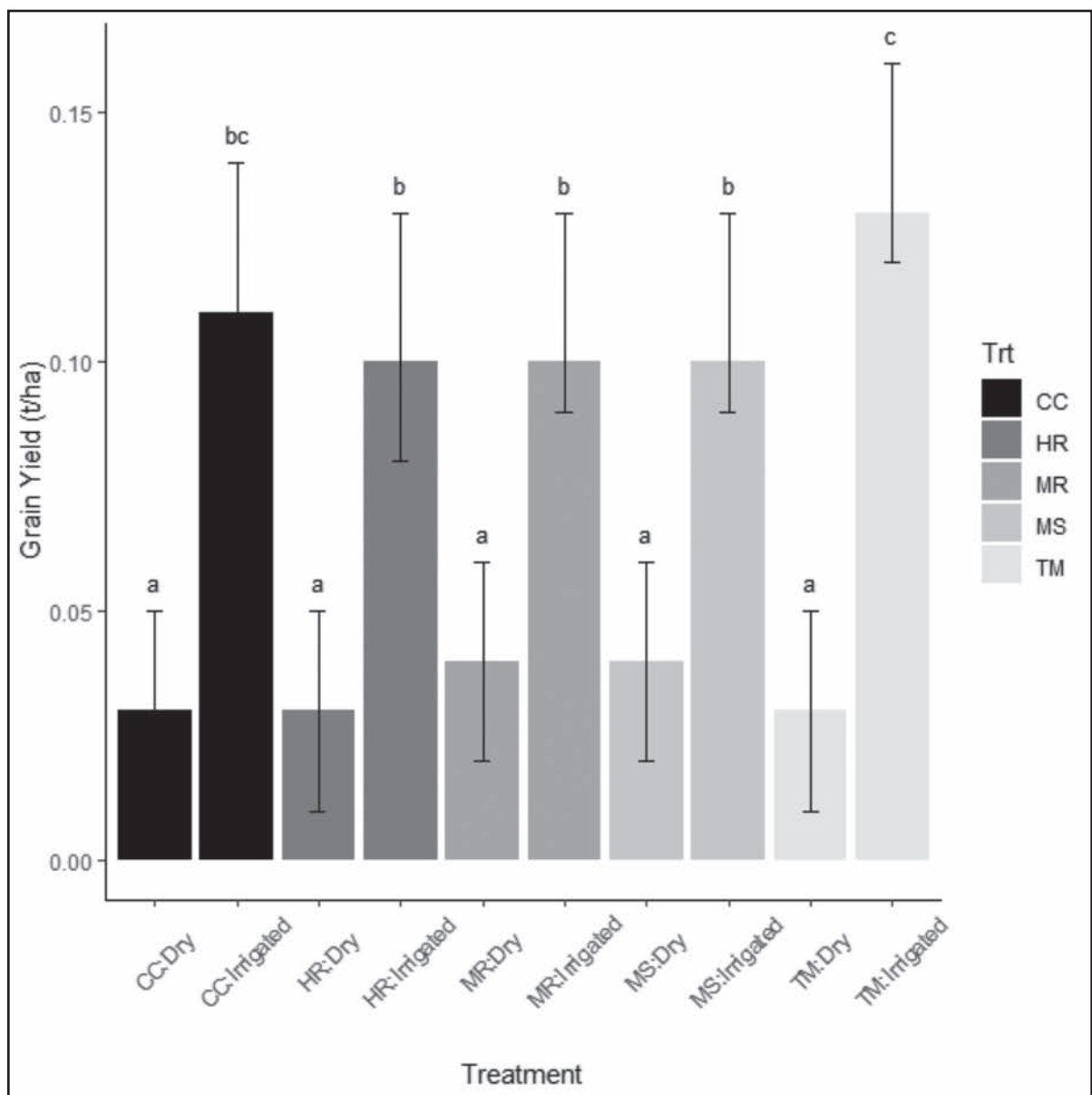


Figure 5. Grain yield (t/ha) by treatment*irrigation in lentil in the *Didymella pinodella* trials at Loxton, 2023. Error bars indicate ± 1 95% confidence interval.

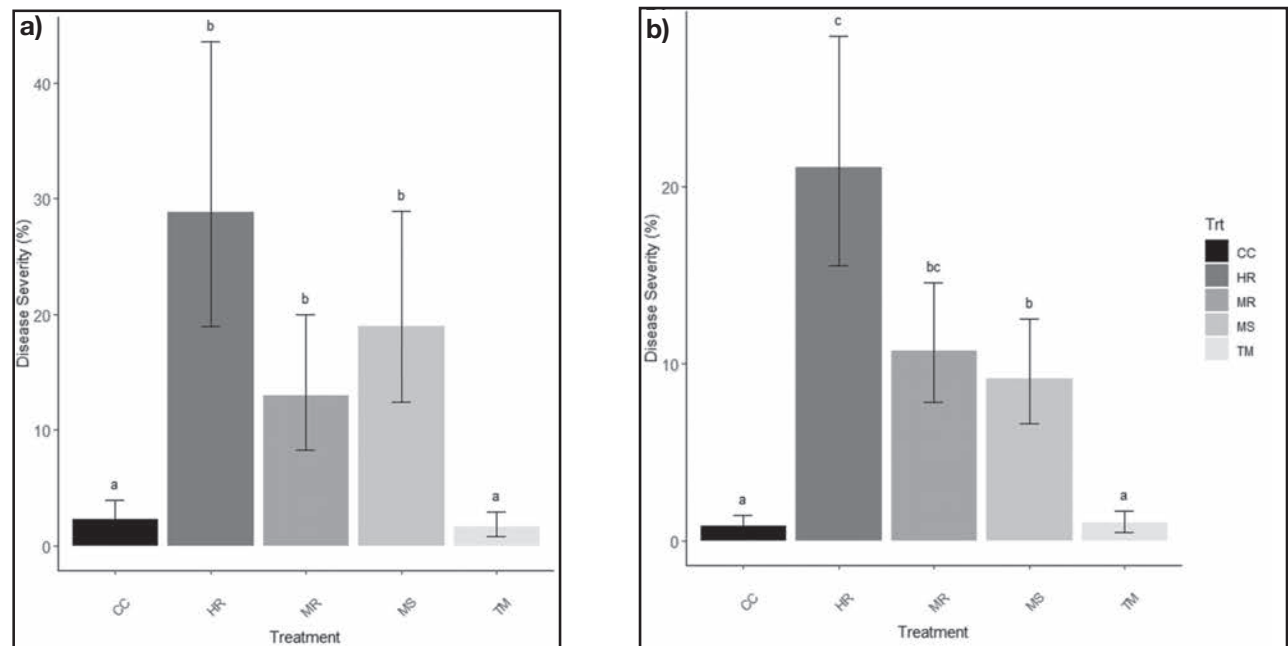


Figure 6. Root disease severity (%) by treatment in lentil in the *Didymella pinodella* trials at a) Roseworthy and b) Loxton, 2023. Error bars indicate ± 1 95% confidence interval.

