SARDI

2019

Eyre Peninsula Farming Systems Summary

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GRDC Foreword

The 2019 Eyre Peninsula (EP) Farming Systems Summary is a highly valuable publication that consolidates information on local research, development and extension (RD&E) activities and provides insights to enhance knowledge and inform on-farm decision making.

This summary highlights the impact and value of collaboration between the Grains Research & Development Corporation (GRDC), the South Australian Research and Development Institute, the University of Adelaide, the South Australian Grain Industry Trust, Commonwealth Scientific and Industrial Research Organisation (CSIRO), EP Agricultural Research Foundation, Lower Eyre Agricultural Development Association, EP Natural Resources Management Board, National Landcare Program and others. Important support and valued input from local advisers and agribusinesses are also acknowledged.

The 2019 season was yet again a highly variable one on the EP. The diverse cropping challenges experienced by the region's grain growers during the year were clearly evident during the GRDC Southern Region Panel's annual spring tour which traversed the peninsula in the second week of September. Panel members, GRDC staff, and representatives from the GRDC Northern and Western Region Panels and the Board, met with growers, researchers, advisers, farming systems groups, agribusiness and other grains industry specialists.

The tour enabled the GRDC to gain a first-hand understanding of the constraints limiting EP growers' ability to optimise farm profit whilst dealing with seasonal and economic risk. Valuable conversations were had regarding current and potential future GRDC investment in locally relevant RD&E and the visits enabled constructive debate regarding important issues, including ongoing challenges in attracting and retaining the people required to deliver local research and development outcomes for growers. To ensure grains RD&E is meaningful and regionally relevant grassroots input and involvement is essential. To that end, I strongly encourage you to play a role in helping to shape the research investment agenda in your region – we are here to listen so please come and speak with a member of GRDC staff, panel or the broader GRDC Grower Network.

Of the issues raised and dissected during the tour, calcareous soils were frequently discussed. Whilst the impact of these soils - in terms of water use efficiency, nutrient availability, root diseases, crop establishment, yield and returns to growers - were largely known, the tour exchanges reinforced the severity of the constraint and helped to inform a new RD&E investment commencing this coming season. A significant four-year investment by the GRDC, in collaboration with partners, this project will improve our understanding of the unique characteristics of these highly calcareous soils and investigate novel management practices that address the constraints identified. Research is proposed into soil amelioration practice, soil/water relations, soil health and nutrient cycling, field validation of soil and crop management, and decision support. We look forward to extending the outcomes from this and other related investments to EP growers and the broader industry in the future.

GRDC is investing in a broad range of issues to support the profitability of grain growers on the EP. One recently initiated GRDC investment will enable the characterisation of 10 soils within the existing soil moisture probe network on the EP to increase sampling accuracy, improve soil test results and advance our understanding of the plant available soil moisture at the sites. This will then provide a more rigorous interpretation of soil moisture data for growers.

We have also recently invested in utilising cutting-edge 'synchrotron' scanning technology (a particle accelerator that acts like a super-powered microscope) at Monash University, to provide further insights into interactions between root and water distribution and nutrient availability in soils (UOQ1910-002RMX,USA1910-001RTX, UOQ1910-003RTX). Only 60 synchrotrons exist in the world, and this technology brings to our grains industry a whole new research dimension with many potential applications.

Other blue-sky investments include several innovative new approaches to fertiliser manufacture. GRDC has partnered with CSIRO, the Australian Renewable Energy Agency (ARENA) and Orica to explore an innovative and potentially transformational hydrogen to ammonia discovery project. In a separate planned investment, GRDC is exploring new nitrogen fertilisers aimed at cost-effectively matching nutrient availability to plant demand though novel formulation technology and the inhibition of nitrogen-loss pathways.

An improved understanding of crop phenology remains a focus for GRDC and significant research is underway to inform our understanding of the phenology drivers of different crops/varieties and related management approaches. This includes an investment in a National Phenology Initiative, led by La Trobe University (ULA00011), as well as a new investment starting this season targeted at matching adapted pulse genotypes to soil and climate to maximise yield and profit with manageable risk (PROC-9176094).

Also of relevance to growers on the EP is the GRDC's intent to collaborate or partner, where appropriate and aligned to strategy, to address broad agricultural industry issues such as climate risk, avoidance of spray drift, virtual fencing technology, sustainability and community trust - all of which were raised during the Southern Region Panel tour of EP. Transformational opportunities around three-dimensional characterisation of soils and radical approaches to amelioration aiming to deliver new understandings and solutions to multiple soil constraints are other examples of new GRDC investments.

This EP Farming Systems Summary presents considerable information generated from trials being undertaken in your region, together with relevant data and knowledge from further afield. Many of these trials results are also catalogued on the GRDC's Online Farm Trials website (www.farmtrials.com.au) which provides free access to on-farm or field-based cropping research data. I encourage you to visit the site and utilise the available information.

In the meantime, I congratulate all involved in the preparation and production of this summary, especially those who have worked tirelessly to collate the comprehensive content.

On behalf of the GRDC, I also extend best wishes to everyone involved in the formation of Agricultural Innovation and Research EP, signifying a new era of collaborative grower representation on the EP.

May season 2020 be a productive, profitable and safe one for you all.

Craig Ruchs, GRDC Senior Regional Manager - South

Eyre Peninsula Farming Systems Summary 2019

Editorial Team

Naomi Scholz	SARDI, Minnipa Agricultural Centre, (MAC)
Amanda Cook	SARDI, MAC
Fiona Tomney	SARDI, MAC
Nigel Wilhelm	SARDI, MAC/Waite
Fabio Arsego	SARDI, MAC/Port Lincoln
Holly Whittenbury	EPNRM, Wudinna/MAC

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

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March 2020

Front Cover: Amanda Cook presents her trial at the Minnipa Agricultral Centre annual field day, 2019.

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Minnipa Agricultural Centre update

Naomi Scholz
SARDI, Minnipa Agricultural Centre

Welcome to the twenty first 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 SAGIT, GRDC, the Australian Government (National Landcare Program, Rural R&D for Profit, Soils CRC) and EPARF for their contribution to Eyre Peninsula for research, development and extension and for enabling us to extend our results to all farm businesses on EP and beyond in other low rainfall areas. All articles since 2010 are also available on the EPARF website www.eparf.com.au. Many of the trials are also catalogued in the GRDC Online Farm Trials Database, www.farmtrials.com.au, which is an excellent searchable resource for finding trials and research outcomes from across Australia.

At MAC, 2019 was the final year for a number of larger projects. We have been fortunate to receive some new project funding via the National Landcare Program. Amanda Cook will be working on project that will demonstrate the benefits of increasing the distribution of seed per m^2 to increase crop competition with barley grass, and Fiona Tomney will be demonstrating perennial pastures as an option for improving the productivity of low productive cropping land on upper EP.

EPARF have also been successful in securing funds from the National Landcare Program for ‘resilient and profitable dryland farming on the Eyre Peninsula using data to improve on-farm decision making’. New and emerging technologies will be used to assist farmers make efficient use of soil moisture using the existing soil moisture probe network which is under-utilised. A Regional Innovators group of farmers and advisers will engage researchers and link with the region’s farmers to develop techniques to integrate information generated from the probe network, satellite imagery, climate and yield models. Farmers will be able to make more informed, timely decisions underpinned by innovations in agronomy and livestock management in order to optimise the region’s productive potential whilst protecting soil and water resources in a changing climate.

We are currently putting the finishing touches on a major calcareous soils research project proposal, watch this space!

Current projects in which MAC and/or EPARF is a partner are listed in Table 1 below.

Staff

In 2019 we welcomed Neil King to the research team as an Agricultural Officer, and also Holly Whittenbury, employed by DEW, based at MAC two days per week to deliver the Regional Agricultural Landcare Facilitator role.

We farewelled Linden Masters in mid 2019 as he completed the his Regional Agricultural Landcare Facilitator role, we wish Linden all the best in future endeavours and will miss his enthusiasm and passion for working with farmers and groups across EP.

Students/work experience

We hosted two students in 2019, Will Long completed practical placement as part of his Marcus Oldham College qualification and Dusty Wheare from Navigator College completed Year 10 work experience.

Tom Flinn, University of Adelaide, assisted with the collection of lambing data while working on his PhD.

Visitors

The GRDC Southern Panel visited MAC and a number of project trial sites on their EP tour in August. This was a valuable exercise for the Panel members to gain insight into our local farming systems and experience first-hand some of the issues and opportunities for the region.