***Rhizoctonia solani* AG8 trial**

Under a high inoculum load lentil yield was reduced by *Rhizoctonia solani* AG8. In conducive conditions, using lentil as a break crop after an intensive cereal phase (2-3 consecutive years of cereal) will likely result in reductions in lentil yield, as *R. solani* inoculum is known to build up most under cereal phases. However, as legumes are not the preferred host there will still be a break crop effect and a reduction in inoculum in the paddock, as demonstrated in previous work. In paddocks with a low-medium inoculum load, lentil may function effectively as a break crop without a significant reduction in yield. Given the current high market value of lentil (\$700/t) it may be preferable to incorporate another non-cereal (such as canola, which is less susceptible to *Rhizoctonia*) into the rotation in high-risk paddocks before planting lentil to reduce yield loss and maximise lentil profitability. Alternatively, management of *Rhizoctonia* through fungicides may potentially reduce lentil yield loss and be cost effective. However, our understanding of chemical control of *Rhizoctonia* in lentil is limited and attempts at management through fungicides in this year's

trial were unsuccessful. There was no statistically significant difference in yield between the fungicide-treated treatments (liquid fungicide, P-Pickle T, and seed treatment) and the untreated high inoculum treatment. Future research will be directed at investigating management options, including in-furrow application of the liquid fungicide (as opposed to post-harvest surface spraying). In the absence of proven chemical management techniques, it is important to be alert to *Rhizoctonia*-like symptoms in lentil (patches of stunted growth), especially in high-risk paddocks, and to send in samples to PIRSA for analysis if *Rhizoctonia* is suspected.

***Didymella pinodella* trials**

Didymella pinodella is ubiquitous in EP soils but alone does not appear to significantly reduce lentil yield. However, in conjunction with other soil pathogens, may reduce yield, as occurred at Loxton. At Loxton, lentil exposed to the dual disease pressures of *D. pinodella* inoculation and low-level background pathogens yielded significantly less than lentil that was exposed to these same pressures but was treated with P-Pickle T. In paddocks with a suite of common

pathogens present a seed treatment of P-Pickle T may be a technique to reduce yield loss due to disease. However, the ecology of *Didymella pinodella* is not well understood. The seed treatment only provided a benefit at Loxton in the irrigated lentil. In this way, more research is needed to aid in making informed management decisions. Controlled Environment Room experiments in 2024 aim to tease apart the interaction effect of soil moisture and temperature on *D. pinodella* disease expression in lentil. This information can then help to inform management strategies.

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Acknowledgements

The research undertaken as part of this project is made possible by the support of SAGIT and GRDC, as well as the staff at the SARDI Loxton Research Centre.



Eyre Peninsula Cereal Disease Survey 2021-2023

Blake Gontar^{1,2} and Tara Garrard^{1,2}

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Key messages

- **Visual disease symptoms of Septoria tritici blotch (STB) were common in wheat across the three years of a survey conducted on the EP and is the most prevalent and severe disease for EP growers to manage.**
- **Eyespot, powdery mildew and stripe rust were observed occasionally, but generally not at serious levels.**
- **The pathogens causing yellow leaf spot and crown rot were detected using molecular tests, indicating these are widespread, but not having severe impact.**
- **Current management approaches, including crop rotation, STB-registered seed treatments and increasingly diverse foliar fungicide strategies appear to be managing foliar disease well.**
- **No exotic plant diseases were discovered across the three survey years.**

Why do the survey?

- To determine the incidence and severity of endemic leaf diseases of cereal and pulse crops in South Australia.
- Contribute to “proof of area freedom” from high priority

exotic grain crop diseases. This provides confidence that the region is free of those exotic diseases.

How was it done?

Pathologists from SARDI conducted field surveys in commercial wheat and faba bean paddocks across SA each spring from 2021 to 2023, to record the incidence and severity of key foliar diseases. In each year, 60 paddocks were surveyed; this included 40 wheat and 20 faba bean paddocks. Crops were located in the medium and high rainfall zones where foliar diseases are a common issue across seasons. The number of crops sampled per region was based on the area sown of each crop type in each region. Only wheat was surveyed on the Eyre Peninsula (EP), with 12 paddocks surveyed each year. The location of paddocks sampled is indicated in Figure 1.

Agronomists in each area were randomly selected (from a list of agronomists known to SARDI) and asked to nominate paddocks for surveying at the start of the growing season. Paddock information was provided by the agronomist or grower, including property owner contact details, GPS coordinates, sowing date, crop type and variety, fungicide applications (products and timing), and a three-year paddock history.

Wheat paddocks were sampled at flowering to mid grain filling. A paddock sample consisted of 50 plants collected along a single V-shaped transect. Transects started a minimum of 50 m away from the fence line with 5 whole

plants collected at 10 locations approximately 50 m apart. Plants were transferred back to the laboratory for disease rating.

Biosecurity protocols were followed to ensure no transfer of pests, weeds or diseases from one paddock to the next. This included not taking vehicles into paddocks and boot disinfection between each paddock.

The presence/absence of major endemic and priority exotic diseases (Table 1) was recorded for whole samples for each paddock, and severity of disease on the stem, upper three leaves (Flag, F -1 and F -2) and head of each plant were assessed visually.

The whole sample comprising 50 whole plants from crown above was then milled and a subsample was tested using qPCR tests, similar to PREDICTA B. PREDICTA B is a qPCR testing platform developed by SARDI for testing soil samples for the presence of soilborne diseases, however a suite of crown and foliar disease tests have also been developed (Table 2) and provides an opportunity to detect disease presence in the absence of symptoms i.e. latent STB infection. The DNA tests also allow capture of asymptomatic disease infection on the lower leaves, as the DNA tests were applied to the whole plant, whereas visual disease severity scores were only made on yield-critical plant parts as described above. Identifying asymptomatic pathogen infection or diseases commonly affecting lower plant parts through DNA tests is likely important for diseases like YLS.



Figure 1. Location of wheat paddocks sampled for foliar diseases on the Eyre Peninsula in 2021 (white pins), 2022 (gray) and 2023 (black).

Table 1. Diseases assessed in SA wheat crops in 2021.

	Disease
Endemic	Septoria tritici blotch (STB), powdery mildew (PM), stripe rust, stem rust, leaf rust (LR), yellow leaf spot (YLS), barley yellow dwarf virus (BYDV) eyespot, crown rot
Exotic	Wheat blast, wheat leaf blight, wheat stem rust UG99, flag smut

Table 2. Pathogens targeted using qPCR tests in SA wheat samples in 2021.

Pathogen	Disease
<i>Bipolaris sorokiniana</i>	Common root rot, spot blotch, black point
<i>Eutiarospora tritici-australis</i>	White grain disorder/disease
<i>Eutiarospora darliae/pseudodarliae</i>	White grain disorder/disease
<i>Fusarium culmorum</i>	Crown rot
<i>F. graminearum</i>	Fusarium head blight
<i>F. pseudograminearum</i>	Crown rot
<i>Oculimacula yallundae</i>	Eyespot
<i>Pyrenophora teres f. maculata</i>	Spot form net blotch
<i>Pyrenophora tere f. teres</i>	Net form of net blotch
<i>Ramularia collo-cygni</i>	Ramularia leaf spot
<i>Puccinia sp.</i>	Rusts including leaf, stripe and stem
<i>Stagonospora nodorum</i>	Septoria nodorum blotch
<i>Gaeumannomyces tritici</i>	Take-all
<i>Pyrenophora tritici-repentis</i>	Yellow leaf spot
<i>Zymoseptoria tritici</i>	Septoria tritici blotch

What happened?

Visual Disease Expression

The prevalence of key wheat diseases on the Eyre Peninsula differed over the three survey years, with wet conditions in 2022 associated with a greater number of diseases observed, in a greater number of paddocks.

Only STB and PM were observed in 2021, present in 25% and 8% of paddocks respectively. DNA tests confirm that *Zymoseptoria tritici*,

the pathogen causing STB, was present in more paddocks and that other pathogens were also present (see below section) but visual symptoms were not observed at the time of assessment. In 2022, Both STB (100% of paddocks) and PM (33%) increased in prevalence, and Stripe Rust (25%) and Eyespot (33%) were also recorded. In 2023, only STB and PM were again present in 100% and 17% of surveyed paddocks.

In general, disease prevalence on the Eyre Peninsula was similar to that in other regions of SA across the three years (Figures 2a, 2b, 2c), including an increase in STB and Stripe Rust in 2022. Stem rust was not observed in any region in any year, and leaf rust was confined to the SE and MN. Yellow Leaf Spot was rarely observed visually (assessments conducted on top 3 leaves only), despite being widespread and likely visually present earlier in the season on lower plant parts.

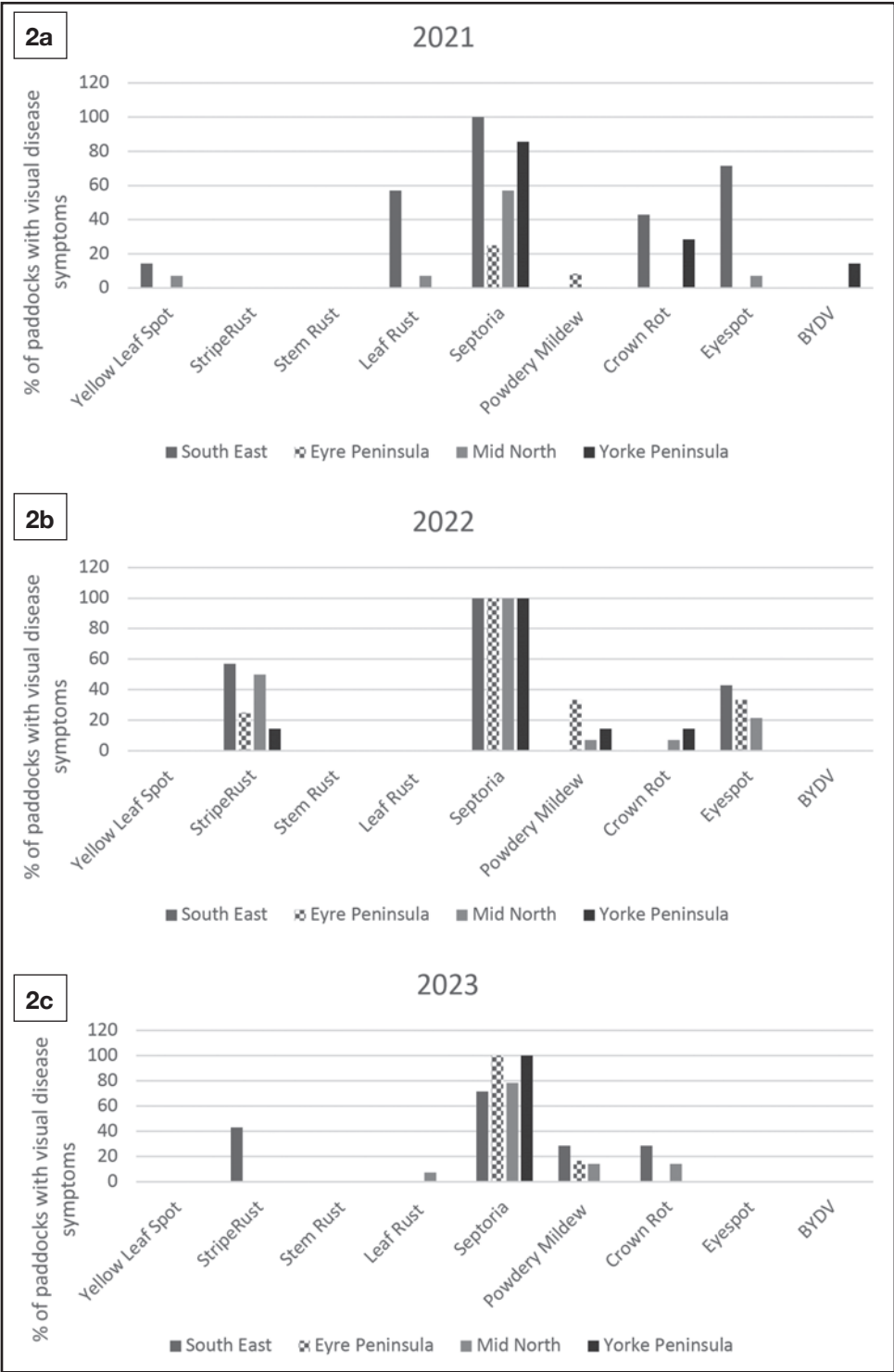


Figure 2a-c. Incidence of key foliar/stem diseases of wheat across four regions of South Australia, 2021-23.

Disease severity was generally very low across the three years of the survey on the EP, including 2022, despite tough conditions for managing foliar disease. STB, the most commonly assessed disease over the survey period, was generally present at high incidence within paddocks, but still low severity, while all other diseases were generally low in both incidence and severity.

Of the three paddocks affected by STB in 2021, one had a low incidence (2%) and two had quite high incidence (56-96%). In 2022, 4 paddocks had very low disease incidence (2-6%) while the remainder had high incidence (96-100%), suggesting that where the inoculum was present, it generally spread throughout the whole canopy in 2022. Of the four paddocks with low incidence, 3 had either a canola or vetch pasture the year before, with the fourth being wheat on wheat, but having seed treated with a fungicide registered for early STB control. In 2023, incidence was generally low (<10%) in all but 4 paddocks where incidence ranged from 38-98%. None of these four paddocks were sown with a seed treatment registered for STB control, whereas those with low incidence had either a seed treatment or recent break crop.