Events

A range of events were held or attended by MAC staff, with details listed in the following article Minnipa Agricultural Centre Events in 2019.

Thanks for your continued support at farmer meetings, sticky beak days and field days. Without strong farmer involvement and support, we lose our relevance to you and to the industries that provide a large proportion of the funding to make this work possible.

We look forward to seeing you all at farming system events throughout 2020, and wish you all the best for a more productive and profitable season!

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

Table 1. Research projects being delivered by SARDI Minnipa Agricultural Centre in 2019.

Project name	Funder	Summary
EPARF Sponsored Projects		
Adapting cropping systems through improving crop competitiveness	NLP *4-BA9KBX5*	The project will demonstrate the benefits of improving crop competitiveness with weeds by increasing the distribution of seed per m^2 using innovative farmer equipment. Two demonstration sites will be monitored to measure ground cover, water use, erosion risk and weed numbers. The sites will be a focus for farmer discussion groups to discuss ways of incorporating the practices into their farming systems. EPARF will promote the outcomes of the project to the broader farming community. End: September 2021
Perennial pasture systems for the upper Eyre Peninsula and other dryland farming areas	NLP *4-BA96C6H*	This project will demonstrate perennial pastures as an option for improving the productivity of low productive cropping land on the upper Eyre Peninsula. The aim will be to turn this land into productive livestock pasture, with only minimal inputs of fertiliser, and without the need for herbicide and tillage. Two demonstration sites will be established; one on a grey calcareous soil and the other on a red sandy loam/typical Mallee soil. A mixture of species including grasses and legumes will be sown based on their suitability for local soil and rainfall conditions. End: September 2021
Dryland Legume Pasture Systems (DLPS) demonstration sites	MSF *9175959*	Delivery of upper EP demonstration sites for DLPS project, local awareness raising activities, host a technical pastures workshop on EP, entry and exit surveys, publish 3 x local awareness articles in local media, case studies produced on demo sites. End: March 2022
Demonstrating and validating the implementation of integrated weed management strategies to control barley grass in the low rainfall zone farming systems	GRDC *9176981*	Demonstrating and validating the implementation of integrated weed management strategies to control barley grass in the low rainfall zone farming systems. Research into the ecology and control tactics of barley grass has occurred and now this needs to be transferred into the development and testing of localised IWM strategies. This investment will test localised IWM strategies against barley grass utilising large plot replicated demonstration sites and delivered within key areas of the low rainfall zone. End: December 2021
Regional Agriculture Landcare Facilitator service delivery	EPNRM	Providing a central contact person for farmers, industry, and community groups. Collection of regional intelligence – understanding the needs of the agricultural community and keeping abreast of emerging challenges, issues or threats that may affect the agricultural sector in the region. Supporting agriculture groups to develop new projects and seek grant funding. End: June 2023
Warm and cool season mixed cover cropping for sustainable farming systems	NLP2/GRDC *4-60A5VY4*	The performance of a broad range of cover crops will be evaluated in targeted field trials across the southern region to answer two key questions: What are the new and emerging plant species/varieties, summer and winter active, most suited to different environments across the region? What are the most effective strategies and timings to terminate a cover crop for achieving the optimum benefits for subsequent crops and soil health? End: June 2022
Developing knowledge and tools to better manage herbicide residues in soil	Soils CRC *4.2.001*	Development of tools to enable in-field assessment of risk of herbicide carry-over to the crop. A replicated field trial at MAC N7 and in season soil sampling of five growers paddocks to monitor the breakdown of clopyralid in EP farming systems. End: June 2022
Using soil and plant testing data to better inform nutrient management and optimise fertiliser investments for grain growers	GRDC *9176604*	Work with 5 EP growers x 6 paddocks = 30 paddocks on EP. Soil testing of 2 sites per paddock, with fertiliser test strips in 3/6 paddocks sampled on their property. In-season tissue testing (GS30) in the paddocks where test fertiliser strips are located and biomass cut. Field day/workshop to be held at one of the test strip sites in-season. Discussion of soil testing, nutrition and determining fertiliser rates. At the end of the season need to obtain the yield map data from the growers. End: June 2022

Project name	Funder	Summary
Using soil water information to make better decisions on Eyre Peninsula	SAGIT *EP216*	To use an existing network of soil moisture probes across EP to provide growers across the region with information on how data the soil moisture probes collect can be converted into easily utilized decision support tools that will assist them in targeting yield potential and tailoring inputs to match. End: June 2019
Eyre Peninsula Farming Systems Summary 2016-2018	SAGIT *EP116*	This project will support the cost of printing Eyre Peninsula Farming Systems Summaries 2016, 2017 and 2018, enabling the free distribution to all growers on Eyre Peninsula. End: June 2019
SARDI Projects		
Delivering value from Soil Moisture Probes on EP	GRDC *DAS1911-004BLX*	Full characterisation of ten soils within the EP soil moisture probe network for better soil characterisation and understanding of the plant available soil moisture. End: June 2020
Improving the early management of dry sown cereal crops	SAGIT *S419*	This research project will assess the impact of management on seed germination and establishment on three different soil types in field trials and pot experiments which are kept very low in moisture; a red loam [MAC] and two grey calcareous soils [Cungena and Streaky Bay] for: impact of fertiliser type [P and N] and fertiliser placement, impact of herbicides, impact of seed dressings. These investigations will also be undertaken in pots so that a range of moisture regimes can be accurately implemented and maintained. Further pot experiments will assess how much moisture is needed on the three soil types to germinate wheat and achieve emergence, and how long a germinated seed can survive in dry or barely moist soil and still establish. End: June 2022
Boosting profit and reducing risk of mixed farms in low and medium rainfall areas with newly discovered legume pastures enabled by innovative management methods	Rural R&D for Profit *RnD4Profit-16-03-010*	Dryland Legume Pasture Systems (DLPS) Develop recently discovered pasture legumes together with innovative management techniques that benefit animal and crop production and farm logistics, and promote their adoption on mixed farms over one million hectares in the low and medium rainfall areas of WA, SA, Victoria and southern NSW. At MAC, a large scale grazing trial and several small plot species evaluation trials will be conducted. End: June 2022
Updated nutrient response curves in the northern and southern regions	GRDC *UQ00082*	This project is developing critical levels for commercial soil tests of N, P, K and S for the major break crops. Two trial sites have been set up on the EP. One is at Minnipa to calibrate Colwell P for canola on a red sandy loam. The other is at Mt Hope on a gravelly sand over limestone and is to calibrate the deep mineral N test for canola. End: June 2022
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 to investigate both low cost modified agronomy (e.g. use of wetters) and high cost interventions (e.g. spading incorporation of organic matter). End: June 2021
Swathing for barley grass weed seed collection and applying drone technology	SAGIT *S117*	Swathing cereal crops with problem weed issues early (between 20 and 40% grain moisture) for grass weed seed capture into windrows, followed by harvest and using a chaff cart for weed seed collection may provide farmers with another tool for integrated weed management. Testing the use of UAV (drone) technology to assess barley grass weed density in crop. End: June 2020

Project name	Funder	Summary
Delivering enhanced agronomic strategies for improved crop performance on water repellent soils in WA	GRDC *DAW00244*	The main focus of this project is to explore management techniques that promote water infiltration into non-wetting soils and increase crop production and profitability. A trial has been conducted at Wharminda since 2015 investigating the impact of wetting agents and near-row seeding on crop establishment and performance. End: June 2019
Application of CTF in the low rainfall zone - MAC Research Site	GRDC via ACTFA *ACT00004*	Adoption of Controlled Traffic Farming (CTF) in the LRZ is very low (eg SA/Vic Mallee, 4%) compared to other zones in the Region (eg Vic HR, 26%). This is believed to reflect scepticism about its benefits in many LRZ environments when weighed up against the cost of adopting the practice. The project will evaluate whether or not this scepticism is justified. End: June 2019
National Variety Trials	GRDC	Yield performance of cereal & break crop varieties at various locations across upper EP.
Crop Improvement Trials	Various	Various trials including district variety trials, product trials, species trials.

MAC staff and roles 2019

Nigel Wilhelm	Science Program Leader Farming Systems
Dot Brace	Senior Administration Officer
Leala Hoffmann	Administration Officer
Naomi Scholz	Project Manager
Jake Hull	Farm Manager
Amanda Cook	Senior Research Officer (Farming Systems)
Fabio Arsego	Senior Research Agronomist (Minnipa/Port Lincoln)
Jessica Gunn	Research Officer (Livestock)
Fiona Tomney	Research Officer (Pastures)
Brenton Spriggs	Agricultural Officer (NVT, Contract Research)
Ian Richter	Agricultural Officer (Farming Systems)
Neil King	Agricultural Officer (Farming Systems)
Wade Shepperd	Agricultural Officer (MAC Farm)
John Kelsh	Agricultural Officer (MAC Farm)
Sue Budarick	Casual Field Assistant
Katrina Brands	Casual Field Assistant
Steve Jeffs	Casual Field Assistant
Ashley Scholz	Casual Field Assistant
Bradley Hutchings	Casual Field Assistant

DATES TO REMEMBER

EPARF Member Day, Pre-emergent herbicides: 29 January 2020

MAC Annual Field day: Wednesday 9 September 2020

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Market Check

Minnipa Agricultural Centre events in 2019

Naomi Scholz
SARDI, Minnipa Agricultural Centre

Event	Topics	Attendance
GRDC Soil and Plant Testing workshop Lock 1 Feb	For those participating in the GRDC funded project with Fiona Tomney and Amanda Cook: "Using soil and plant testing data to better inform nutrient management and optimise fertiliser investments for grain growers in the southern region".	17 people (7 growers, 3 advisors, 3 researchers, 2 presenters, 2 others)
LEADA Expo Ungarra 15 March	Jessica Gunn and Naomi Scholz provided an introduction of Dryland Legume Pasture Systems (DLPS) project and demonstration opportunities. DLPS entry survey was conducted.	63 people attended (33 growers, 20 advisors, 5 researchers, 5 other)
Harvest report farmer meetings Minnipa, Wirrulla, Kalanbi, Elliston, Kimba, Cowell, Rudall and Warramboo 18-22 March	Presenters (in person): Amanda Cook (barley grass management, Piednippie biomass/break crop trial, BigFIG oats trial, soil and plant nutrition, herbicide residues), Jessica Gunn (sheep nutrition and management, containment areas, DLPS project overview), Fiona Tomney (DLPS and inoculation trial results), Fabio Arsego (co-limitation of N and water, and proximal sensing), Naomi Scholz (evaluation, coming events). Via pre-recorded video presentation: Andrew Ware (soil moisture probes), Kenton Porker (winter wheats) and Neale Sutton (NVT online features).	198 people attended (153 growers, 25 advisors, 4 researchers, 16 others)
GRDC Low Rainfall Barley Grass Minnipa 27 March	Gurjeet Gill and Amanda Cook held a project planning meeting for the upper EP paddock demonstration site.	13 participants (10 growers, 1 advisor and 2 researchers)
GRDC/EPARF Effective Spray workshop Minnipa and Cleve 27-28 March	Naomi Scholz hosted on EPARF's behalf the workshops presented by Jorg Kitt and Leighton Wilksch.	28 growers attended in total
EPARF Research & Review Committee annual trial planning meeting MAC 10 April	Current trials and potential new research opportunities were discussed and planned.	19 participants (9 growers, 2 advisors, 8 SARDI)
EPNRM Exploring Soil Health workshop Ungarra 21 June	Jessica Gunn and Naomi Scholz attended a soil health – mixed species and legumes seminar and field walk, funded by LEADA and NRM. Jessica presented information about the 5-year Rural R&D for Profit Dryland Legume Pasture Systems (DLPS) project. Visited Butler Tanks DLPS demonstration site.	19 participants (10 growers, 5 advisors, 1 researcher, 3 others)
Recovering from a Dry Start workshop Mallala 26 June	Jessica Gunn presented information about the Grain and Graze project at a 'Recovering from a dry start' workshop run by the Mid North Young Guns. Jessica was sponsored by GRDC to speak at the event.	

Event	Topics	Attendance
2019 Annual SAGIT Update Adelaide 11 July	Amanda Cook was a key note speaker presenting results from the SAGIT Swathing for barley grass weed seed collection and applying drone technology (S117 project).	
GRDC/EPARF Rhizoctonia workshops Cowell and Kalanbi 29-30 July	In-paddock workshop for refresher on Rhizoctonia development and symptoms and how this relates to modern farming systems, digging plants, examining the roots and identifying disease symptoms. Group discussion with researchers and agronomists on symptoms, identification, seasonal factors affecting yield loss, sowing strategies, seeding rate, nutrition and crop selection. Strategies to identify which paddocks are at risk and resources to support future decision making. Alan McKay, Blake Gontar, Gupta Vadakattu, Craig James and Andy Bates.	72 attendees (60 farmers, 7 advisors, 3 researchers, 2 others)
GRDC Farmer Update MAC 31 July	Emerging management tips for early sown winter wheats - Kenton Porker. A profit first approach to precision agriculture - Patrick Redden. Underperforming sandy soils - Lynne McDonald. Sustaining our herbicides into the future - Chris Preston. Grain & pulse storage - Ben White.	
BigFIG Crop Walk Buckleboo 9 August	Eucalyptus oil harvesting - Bernie Henderson Livestock management - Luke Ramsay and Jess Gunn Deep Ripping Trials - Tristan Baldock NVT Trials - Dan Vater Hay Variety Trials - Pat Guerin (SARDI contract trial, A Cook) GPSA - Dion Woodford GRDC & Grain Growers - Tristan Baldock	
DLPS Pasture Tour WA 18-23 August	Organised by Angelo Loi and assisted by the WA team, a small group of EP growers and researchers participated in a tour of WA farms and facilities: Northam DPIRD facilities, Boyle's farm - Yorke, Roberts farm - Dandaragan, Brodie/Kelly/Forward farms - Mingenew area, Stokes farm - Chapman Valley, Teakle, Reynolds, Cripps, Harris, Johnson Farms - Northampton and Binnu, Paish farm - Badgingarra, CSIRO - Perth. Pasture species, seed production machinery, silage, herbicides, sheep.	SA contingent 7 (3 growers, 3 researchers, 1 other)
Australian Agronomy Conference Wagga Wagga 25-29 August	Fabio Arsego presented his paper: Proximal sensing technologies on soils and plants in the Eyre Peninsula. Fiona Tomney presented her paper: 'Identifying the causes of unreliable Nitrogen fixation by strand medic (*Medicago littoralis*) based pastures.' By Fiona Tomney, Brian Dzoma, Ross Ballard & Nigel Wilhelm.	
GRDC Southern Panel Spring Tour MAC, Cungena 9-11 September	The GRDC Southern Panel visited MAC and a number of project trial sites on their EP tour in August. This was a valuable exercise for the Panel members to gain insight into our local farming systems and experience first-hand some of the issues and opportunities for the region. Current research projects presented by Amanda Cook and Fabio Arsego.	~30 participants
Mixed Farming Masterclass Lock 12 September	Decision making, assessing and managing risk in mixed farming systems - Cam Nicholson, Nicon Rural Services Fodder options in a mixed farm; matching supply and demand with seasonal conditions and livestock requirements - Hamish Dickson, AgriPartner Consulting Livestock technology, innovations and data management options - Michael Wilkes, Thomas Elder Consulting Facilitated session on managing risk in variable seasons (decision making about the end product; grain, graze or hay) Panel discussion on seasonal conditions and Q&A Managing soil cover in variable seasons - Brett Masters, PIRSA Rural Solutions SA	34 participants (25 of the total were attendees, with 9 presenters) [farmers 24, advisors 8, researchers 1, other 1]