STB disease severity (% Leaf Area Affected, LAA) was generally low across all years, with only a small number of crops likely to have experienced any yield loss. Infection of the head and flag leaf was rare. These plant parts have been shown to be key drivers of yield in wheat. Only in 2022 did

any crop have substantial average disease severity on the flag leaf (Fig 3a-c), and none showed symptoms in the head.

In 2021, only one paddock had substantial infection, but this was restricted to the Flag-2 leaf (25% LAA) and below. At severity of this level, restricted to the lower canopy, yield loss likely did not occur. In 2022, infection in the upper canopy was more severe, with 42% of paddocks having greater than 25% LAA of the Flag-1 leaf, and one of these paddocks having significant (47% LAA) Flag leaf infection as well. It is likely STB reduced yield in this crop, as well as in 4 other paddocks where disease severity ranged from 19-75% LAA in the Flag-1, but also 45-98% in the Flag-2 leaf. Only one paddock in 2023 had substantial average infection (26% LAA) of the Flag-1 leaf and likely did not incur yield loss.

Powdery mildew, present in all years but at low prevalence, was also not likely to have impacted yield, owing to very low incidence and severity within affected paddocks. In 2021, the single paddock with PM present had 40% of plants affected, but mostly within distinct patches, where severity did not exceed 15% of the whole plant infected. Infection severity was worst in the lower canopy only, with very little infection of upper leaves or head. In 2022, PM incidence ranged between 2-10% of plants affected, in the 4 paddocks where PM was present. Average disease severity in affected paddocks did not exceed 5% in any paddock. In 2023, only minor PM was found on a few plants.

Despite the re-emergence of stripe rust as an issue across the state in 2022, EP paddocks were generally not badly affected, and the increase in inoculum did not impact crops in 2023. Of the three paddocks impacted in 2022, incidence ranged from 2-12% of plants affected and severity was less than 5% in all cases. Eyespot, present in four paddocks in 2022, incidence ranged from 2-10%, with only minor lesions assessed in the one paddock with 10% infection rate. It is unlikely that eyespot impacted yield at these low incidence/severity levels.

DNA results

Molecular methods confirmed that STB, caused by the pathogen *Zymoseptoria tritici*, was indeed the most common pathogen present in wheat crops on the EP across all 3 years (Figure 4). However, whereas YLS was rarely assessed visually, DNA showed that the pathogen was present in 93-100% of paddocks across all years. It's likely that YLS infections were mainly present in lower leaves, not assessed visually due to senescence of these leaves at the time of sampling, but it may also be that DNA detected latent upper leaf infection of lesions which were obscured by similar diseases such as STB. In either case, it is clear that YLS inoculum is frequently present, but current management is negating significant impact. Crown rot, consistently present in around half of EP paddocks (40-57%) across the 3 years was also not visually assessed at the sampling timing.

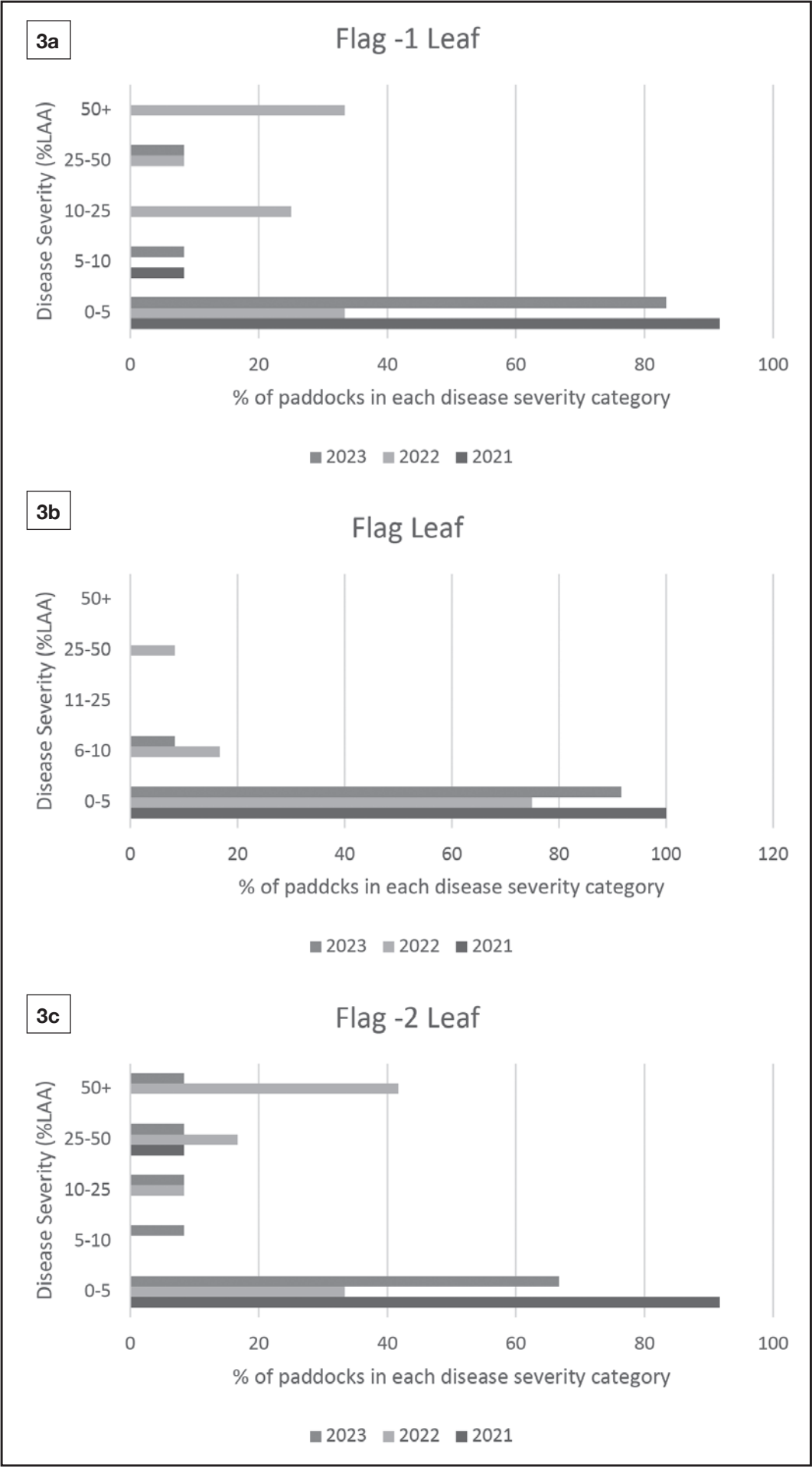


Figure 3a-c. Percentage of crops assessed in each disease severity category for STB of Flag, Flag-1 and Flag-2 leaves, 2021-23.