Event	Topics	Attendance
	Electric fencing (RAPPA system) and pasture meter monitor demonstrations - James Ellis, Datamar and Sarah Voumard, EPNRM NREP Regenerative Agriculture Project mixed species trial - Mary Crawford, EPNRM Seasonal conditions and feed on offer in paddock discussion Dryland Legume Pasture Systems and new varieties - Jessica Gunn, SARDI Minnipa Agricultural Centre and Kerran Glover, Local Farmer	
Minnipa Agricultural Centre annual field day MAC 19 September	MAC Farm update - Jake Hull (SARDI). Barley grass management strategies (GRDC Low rainfall barley grass project), Herbicide residues (Soils CRC project), and Dry sowing (SAGIT Dry sowing project) - Amanda Cook (SARDI). Virtual fencing - Rick Llewellyn (CSIRO), Nutrition strips (GRDC Soil & plant testing project) - Sean Mason (Agronomy Solutions), Razor, Scepter, Vixen - Jake Hull (SARDI), NVT Barley and wheat, Management of Early Sown Wheat – James Hunt (LaTrobe Uni), Farm practices survey - Hanabeth Luke (SCU), GRDC Nutrition management in alkaline soils - Fabio Arsego (SARDI), EPARF AGM - Bryan Smith (EPARF), GRDC Low rainfall pulse options - Sarah Day (SARDI), Vetch - Stuart Nagel (SARDI), Mixed species cover crop trial - Mark Farrell (CSIRO), Overview of Dryland Legume Pasture Species (DLPS) project - Ross Ballard (SARDI), DLPS Pasture species trial - Fiona Tomney (SARDI), DLPS Large scale grazing trial - Jessica Crettenden (SARDI), Russian wheat aphid trial - Tom Heddle (SARDI).	113 people attended (69 growers, 14 guests/speakers, 13 staff, 17 sponsors)
Sticky Beak Days Upper Eyre Peninsula 3 September to 8 October	A series of 15 crop walks organized by local Agriculture Bureau Groups across the Eyre Peninsula. Key contributions from the Minnipa Agriculture Centre staff included the Minnipa Sticky Beak Day on 11 September where Amanda Cook presented rye grass trials and dry sowing research. Amanda Cook also presented her research on the Soils CRC Herbicide Residues, SAGIT Dry Sowing trials, GRDC low rainfall barley grass, and Fabio Arsego's trials on GRDC Characterising water limited yield potential of highly calcareous soils and the soil moisture probe network at Streaky Bay, Wirrulla/Cungena and Mount Cooper Sticky Beak Days. Fiona Tomney presented the Dryland Legume Pasture trials at Wirrulla on 26 September with 13 attendees. The GRDC trial site at Murlong on 3 October attracted a crowd of 25 people. Differences between crops grown within row and inter-row were observed under different treatments utilising surfactants and wetters on non-wetting sandy soils.	A total of approximately 300 people: mostly farmers with 60 agribusiness representatives, 3 x RALF's attended 12 Sticky Beak Days, 1 x EPNRM staff, 3 x SARDI staff and 1 x RAP staff.
EPARF Research & Review Committee annual trial planning meeting MAC 10 December	Project progress update, planning for newly funded projects and development of new projects.	16 attended (6 growers, 5 advisors, 5 SARDI staff)

Eyre Peninsula Agricultural Research Foundation Annual Report 2019

EPARF
Eyre Peninsula
Agricultural Research Foundation Inc.

Bryan Smith
Chairperson, EPARF

The Eyre Peninsula Agricultural Research Foundation (EPARF) was incorporated in 2004 and has a Board comprising of farmers, special skills consultants, SARDI and University of Adelaide representatives.

The Board is a consultative committee for farmers. Its purpose is to represent the interests of research, development and extension on the Eyre Peninsula.

Vision

To be an independent advisory organisation providing strategic support for the enhancement of agriculture.

Values

To proactively support all sectors of agriculture research on Eyre Peninsula including the building of partnerships in promoting research, development and extension.

Purpose

The EPARF Board is committed to ensuring the ongoing development of agricultural systems in low rainfall zones of Australia and recognises its obligations to the Eyre Peninsula.

The Board provides a link between farmers, researchers, scientists and industry.

The role of the Board member is to consult with and represent farmers in their local area, to bring farmer and community views to the table.

EPARF is a not for profit foundation drawing its income from membership, industry funding and sponsorship.

EPARF Board Members

Farmer elected members:

Bryan Smith, Greg Scholz, Matthew Cook, Jerel Fromm, Angus Gunn.

Special Skills and Experience representatives:

Andy Bates, Mark Stanley.

SARDI representative: Dr Kathy Ophelkeller, Research Director, Crop Sciences.

University of Adelaide representative: Prof Jason Able, Head Department Agricultural Science.

Membership

261 members.

Activities in 2019

Again 2019 has been a difficult year for some areas. Areas on eastern and upper EP and areas west of Ceduna have all had decile 1 rainfall while western EP south of Streaky Bay enjoyed average to above average seasonal conditions. To add to the issue of below average rainfall, frost caused significant damage in many areas and to finish the season off, significant wind damage was reported from some of the later areas.

Unfortunately, the Board was unable to organise an EPARF Members Day in 2019, due to the difficulty in finding a date that was available and a suitable speaker on the topic we chose.

At the AGM we farewelled Board Members Simon Guerin and Wes Matthews as they both chose not to re-nominate for their positions on the Board. On behalf of all members I would to thank Simon for his Leadership as past Chair and his contribution over 12 years as a board member. We now welcome Angus Gunn as a new Board Member.

Another veteran of the organisation, Linden Masters, has also decided to move on after 10 years as the Regional Landcare Facilitator to pursue other interests.

Holly Whittenbury has been appointed as the Regional Agricultural Landcare Facilitator (RALF) with the position now combined with the NRM position to have an Authorised Officer to serve the upper Eyre Peninsula.

We were fortunate to have the GRDC Southern Panel visit the EP for two days in August during which time we were able to highlight what we saw as major research deficiencies on EP. This has resulted in a project being funded by GRDC and Soils CRC to explore the constraints of highly calcareous grey sands.

Over the last few years there has been a number of changes within SARDI and GRDC. These changes have seen research staff numbers decline on EP and with the additional requirements of research funding organisations it has been necessary to review the role of EPARF.

The complexity of applications, project oversight requirements and reporting standards have all become far more stringent. To meet the standards required and win competitive tenders for research, specialised skills are needed. This all comes at a cost.

To remain viable and maintain research capacity on EP, discussions were held with LEADA to form an EP based research organisation which is large enough to contract experienced people to manage and conduct research. These discussions have progressed to a point that we should be announcing the formation of a new organisation in the near future. Both organisations are acutely aware of the need to have local farmer input into research so a ‘low’ rainfall committee will be formed at Minnipa and a ‘medium’ rainfall committee will be formed on Lower EP. Both committees will be represented at Board level and all members will be transferred to the new organisation. The majority of members will not notice any changes as this is predominantly a governance and administrative change, to maximise research opportunities and improve research capacity on EP.

We hope you continue your membership with the new organisation. The value of your membership can not be overstated, as the number of members is an extremely important tool to leverage funding when making applications. We look forward to continuing delivering research outcomes to farmers on Eyre Peninsula.

EPARF Projects

- SAGIT: Using Soil Water Information to make better decisions (Soil Probe Network), completed June 2019
- Soils CRC 4.2.001: Developing knowledge and tools to better manage herbicide residues in soil
- Soils CRC 1.2.002: Understanding adoptability of techniques and practices for improved soil management
- Soils CRC 1.4.002: Addressing barriers to adoption. Building farmer innovation capability
- NLP 2: A new paradigm for resilient and profitable dryland farming on the Eyre Peninsula using data to improve on-farm decision making
- NLP 2: Regional Agriculture Landcare Facilitator service delivery
- NLP 2: Adapting cropping systems to changing climatic conditions to reduce inputs and maximise water use through improving crop competitiveness 4-BA9KBX5
- NLP 2: Perennial Pasture Systems for the Upper Eyre Peninsula and Other Dryland Farming Areas 4-BA96C6H
- NLP 2: Warm and cool season mixed cover cropping for sustainable farming systems in south eastern Australia’ project 4-60A5VY4
- Rural R&D for Profit: Boosting profit and reducing risk on mixed farms in low and medium rainfall areas with newly discovered legume pastures enabled by innovative management methods - southern region: EP demo sites and extension (Delivery of DLPS Demo Sites on Upper EP).
- GRDC: Southern Pulse Extension BWD9175825
- GRDC: Increasing production on sandy soils in low and medium rainfall areas of the Southern Region CSP00203
- GRDC: Demonstrating and validating the implementation of integrated weed management strategies to control barley grass in the low rainfall zone farming systems 9176981
- GRDC: Using soil and plant testing data to better inform nutrient management and optimise fertiliser investments for grain growers in the southern region 9176604
- GRDC: Mixed Farming Masterclass 9176148

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Thank you to all sponsors for their generous support.

Sponsorship has been a vital link in EPARF being able to provide the services to our members and we thank our long term sponsors for their continued support over the past 15 years.

A special mention and thanks goes to Letcher Moroney who willingly audit the finances and supply the Financial Report for the EPARF AGM. This support is greatly appreciated.

And finally a big THANK YOU to Dot Brace for her tireless work as Executive Officer of EPARF since 2007. Dot has been a huge asset to the organisation, making sure everything from events, meetings, membership, sponsorship, finances and the website ran smoothly while keeping the Board members in line! Well done Dot.

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Ty	Kaden	COWELL SA
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Saxon	Kay	TOOLIGIE SA via P/L
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REMINDERS

ANNUAL EPARF MEMBERSHIP

Membership is $132 for the first member in the farm business or entity and $66 for additional members (GST incl)

Contact Naomi Scholz 8680 6233 or eparf31@gmail.com

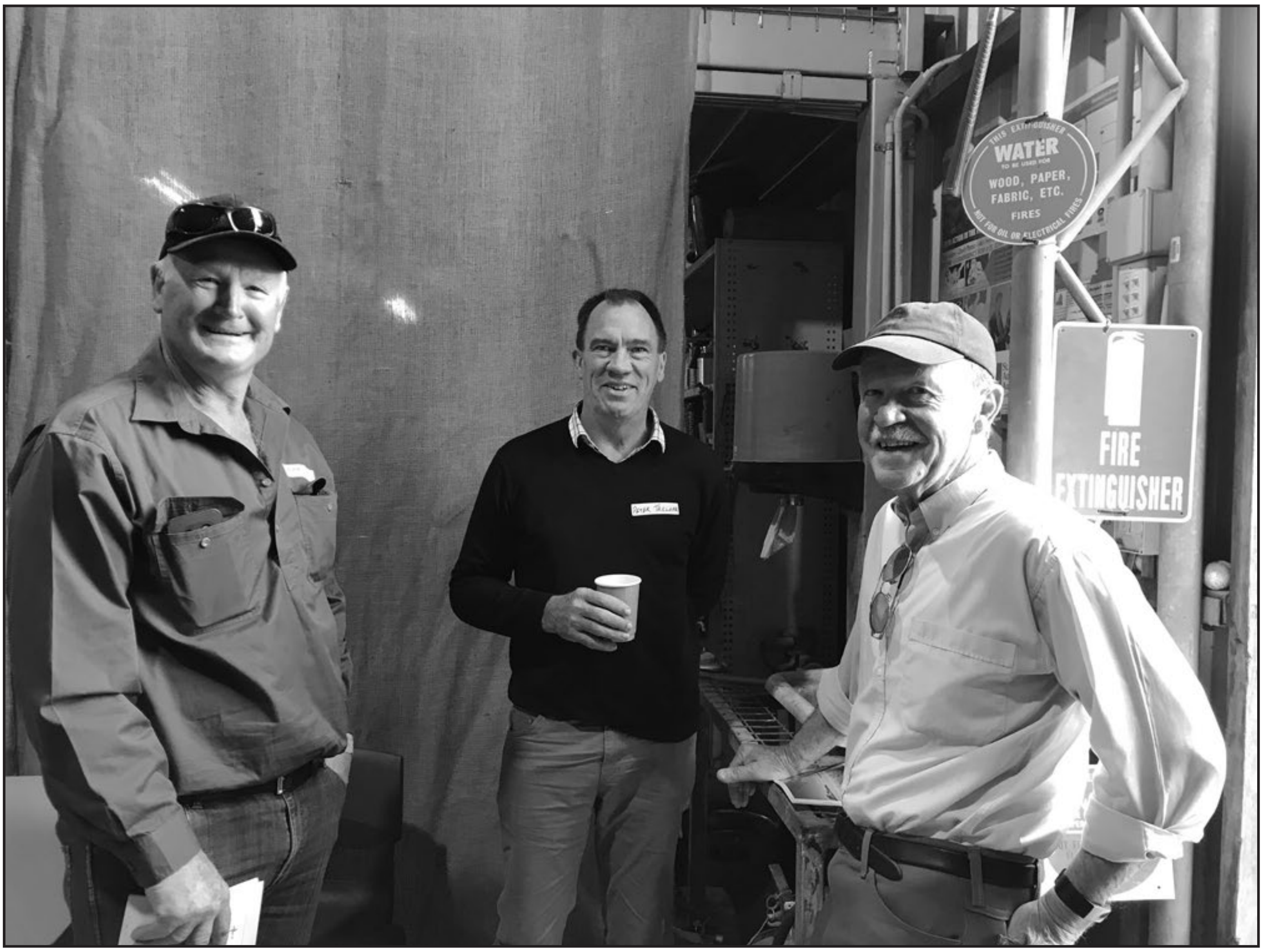


Photo: Bryan Smith, Peter Treloar MP and Bob Holloway catch up at the MAC Field Day, 2019.

Eyre Peninsula seasonal summary 2019

Brett Masters
PIRSA Rural Solutions SA, Pt Lincoln

Key messages

The 2019 cropping season on Eyre Peninsula brought mixed fortunes across the region, with some districts yielding well and yields in other districts severely impacted by continued dry conditions or weather events including frost and wind damage. Hot and extremely dry conditions over summer meant soil profiles contained little stored soil moisture at seeding. Producers in all Western and Eastern Eyre districts needed to supplementary feed livestock as paddocks contained very low levels of paddock feed. Although rain in May allowed most farmers to begin seeding it was an extended affair with those with non-wetting sandy soils waiting to ensure adequate soil moisture for germination before sowing. There was a general decrease in the area of canola and pulse crops replaced mainly with barley. Crop and pasture germination was good and areas that were bare in 2018 generally covered well with sufficient surface cover for erosion protection. The exception to this was in districts west of Ceduna and around Arno Bay and Franklin Harbour where continued drought conditions resulted in poor growth on crop and pasture paddocks.

Continued warm, dry conditions across the region during winter saw rapid development of crops and pastures, and many crops were out in head by mid-August. Soils contained little stored moisture and crops in Central and Eastern Eyre districts were beginning to show signs of moisture stress at this time. Dry conditions and cool nights resulted in severe frost damage to cereal and pea crops in Central and Eastern Eyre districts during August and September. High demand for hay because of drought conditions in eastern Australia, coupled with high prices made it profitable to cut frosted crops (and those suspected of being frosted) for hay. Unfortunately due to dry seasonal conditions some frosted crops near Kimba and Darke Peak had insufficient biomass to cut hay and many of these crops were grazed with livestock. However, growers were hesitant to put livestock into sandy paddocks with low biomass due to the potential erosion risk.

Rainfall in late September helped to fill grain on sandy soils, but was too late to benefit crops on heavier textured soils in Central and Eastern Eyre districts. Strong winds on 20 November caused high grain losses in unharvested crops. Many growers estimated yield losses at 0.5 to 1.0 t/ha, and on crops with high yield potential on Lower Eyre Peninsula losses were estimated at up to 2.5 t/ha.

Most farmers completed harvest quicker than normal in Western and Eastern Eyre districts due to generally below average yields. Many growers reported that the final yields were around 10-15% less than what they had estimated before harvest. The exception to this was in a coastal strip from Haslam to Mt Hope which had good rainfall during the season and realised exceptional hay and grain yields. Yields were very poor in droughted districts north and west of Ceduna and around Kimba, Franklin Harbour and Arno Bay. Crops south of Lock which weren't frosted yielded around the long term average. Grain quality was good with high protein and good test weights.

DISTRICT REPORTS

Western Eyre Peninsula

Summer

Summer rainfall was average in coastal districts and below average inland. January temperatures were well above the monthly average with all observation stations recording their hottest January day on record (24 Jan).

Biomass in stubble paddocks was less than normal and whilst livestock were maintained in good condition, to protect vulnerable soils from wind erosion most growers moved them into containment feeding areas until pastures established.

Autumn/Winter

Hot dry conditions with below average rainfall continued into autumn resulting in little pre-seeding nitrogen mineralisation. Very strong winds on 5 and 15 April raised dust across the region from paddocks with exposed soil. Low stored soil moisture and concerns of potential herbicide carryover, as well as good prices for feed grain led some farmers to increase their area sown with barley and reduce the area of canola and pulses.

Storm events (21 and 30 April) brought rain and resulted in most districts recording close to average April rainfall. Good rains fell in most districts in May, with coastal districts from Ceduna to Elliston receiving above average and Nundroo receiving well above the monthly average. Seeding was completed by the end of May in many districts. Good surface soil moisture and warm soils promoted rapid germination and growth and most farmers were able to reduce or stop supplementary feeding stock as pastures grew.