Management

Fungicide use was consistent across all three years of surveys, with an average of 1.08, 1.30 and 1.25 spray passes completed prior

to the date of assessment (Figure 5). Further spray applications were likely completed after assessment in 2022, owing to continued wet conditions. However, in 2021 and 2023 there were 4 and 2 paddocks

respectively which did not receive any fungicides, whereas in 2022, all paddocks received at least 1 fungicide application prior to assessment.

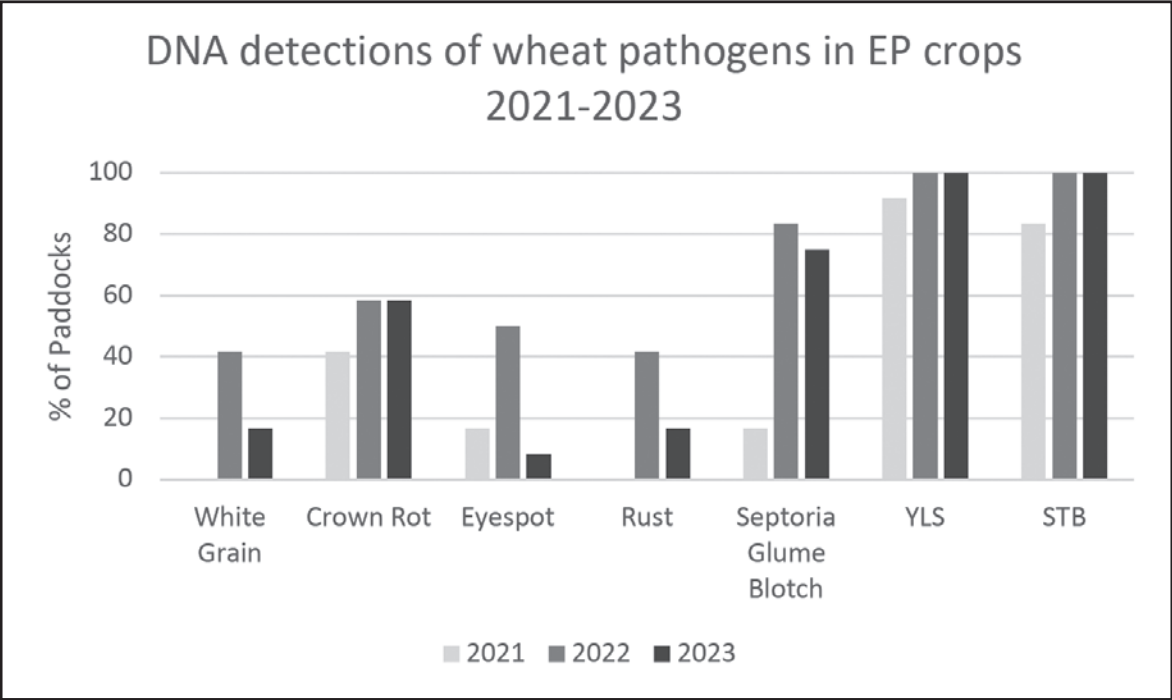


Figure 4. Percentage of paddocks where DNA tests confirmed presence of key wheat foliar and stem pathogens in whole plant samples, 2021-23.

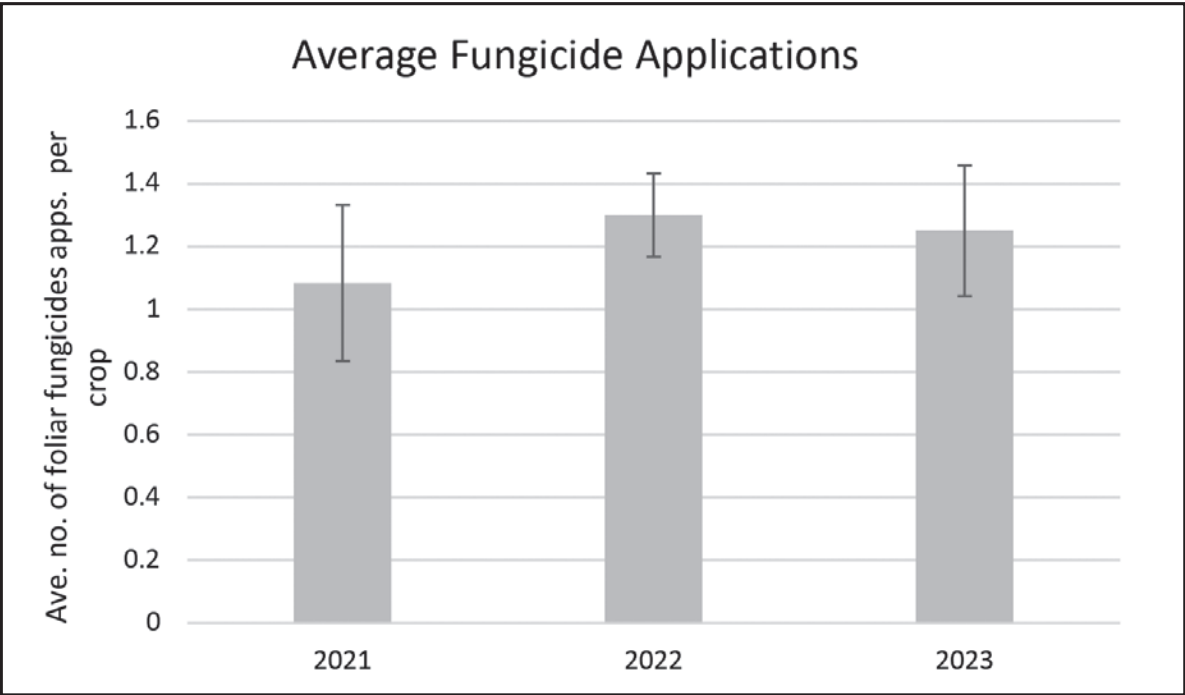


Figure 5. Average number of fungicide applications applied to wheat crops on the Eyre Peninsula, 2021-23. Error bars represent standard error of the mean.

Use of different fungicide groups increased across the three years of the survey, however triazoles were still used on every paddock which received a fungicide application, and were often the only fungicide group used even when multiple applications were made, highlighting the dependency on this fungicide group. Tebuconazole/prothioconazole mixes (i.e. Prosaro®, Mightyze®) and epoxiconazole were the most widely applied fungicides across the course of the survey, with at least half of all paddocks receiving at least one application of either of these products in every year.

A fungicide from an alternative group (i.e. SDHI or strobilurin) was used on only a single paddock in 2021, but increased to 33% and 50% of paddocks in 2022 and 2023. A strobilurin fungicide (i.e. Amistar®Xtra, Maxentis®, Avior®Gold) was used in 33% of paddocks in 2022, and 41% of paddock in 2023. In 2023, SDHI fungicides, namely Elatus®Ace was used in 25% of paddocks.

What does this mean?