Cold fronts in June brought scattered showers and most districts recorded close to the monthly average rainfall. Crop and pasture growth was slowed by cool temperatures with a number of light frosts in inland districts. At the end of June early dry-sown cereal crops were at mid-tillering, but those sown toward the end of May were only at 4-5 leaf stage.

Pre-emergent and knock-down herbicides gave good grass weed control. The growth of some pulse crops and medics was impacted by herbicide residues, carried over due to dry conditions. Many farmers chose to spray-top pastures instead of selectively removing grasses to maintain maximum cover. Rhizoctonia was more prevalent than normal during winter, perhaps due to low soil nitrogen levels from poor medic stands in 2018. Manganese deficiency in barley crops was also common.

Late winter rainfall was below average to very much below average in most districts. Above average July temperatures resulted in rapid crop and pasture growth, and some crops were in head by August. At the end of winter soil profiles had little stored moisture and crops in all districts were showing signs of moisture stress. Growth was slowed by cool August temperatures with numerous frosts recorded in inland districts in mid to late August. Poor autumn and winter rainfall between Ceduna and Penong and around Kyancutta resulted in low crop biomass and yield potential. Where better rainfall was received crops maintained better yield potential with crops near Nundroo, Mudamuckla and south from Wirrulla to Wudinna maintaining slightly below average yield potential, and paddocks near Minnipa, Mt Damper and in the coastal districts around Streaky Bay, Mt Cooper and Elliston had high biomass and above average yield potential. Crops on dune/swale paddocks in Central Eyre districts, began to hay off on the heavier flats, which resulted in some growers cutting crops for hay.

Spring

Dry conditions and cold nights resulted in a number of heavy frosts in early September. The worst affected areas were cut for hay. Widespread storms late in the month resulted in average September rainfall in most districts and well above average rainfall in the Minnipa, Wudinna and Warramboo area.

Harvest commenced slightly earlier than normal in mid-October, with most farmers finishing in early December. October was hot, dry and windy and some districts observed their hottest October day on record. These conditions continued throughout harvest with very much below average rainfall during this period and a number of hot windy days above 40°C resulting in harvest bans.

Yields were highly variable depending on rainfall distribution and extreme weather events. There were widespread reports of frost damage impacting yields in most inland districts. Many pea crops around Wudinna were affected by frost and cut for hay, but those unaffected by frost yielded close to the long-term average. Canola yields were over 2 t/ha around Mt Cooper and 1.2 to 1.5 t/ha near Wudinna. Very strong winds on 20 November resulted in grain loss of up to 1 t/ha on some cereal crops. Fortunately the majority of crops on Western EP were harvested before this date.

Crop yields west of Ceduna to Penong were very poor with reports of some paddocks not harvested. The coastal strip from Haslam and Elliston yielded exceptionally well with reports of cereals yielding more than 2.5 t/ha. Inland crop yields were below average to average depending on rainfall distribution, with crops between Nunjikompita and Wirrulla yielding 0.5 to 0.6 t/ha. Crops that weren't frost affected south of Wirrulla to Wudinna had average to slightly below average yields (0.8 to 1.2 t/ha), and whilst barley crops near Wudinna yielded well (1.8 to 2.0 t/ha) yields on crops south east of Kyancutta were poor. Overall grain quality was generally good with high protein, good test weights and low screening percentages.

Pasture paddocks contained little feed at the end of the year and most livestock producers were supplementary feeding stock.

Eastern Eyre Peninsula

Summer

The growth of summer weeds which germinated after December rainfall was halted by hot dry conditions and very dry soils after harvest. Dams in the Cleve Hills dried up with many farmers needing to cart water for livestock over summer and autumn. Drought conditions in 2018 combined with a dry summer meant paddocks contained little biomass and most producers supplementary fed livestock.

Autumn/Winter

Very dry conditions extended into autumn. The only significant rainfall for April came from a cold front bringing widespread rains of 10-20 mm on 30 April. The northern part of the district received above average May rainfall which enabled seeding to commence, however rainfall was below average in the southern area.

Dry conditions in 2018 increased the risk of herbicide residue carryover resulting in a reduction in the area of canola and pulses sown and an increase in the area sown to barley.

This gave growers the option to either graze, cut hay or harvest grain depending on how the season progressed. Farmers with non-wetting sands waited for good opening rains to ensure sufficient moisture for good germination before sowing the majority of their crop. On sands that were drifting growers increased seed and fertiliser rates to improve plant densities and erosion protection. Warm days in the first half of May resulted in rapid germination of crops and pastures. Pre-emergent and knockdown herbicides provided good early weed control. Good early germination of medic pastures generated considerable bulk prior to cold weather which allowed most livestock producers to reduce or stop supplementary feeding in June.

Red legged earth and Bryobia mite numbers were higher than normal in some districts and damaged emerging crops and pastures. Other insect pest numbers were generally low, perhaps due to the high proportion of seed treated to protect early crops against the threat of Russian wheat aphid.

Rains in mid-June kept topsoils damp but subsoils in most districts were dry requiring good winter and spring rainfall to maintain crop and pasture growth and yield potential. Dry sown crops established quickly and were at mid-tillering by late June, but later sown crop growth was slowed by cold and dry conditions.

Late winter rainfall around Kimba and Franklin Harbour, as well as near Arno Bay was well below average. Severe frosts caused damage to crops in the Lock, Tuckey, Darke Peake and Mangalo areas in August, particularly barley, and those crops with sufficient biomass were cut for hay.

Continued dry conditions resulted in crops starting to hay off in early August near Cootra, Kimba, Tuckey, Cleve, Cowell and Arno Bay. Pulses appeared to be less affected by the dry conditions than cereal crops. Crops were still healthy in districts where better rainfall was received i.e. near Lock, Murdinga, Wharminda, Port Neill and the Cleve Hills, but dry soil profiles required good spring rainfall for crops to realise potential yields.

To maintain surface cover for as long as possible growers opted not to spray out grasses in pastures, choosing instead to spray-top paddocks in early spring to prevent grass weeds from setting seed. Rhizoctonia damage was higher than normal which might result from grasses left in pastures during recent dry seasons. Other crop disease levels were generally low.

Although livestock were generally in good condition, and most producers had already reduced stock numbers to core breeders to reduce pressure on feed supplies, relief from supplementary feeding of livestock was short lived with some farmers in the Arno Bay, Kimba and Franklin Harbour districts needing to recommence feeding in late winter due to low biomass in pasture paddocks. Some growers turned livestock onto failed crops on heavier soils type in August, however on sandier soil growers were reluctant to do this because of poor surface cover and the risk of exposing vulnerable soils to wind erosion.

Spring

Although September rainfall was average to above average, apart from in the Franklin Harbour district, with very much below average rainfall, strong winds and warm temperatures in October caused rapid senescence of crops and continued to erode areas of exposed soil. Late September rainfall whilst possibly helping fill grain on some sandier paddocks in the Cleve Hills, Darke Peak, Kielpa and Wharminda districts was generally too late to benefit crop yields. This rain also resulted in regrowth on some later sown barley crops causing uneven ripening and delaying harvest of those paddocks.

Cold nights combined with dry conditions in early September resulted in moderate to severe frosts near Kimba, Lock and Tuckey and many farmers cut affected crops for hay. Harvest began around Kimba in early October and farmers in other districts began to reap early crops by the end of the month. Very strong winds on 20 November caused grain to be threshed out of the heads of standing cereal crops resulting in yield losses of up to 1 t/ha.

Yields in all districts were below average, resulting in a quick harvest. Pulse crops generally yielded well, except on the heavier soils types which were affected by moisture stress. The small area of canola sown only yielded 0.5 to 0.8 t/ha. Yields varied from 0.1 to 2 t/ha, depending on soil type, time of sowing, frost damage and where rain fell. Crops in the Kimba/Buckleboo districts were severely affected by dry conditions. Yields were also poor in the Cleve, Arno Bay and Cowell districts which had poor rainfall all year, with reports of cereal crop yields in the 0.2 to 0.5 t/ha range. Crops on lighter textured soils yielded better (in the range 0.8 to 1.5 t/ha), whilst in the Cleve Hills and Darke Peak districts which received more rainfall, cereals yielded 1.2 to 2.0 t/ha. Grain quality was generally extremely good with high protein and low screenings.

Lower Eyre Peninsula

Summer

Stubbles from a good 2018 season on Lower Eyre Peninsula provided high amounts of quality feed and livestock retained excellent condition. Summer weeds germinated with harvest rains and most farmers began spraying immediately after harvest.

Although many soil profiles contained moisture in deeper subsoil layers over summer, surface and subsurface layers were extremely dry stalling weed growth during late summer.

Autumn/Winter

Autumn rainfall was below average to well below average. Paddock feed supplies had severely reduced at this point and most farmers were supplementary feeding stock.

Farmers began dry-sowing vetch or cereals for feed in mid-April, to allow pastures to get well established before grazing. Those with large cropping programs also sowed some canola and pulses dry but most waited until a cold front on 30 April brought the first significant rainfall for the year.

A large amount of lime and gypsum was applied during this period to ameliorate soil constraints. Mice, snail and insect pest numbers were generally low. Most farmers also treated a portion of their seed with insecticide to protect early growth from Russian wheat aphid.

Good rains followed the April break with well above average May rainfall in most districts. June rainfall was below average for coastal districts from Port Lincoln to Port Neill. Seeding was finished by the first week of June in most districts. The dry start combined with low stored soil moisture also saw a slight reduction in the area of canola and a corresponding increase in the area of barley sown.

Good soil moisture and warmer temperatures in May resulted in good crop and pasture germination and growth. Pre-emergent and knockdown herbicide applications were very effective and most crops had low grass weed numbers. Red legged earth mite, Bryobia mite and Lucerne flea caused some damage to emerging crops and pastures. There were also reports of Cabbage and Turnip aphids in canola as well as Cow-pea aphids in vetch crops, however these were isolated and in low number.

Crop growth stage varied with time of sowing. By mid-June early sown crops were at mid-tillering, whilst those sown later in cooler conditions were only at 4-5 leaf stage. By the end of August many cereal crops were are at head emergence with good yield potential with pulse crops and canola crops flowering. A number of leaf diseases were reported in cereal crops including net blotch and scald in susceptible barley varieties and Septoria in wheat. However these were effectively controlled with fungicide applications.

With good growing conditions, many growers applied early nitrogen to cereal crops. Given limited stored soil moisture and predictions of a drier than average spring, growers were cautious, applying lower nitrogen rates than normal with preparations to apply more if good seasonal conditions continued.

July and August rainfall was below average to very much below average across the district. Whilst warmer days in August resulted in rapid growth of crops and pastures, cold nights resulted in a number of frosts in inland districts.

Spring

September rainfall varied considerably across the region from below average in the south to above average in the Kapinnie, Cummins, Ungarra and Tumby Bay districts. Late September rains helped fill grain on all but the earliest crops and maintained above average yield potential in most districts. The exception to this was around Butler and Port Neill where patchy rainfall at the start of the season resulted in delayed crop growth.

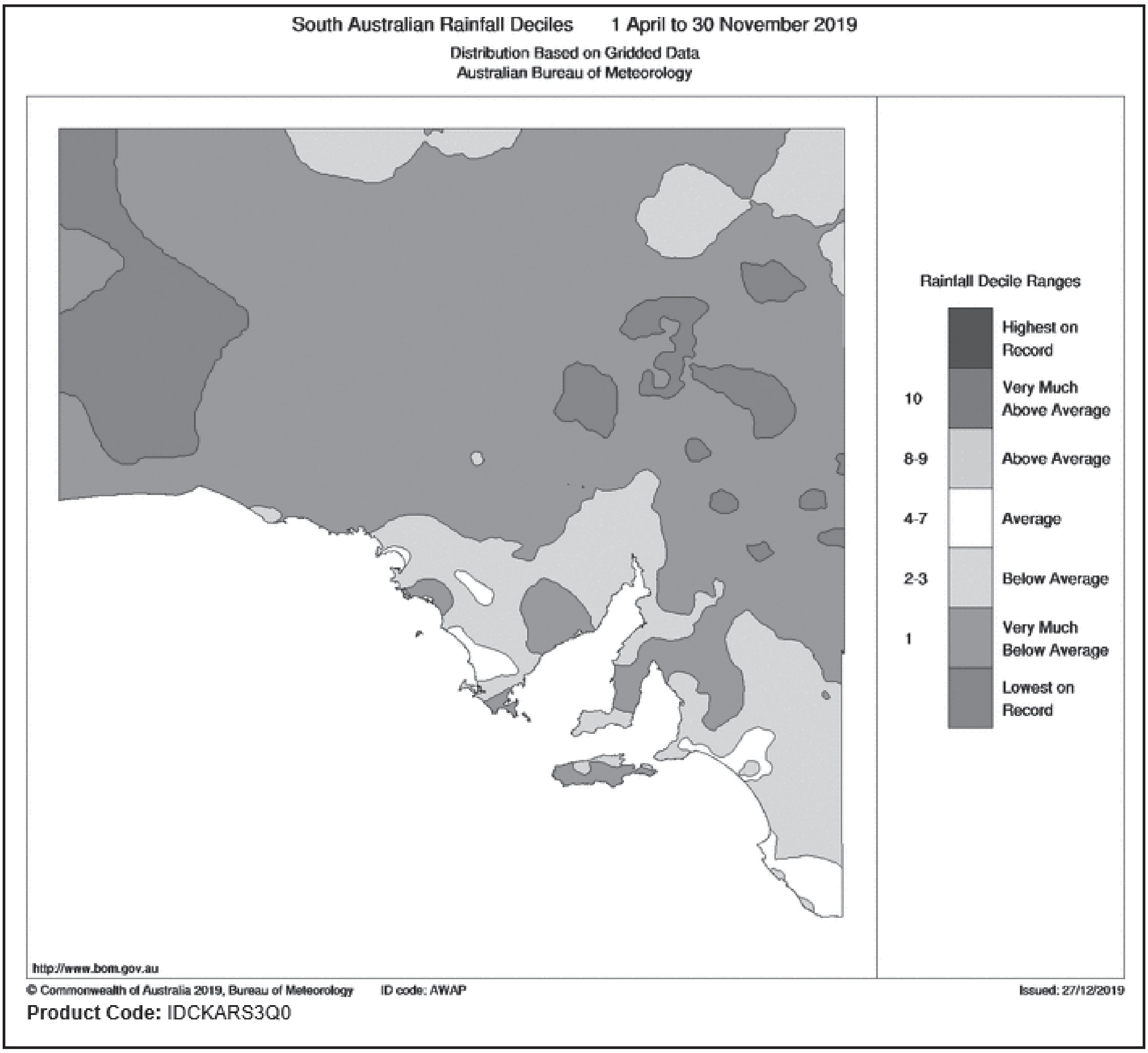
A number of frosts reported in early September caused some damage to crops. High biomass levels, suspected frost damage and weed control opportunities combined with good demand and hay prices, meant that more hay was cut on lower EP than normal. Cereal paddocks cut in mid-September regrew quickly providing extra grazing opportunities for livestock. Growers also baled cereal straw after harvest as an alternative supplementary feed option for livestock producers in droughted parts of the region.

Below average October rainfall combined with warm days, including hot north winds and the hottest October day on record, resulted in rapid crop senescence. Farmers commenced windrowing canola in mid-October and harvesting earlier sown crops in the last week of October. Very strong winds on 20 November threshed grain from the heads of cereal crops. Crops with the highest yield potential were generally worst affected with some growers estimating losses up to 2.5 t/ha.

Most growers had finished harvest by the end of December. Canola yields were better than the long term average (in the 1.8 to 2.2 t/ha range) with generally high oil content. Peas and lentil crops yielded 1.5 to 1.8 t/ha with many bean crops yielding more than 1.8 t/ha. Except for those crops impacted by wind damage or frost, cereal yields were generally average to slightly above average in the range 2.5 to 4.5 t/ha. Grain quality was generally good with high protein and grain weights.

Acknowledgements

The author wishes to acknowledge that much of the information contained within this summary has been compiled from PIRSA’s 2019 Crop and Pasture Reports.



http://www.bom.gov.au

Figure 1. April to November rainfall deciles, 2019.