Foliar disease severity across SA was generally low in 2021 and 2023 including on the EP, however 2022 saw more disease develop. STB was widespread across SA, including on the EP, whilst YLS and crown rot inoculum was also commonly detected using DNA methods on the EP. Despite challenging conditions in 2022, the majority of wheat crops are not likely to have experienced significant yield loss, despite fungicide inputs remaining fairly consistent with previous years. In general, paddocks coming off a break crop or sown with a STB-registered seed treatment did not experience significant disease later in the season. Disease inoculum is very widespread, but current management practices, including canola and pulse rotations and seed treatments followed with timely foliar applications generally kept disease levels in check and likely limited yield losses.

Changes in fungicide use appeared to take place over the short period of the surveys, with only triazoles used in 2021, then an increase in strobilurin use in 2022 and 2023, and some use of SDHI fungicides in 2023. Given the historical efficacy of triazole fungicides, confirmed in this survey across multiple years, as well as in research trials, it appears this increase in uptake of alternative MOAs reflects increased industry awareness of fungicide resistance issues and proactive management.

No high priority exotic plant pathogens were detected during the survey.

Acknowledgements

This research project was funded by GRDC (Project UOA2104-012RTX). Thank you to Marg Evans, Greg Naglis, Ioane Vakaci, Mark Butt and Chris Stone from SARDI Waite Crop Sciences for assistance with plant sampling and disease rating. The assistance of regional agronomists and growers is also gratefully acknowledged.



Growers visiting the GRDC Rhizoctonia trial at the Streaky Bay Sticky Beak Day, 5 October 2023.

Managing crown rot on upper Eyre Peninsula - a joint learning experience

Margaret Evans¹ and Andrew Ware²
¹Evans Consulting; ²EPAG Research



Location
Buckleboo - Matthew Vandeleur
AIR EP and Buckleboo Farm
Improvement Group

Rainfall
Av. Annual: 297 mm
Av. GSR: 195 mm
2023 Total: 280 mm
2023 GSR: 160 mm

Yield
Potential: potential yield calculator
- 2.53 t/ha (good finish); 1.26 t/ha
(poor finish)
Actual: 1.08 - 2.14 t/ha (W); 1.76 -
2.18 t/ha (B)

Paddock history
2023: Wheat
2022: Barley
2021: Barley
2020: Lentils

Soil type
Sandy loam

Soil test
PREDICTA® B analysis showed
inoculum of the following
stem-base/root diseases was
present at the site: high risk -
crown rot; low risk - take-all,
rhizoctonia, *Pratylenchus neglectus*
and pythium.

Plot size
12 m x 2 m

Trial design
Variety - blocked split-plot x 4 reps.
Inoculum carryover - paired plots
x 8 reps.

Yield limiting factors
Moisture stress during flowering/
grain filling. Mouse damage during
flowering and grain filling.

Location
Mitchellville - Ty Kaden
AIR EP and Franklin Harbour
Agricultural Bureau

Rainfall
Av. Annual: 282 mm
Av. GSR: 190 mm
2023 Total: 309 mm
2023 GSR: 160 mm

Yield
Potential: potential yield calculator
- 2.40 t/ha (good finish); 1.20 t/ha
(poor finish)
Actual: 1.14 - 2.16 t/ha (W); 1.37 -
2.33 t/ha (B)

Key messages

- Positive average yield responses to VICTRATO® were seen in bread wheat (1%-11%) and barley (7%-12%) in 2022 and 2023, despite limited crown rot expression. These minor responses are consistent with lower-end responses seen at medium and high rainfall sites in South Australia (SA).
- Consider the economics using t/ha responses. For example, with a 10% yield improvement for Scepter at Buckleboo the yield response would be 0.39 t/ha in 2022, untreated yield 3.91 t/ha, but would only be 0.15 t/ha in 2023 where untreated yield was much lower at 1.56 t/ha.
- Analysis of 2022 data indicates that varietal responses to VICTRATO® will be similar, regardless of varietal maturity and resistance ratings.
- These findings make VICTRATO® a useful addition to the strategies currently available for crown rot management. It is clear VICTRATO® should not be used as a stand-alone option, but will best be pyramided with other management options where there is a known risk of yield loss from crown rot.
- At Mitchellville in 2023, a combination of season, soil and site conditions disadvantaged the barley yield response (22% yield decrease) to VICTRATO® due to good early growth promoted by VICTRATO® in

the presence of crown rot. This result was unexpected and is unlikely to occur often, nor is it as likely to occur in bread wheat varieties due to their different tillering habits.

- VICTRATO® slightly reduces severity but not visual incidence of crown rot on main stem bases. To better understand the effects of VICTRATO® on inoculum carryover, dedicated trials were established in 2023 and crown rot risk levels will be assessed in 2024.
- Once all data are available for 2023 and statistical analyses are complete (including met-analysis), more extensive interpretation of project findings will be publicised.

Why do the trial?

The key deliverables of the project are to A) Assess effects of varietal resistance and maturity on crown rot expression; and to B) Quantify the efficacy of a fungicide seed treatment (VICTRATO®) for managing crown rot in the low rainfall environments of upper Eyre Peninsula (UEP).

Following discussions with the Buckleboo Farm Improvement Group and Franklin Harbour Agricultural Bureau farmer groups, additional research measures were included in field trials. These included:

- sowing depth effects on crown rot expression and efficacy of VICTRATO®; and
- the effects of VICTRATO® on inoculum carryover.

Paddock history
2023: Wheat
2022: Medic pasture
2021: Barley
2020: Wheat
Soil type
Sandy loam
Soil test
PREDICTA® B analysis showed inoculum of the following stem-base/root diseases was present at the site: medium risk - crown rot; low risk - common root rot, *Pratylenchus neglectus* and pythium.
Plot size
12 m x 2 m
Trial design
Variety - blocked split-plot x 4 reps.
Inoculum carryover – paired plots x 8 reps. Sowing depth - blocked split-plot x 8 reps
Yield limiting factors
Moisture stress during flowering/ grain filling.

VICTRATO® (with Tymirium® chemistry) is a Syngenta seed applied fungicide. VICTRATO® is in the process of being registered for assisting in reducing yield losses in cereals due to crown rot, and should be commercially available in Australia in 2024. VICTRATO® has demonstrated improved cereal

yields in medium and high rainfall areas in the presence of crown rot, but no information is available for low rainfall environments. This project will quantify the effects of VICTRATO® in low rainfall situations.

The decision to target UEP, specifically locations near Cowell and Kimba, was based on the results of a survey undertaken by Agricultural Innovation and Research Eyre Peninsula (AIR EP) in 2021. AIR EP facilitated the project management and extension activities for the delivery of this project in consultation with Buckleboo Farm Improvement Group and Franklin Harbour Agricultural Bureau in planning and implementing trials, to ensure the research remained relevant to UEP farming systems.

How was it done?

Field trials were established in 2022 and 2023 in paddocks with a medium to high risk of yield loss

due to crown rot at Buckleboo and Mitchellville on UEP. An additional field trial (funded by Elders) was established at Booleroo Centre in 2022 with the same treatments and risk profile as the main trial on UEP.

Trials relied on natural crown rot inoculum (Table 1) to ensure treatments were undertaken in a situation that reflected commercial paddock situations. Other soil-borne cereal stem and root pathogens were quantified for each site (Table 1). At all sites, nematodes and Rhizoctonia root rot were either at low risk levels or below detection at all sites, so these pathogens are unlikely to be influencing VICTRATO® effects (Tymirium® chemistry has some activity against these pathogens). Pythium root rot was present at medium risk levels at Booleroo Centre in 2022 and might have influenced VICTRATO® effects at that site (Tymirium® chemistry has some activity against this pathogen).

Table 1. Soil inoculum concentrations and risk levels for yield loss due to soil-borne diseases that might interact with crown rot (PREDICTA B® analysis of soil samples taken pre-sowing).

	2022			2023	
	Booleroo	Buckleboo	Mitchellville	Buckleboo	Mitchellville
Crown rot	4898	6542	23017	2135	172
Cereal cyst nematode	0	0	0	0	0
<i>Pratylenchus thornei</i>	3	0	0	0	0
<i>P. neglectus</i>	5	1	3	10	1
Rhizoctonia root rot	13	4	12	5	2
Take-all	13	16	15	6	1
Common root rot	81	11	4	0	12
Pythium root rot	51	15	3	12	11

Risk categories	
Validated	Provisional
Below detection	
Low risk	
Medium risk	
High risk	

Table 2. Preliminary information on yield changes (%) due to VICTRATO® in bread wheat and barley varieties with different maturities¹ and varietal resistance ratings². Sites on the Upper Eyre Peninsula (2022, 2023) and in the Mid North (2022) had naturally occurring, medium to high risk levels of crown rot inoculum.

Ratings	Maturity	Varieties	2022			2023	
			Booleroo	Buckleboo	Mitchellville	Buckleboo	Mitchellville
MSS	VQ-Q	Emu Rock	6	0	6	4	-1
S	Q	Vixen	-1	8	10	8	2
MSS	Q-M	Anvil	6	5	7	4	7
S	Q-M	Razor	1	1	10	3	8
U	Q-M	Calibre	9	11	6	3	8
S	M	Scepter	4	4	2	10	8
MS	M-L	Trojan	na	na	na	10	3
-	Q-M	Commodus	0	12	7	7	-22
Untreated Scepter yield t/ha			2.28	3.91	2.82	1.56	1.60

¹ U=unknown; S=susceptible; MS= Moderately susceptible; MSS=moderately susceptible to susceptible.

² Q=quick maturing; M=mid maturing; M-L mdi to late maturing; VQ=very quick maturing.

Six (2022) or seven (2023) bread wheat varieties and one barley variety, all suited to UEP, were sown at all sites with and without seed applied VICTRATO® fungicide. Barley was included as it may “escape” yield losses due to crown rot due to grain filling before moisture stress occurs. Bread wheat entries (see Table 2 for details) included varieties with a range of maturities (which can influence responses to crown rot) and different crown rot resistance ratings.

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.

Statistical advice and trial designs will be provided by Sharon Nielsen (SN Stats). Sharon has commenced analysis of 2022 data and will complete more comprehensive statistical analyses once data from 2023 are available. When data sets are complete for both seasons and statistical analyses (including met-analysis) have been undertaken, the findings will be publicised.

What happened?

In 2022, very mild conditions during flowering and grain filling meant white heads, due to crown rot, did not express but (limited) stem browning symptoms, due to crown rot, developed at all sites. The good season on UEP also meant yields were higher than average at both Buckleboo and Mitchellville. At Booleroo Centre in 2022, the trial was late-sown due to timing of opening rains which reduced plant growth and yields.

2023 was more challenging for the UEP. Good seasonal conditions were present until around flowering, when rainfall abruptly ceased and moisture stress resulted in more crown rot expression (white heads and basal stem browning) than 2022.

At Buckleboo, there was significant mouse damage during flowering and early grain filling. Plots were scored for damage and that will be taken into account during data analysis. Neither 2022 nor 2023 trials were adversely affected by weeds, leaf diseases, insect pests or frosts.

Varietal maturity and crown rot resistance and fungicide seed dressing effects.

Average yields of untreated Scepter (Table 2) and other varieties (data not presented) reflect seasonal conditions at the sites. Yields were lower in 2023 than in 2022, and in 2022 were lowest at Booleroo Centre and highest at Buckleboo (Table 2).

As expected for years with low crown rot expression, percentage yield changes were small but consistent with the lower end of responses where crown rot expression was significant at medium and high rainfall sites in South Australia in previous years.

The yield decrease for Commodus in 2023 at Mitchellville (Table 2) was unexpected, as other responses of this entry on UEP have been positive (7%-12%). This anomaly was possibly due to exceptional early growth in treated plots which meant grain filling could not be supported as moisture ran out. Barley has the potential to produce many tillers on a single plant if early season conditions are good but tiller numbers per plant are much lower in bread wheat, which makes it unlikely there would be a similar response in bread wheat varieties.

Replicate	Buckleboo		Mitchellville	
	%	t/ha	%	t/ha
1	-1	-0.02	19	0.40
2	31	0.41	17	0.36
3	31	0.34	0	0.01
4	12	0.15	12	0.25
5	29	0.42	5	0.12
6	29	0.38	1	0.03
7	2	0.04	4	0.10
8	4	0.07	5	0.11
Untreated Calibre yield		1.44		2.25

Table 3. Preliminary information on variability in the magnitude of yield changes (%) due to VICTRATO® seed treatment in paired plots of Calibre wheat on upper Eyre Peninsula in 2023.

	Mitchellville		Buckleboo	
	Untreated	Treated	Untreated	Treated
Calibre	2.00	1.22	1.82	1.33
Emu Rock	2.00	1.50	1.87	1.48
Scepter	2.09	1.62	1.86	1.38
Anvil	2.16	1.48	1.81	1.64
Vixen	2.27	1.64	2.07	1.48
Razor	2.31	1.50	2.08	1.73
Commodus	2.50	2.11	2.54	2.30

Treated = VICTRATO® fungicide seed dressing applied pre-sowing

0	No crown rot incidence
>0-1.5	Low risk of yield loss
>1.5-2.5	Some risk of yield loss
>2.5-3.5	Medium risk of yield loss
>3.5-5	High risk of yield loss

Table 4. Preliminary information on main stem basal browning expression and risk categories for bread wheat and barley varieties with different maturities¹ and varietal resistance ratings² when treated with VICTRATO® on upper Eyre Peninsula in 2022.

There was no obvious visual influence of varietal resistance or maturity on bread wheat yield responses to VICTRATO® treatment in either season (Table 2). Analysis of 2022 data supports this, as there was no significant difference in yield responses amongst the varieties assessed.

There has been a lot of variability amongst replicates in response to VICTRATO® (e.g. Table 3) in all trials, with % yield changes in the negative not being uncommon. Despite this, average yield changes were not usually negative. Crown rot expression was low in 2022 and 2023, so this variability in yield responses may have been brought about by spatial changes in crown rot inoculum and soil characteristics having a lot of influence on yield.

For ease of comparison across seasons and sites, % yield changes (not t/ha changes) due to VICTRATO® are presented (e.g. Table 3). It is extremely important to remember that the same % yield change means different t/ha yield increases for crops with different yield potentials/absolute yields, as demonstrated in Table 3 where untreated Calibre yield was lower at Buckleboo than at Mitchellville. A 31% yield improvement at Buckleboo resulted in a 0.34 or a 0.41 t/ha yield increase, but a much smaller (17% and 19%) % yield improvement at Mitchellville resulted in similar yield increases - 0.36 and 0.40 t/ha, respectively (Table 3).

VICTRATO® effects on carryover of crown rot inoculum

Incidence of main stems with basal browning (data not presented) was similar for Treated and Untreated plots. Basal stem browning severity was slightly lower in VICTRATO® Treated plots than Untreated plots, occasionally resulting in the Treated plots being placed in a lower risk category than the Untreated plot (Table 4). The “low risk of yield loss” category was only seen in Treated plots.

The small differences in crown rot incidence and severity due to treatment with VICTRATO® mean it is unclear whether VICTRATO® will influence inoculum carryover. The trials in Table 3 were established in 2023 to assess crown rot inoculum carryover at the start of 2024. Soil samples were taken in mid-January 2024 for PREDICTA® B analysis and when data are available the findings will be publicised.

What does this mean?

Mild seasonal conditions and good moisture availability during grain filling meant crown rot pressure on yield was limited and this led to small responses to VICTRATO®. Responses were consistent with the lower end of responses seen in replicated trials in medium rainfall areas of SA in 2020 and 2021, where crown rot pressure was much higher.

VICTRATO® is a useful addition to other management options for crown rot. However, it is not a “silver bullet” as it is likely to result in average yield improvements ranging from 0% to around 15% on UEP in seasons with no moisture stress during flowering/grain filling. VICTRATO® is recommended for use in paddocks with a known risk of yield loss due to crown rot. It should be combined with other best-practice management options e.g. rotation to reduce crown rot inoculum, inter-row sowing etc. Better performing paddocks/areas (usually produce higher yields) are more likely to provide an economic yield response to VICTRATO®, so it is important to consider gross margins prior to using VICTRATO®.

The unexpected negative yield response of Commodus barley at Mitchellville in 2023 highlights the effects that season/site combinations might have on barley responses to VICTRATO®. Overall, the likelihood of such a negative average yield response to VICTRATO® is not high for barley - only 1 of 4 trials on UEP had such a response and none of the 3 trials in the mid-North had an average negative yield response.

Apart from an occasional -1% or 0% yield change, all bread wheat variety yield responses to VICTRATO® have been positive in 2020, 2021, 2022 and 2023. Given these results and the different growth habits of barley (large number of tillers per plant) and bread wheat (low numbers of tillers per plant), it seems unlikely that bread wheat will exhibit any magnitude of negative average yield response to VICTRATO®.

Findings from trials established in 2023 to assess effects of VICTRATO® on crown rot inoculum carryover into 2024 will be publicised once data from analysis of soil samples are available. If inoculum carryover is reduced, this will influence when and how VICTRATO® is used to manage crown rot on UEP and in other low rainfall environments.

Acknowledgements

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VICTRATO® fungicide (with Tymirium® chemistry, proposed release in Australia in 2024) - registered trademark of Syngenta Crop Protection Pty Ltd.



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
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VICTRATO - registered trademark of a Syngenta Group Company

Acronyms and abbreviations

AB	Ascochyta blight	LSD	Least Significant Difference
ADF	Acid Deterent Fibre	MAC	Minnipa Agricultural Centre
AH	Australian Hard	MAP	Monoammonium Phosphate
APG	Australian Pastures Genebank	ME	Metabolizable Energy
APW	Australian Premium Wheat	MJ	Megajoules
AWW	Australian White Wheat	MJ ME/kg D	Megajoules of metabolizable energy per kilogram of dry matter
BCG	Birchip Cropping Group	MLA	Meat and Livestock Australia
BGA	Bluegreen Aphid	MR	Moderately Resistant
BGM	Botrytis grey mould	MR#	Moderately Resistant (Warning more susceptible to alternate pathotypes)
BLR	Barley leaf rust	MRMS	Moderately Resistant - Moderately Susceptible
BYDV	Barley yellow dwarf virus	MRMSp	Moderately Resistant - Moderately Susceptible (Provisional rating)
CCM	Carbon Coated Mineral	MRp	Moderately Resistant (Provisional rating)
CL	Chicken litter	MS	Moderately Susceptible
CV	Coefficient of variation	MSp	Moderately Susceptible (Provisional rating)
DAP	Di-ammonium Phosphate	MSS	Moderately Susceptible to susceptible
DLPS	Dryland Legume Pasture Systems	ns	not significant
DM	Dry Matter	NAP	Nucleic Acid Preservation
EP	Eyre Peninsula	NDF	Neutral detergent fibre
EPR	EPR - End point royalties	NDVI	Normalised difference vegetation index
Ex-GST	Goods and Service Tax exclusive	NFNB	Net form net blotch
FHB	Fusarium head blight	NIR	Near-infrared spectroscopy
GDD	Growing degree days	NVT	National Variety Trials
GPE	Grain number per ear	OC	Organic Carbon
GS	Growth Stage	OM	Organic Matter
GSR	Growing Season Rainfall		
HEI	Plant height at maturity		
HI	Harvest index		
HS	Head Scab		
HSW	Hundred seed weight		
IBS	Incorporated by sowing		
IDM	Integrated disease management		
IHM	Indian Hedge Mustard		
IMI	imidazolinone		
LAA	Leaf affected area		
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		
LR	Leaf rust		

PBI	Phosphorus Buffer Index	STB	Septoria tritici blotch
PIRSA	Primary Industries and Regions South Australia	SU	tolerance of Sulfonylurea
PM	Powdery Mildew	SVS	Susceptible to very susceptible
PSPE	Post-sowing pre-emergent	TBC	To be confirmed
R/S	Resistant pathotype differences susceptible	TE	Trace Elements
RF	Rainfall	TGW	Thousand grain weight
RMR	Resistant to Moderately Resistant	TOS	Time Of Sowing
RMRp	Resistant to Moderately Resistant (Provisional rating)	TW	Test weight
RP	Relative performance	UEP	Upper Eyre Peninsula
S	Susceptible	WGD	White grain disorder
SAA	Spotted alfalfa aphid	WUE	Water use efficiency
SFNB	Spot form net blotch	YLS	Yellow leaf spot
		ZnP	Zinc phosphide

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