Government
of South Australia

Primary Industries
and Regions SA

MAC Farm Report 2019

Jake Hull
Farm Manager
SARDI, Minnipa Agricultural Centre

Location
Minnipa Agricultural Centre
Rainfall
Av. Annual: 324 mm
Av. GSR: 241 mm
2019 Total: 254 mm
2019 GSR: 234 mm

Key outcomes

- **Yields achieved for 2019 were close to the 30-year average, with this year's growing season rainfall also similar to the GSR average for those 30 years.**
- **High grain quality and test weights were achieved in 2019.**
- **Lamb survival rates were very good.**

Background

The performance of the Minnipa Agricultural Centre (MAC) commercial farm is an essential component in the delivery of relevant research, development and extension to Eyre Peninsula. The effective use of research information and improved technology is an integral part of the role of the farm. MAC had research trials in eight paddocks and continued to take full pedigree records and production measurements on the sheep research flock in the 2019 season.

What happened?

Where was our mid-spring rainfall? The season began with promise, with above average rainfall for May and June, then we received very much below average rainfall for July and August. Most crops had completed grain fill when we received a large rainfall event in late September of 45 mm. This rainfall helped some late crops, but not all.

Due to a good start to 2019, the whole seeding program was sown into good moisture, starting on 3 May and completed on 20 May. The fertiliser applied was 70 kg/ha of Granuloc Z (11:22:4:1).

- Wheat sown at 70 kg/ha, total 407.5 ha (Scepter 183 ha, Trojan 20 ha, Chief CL 58.5 ha, Razor CL 93 ha, DS Bennett 28 ha, Vixen 25 ha)
- Barley sown at 65 kg/ha, total 242 ha (Spartacus CL 162 ha, Compass 30 ha, RGT Planet 30 ha)
- Peas sown at 110 kg/ha, 45 ha, PBA Butler
- Beans sown at 90 kg/ha, 10 ha, PBA Marne
- Lentils sown at 60 kg/ha, 35 ha ,PBA Hurricane
- Canola sown at 1.8 kg/ha, 56 ha, 43Y92
- Vetch sown at 40 kg/ha, 40 ha, Volga, RM4
- Hay - oats sown at 40 kg/ha, vetch 40 kg/ha, canola 2.5 kg/ha
- Pasture - 180 ha self-regenerated medic
- Research trials - 45 ha (DLPS, NVT, etc.)
- Lanza tedera sown at 10 kg/ha (small area established)

Livestock

Stock currently on the farm: 325 merino ewes, 124 merino ewe hoggets, 394 merino lambs and 9 merino rams. Reproduction results overall for 2019: 342 ewes mated with 37 ewes scanned dry and 434 lambs marked (including 14 April-May drop which were sold in August). Ewe and wether lambs weighed in at an average of 26.6 kg per animal weaned at 12 weeks.

Shearing of the flock was completed on 27 August at six months, with the previous shearing on 27 February. Fleece weight data are presented in Table 3.

Issues encountered in 2019

- Lack of late winter and early spring rainfall
- Wild oats and barley grass in crop
- Barley grass escaping selective herbicides in medic pastures
- Three corner jack population increase on farm

Farm improvements and equipment

- Tractor leased for 5 years
- Sheep yards built early 2019
- Sheep yard shelter to be installed early 2020
- Combi clamp purchase

Items of interest

- Variety comparisons in wheat and barley - Scepter and Vixen very similar. Razor CL performing better than Chief CL at MAC. Compass and Spartacus CL the stand out barley varieties at MAC.
- Faba beans - left a lot in the ground due to low podding height, approx. 0.5 t/ha.
- DLPS large-scale grazing trial - very impressed with the trigonella in particular.
- Lentils performing well
- RM4 vetch new woolly pod variety
- Lanza tedera established well on heavy loam
- SARDI farm manager meeting held at MAC
- GRDC Southern panel visit
- MLA "increasing weaning weights" trial participation

Acknowledgements

MAC farm staff: Wade Shepperd and John Kelsh

MAC research staff: Jessica Gunn and Tom Flinn (University of Adelaide)

MAC administration staff: Leala Hoffmann and Dot Brace

Table 1. Harvest results, grain yields and protein (2019) aligned with paddock rotational histories.

Paddock	Paddock History 2015-2019	Crop 2019	Sowing Date	Yield (t/ha)	Protein (%)	Screenings (%)
North 1	W-M-W-M-W	Scepter, Razor CL, Vixen (W), WI4952 (B)	15 May	1.75, 1.53, 1.62, 1.81	N/A	N/A
North 2	M-C-W-M-W	Scepter (W)	14 May	1.90	12.6	0.5
North 3	W-B-V-W-B	Spartacus CL (B)	13 May	1.74	16.1	4.8
North 4	W-M-W-B-M	Medic (M)				
North 5 N	B-M-W-W/B-M	Medic (M)				
North 5 S	M-W-M-W-M	Medic (M)				
North 6	W-W-B-M-O/V/C (hay)	Mulgara/Volga/Mixed (O/V/C)	4 May	Hay 1.5		
North 7	W-M-C-W-B	Spartacus CL (B)	12 May	2.08	16.1	4.8
North 8	W-M-C-W-W	Chief CL (W)	8 May	1.68	13.5	0.7
North 9	B/W-O-W-P-W	Trojan (W)	13 May	1.67	14.1	0.3
North 10/11	M-W-M-B-V	Volga/RM4 (V)	3 May	Spray topped		
North 12	M-W-W-C-W	Razor CL (W)	11 May	1.97	13.2	1.2
South 1	P-W-B-V/B/O-W	Razor CL (W)	10 May	1.61	12.9	0.9
South 2	W-M-W-B-P	PBA Butler (P)	7 May	1.00		
South 3	W-B-V-W-B	RGT Planet, Compass (B)	17 May	1.57, 2.04	15.5	1.2, 0.4
South 4	O/V-W-B-V-W	Scepter (W)	14 May	2.14	13.6	0.8
South 5	M-W-B-M-W	Scepter (W)	13 May	1.94	13.2	0.6
South 6	B-M-W-B-C	43Y92 (C)	6 May	Oil 38.6%		
South 7	M-W-B-M-W	DS Bennett (W)	5 May	1.30	13.3	4.8
South 9	M-M-W-B-M	Medic (M)				
South 10	B-V-W-W-P	PBA Butler (P)	20 May	0.80		
Barn	W-O-M-W-O	Mulgara (O)	20 May	1.20		
House	W-O-M-W-O	Mulgara (O)	20 May	1.20		

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

Table 2. Lambing data 2010-2019.

	Ewes joined	Lambs scanned	Lambs born	Lambs marked	Scanning (%)	Marking (%)	Survival at birth (%)	Survival at marking (%)
2010	335	421	372	333	126	99	88	79
2011	338	426	414	410	126	121	97	96
2012	337	540	558	439	160	130	103	81
2013	350	534	531	448	153	128	99	84
2014	349	442	443	386	127	111	100	87
2015	424	555	534	437	131	103	96	79
2016	422	532	632	502	126	119	119	94
2017	366	428	458	361	117	99	107	84
2018	335	434	382	294	130	88	88	68
2019	342	486	485	434	142	127	100	89
Av.	360	480	481	404	134	116	101	86

**2010, 2011, 2014, 2015, 2016, 2017 all had 1 x sire failure*

Table 3. Wool measurements 2019.

Sheep class	**Ewes (2013-2017 drop)**					**Hogget ewes (2018 drop)**				
Date shorn	**Feb-19**		**Aug-19**		**Total (annual)**	**Feb-19**		**Aug-19**		**Total (annual)**
Measure	AV.	RANGE	AV.	RANGE	TOT/AV	AV.	RANGE	AV.	RANGE	TOT/AV
GFW (kg)	4.2	2.8-6	3.3	2-6.2	7.5	3.1	1-5.2	2.7	2-4	5.8
Staple length (mm)	44.9	29-66	56.5	41-75	50.7	56	24-77	62.9	50-76	59.4
Colour (1-5)	1.9	1-3	1.9	1-3	1.9	1.8	1-3	2	1-3	1.9

“A grower group that specifically addresses issues and finds solutions to improve farming systems in your area”

LEADA’s 2019 achievements and 2020 focus

In 2019 LEADA continued work on several small projects funded by a range of partners, these included the Copper Management Trial funded by SAGIT; Pulse Check Group funded through GRDC’s Southern Pulse Extension Project and the Increasing production on sandy soils in low and medium rainfall area of the southern region project also funded through GRDC. LEADA entered into a number of statewide projects including NLP2 funded Warm and cool season mixed cover cropping; Rural R&D for Profit funded Dryland Legume Pasture Systems; and NLP2/EPNRM Board funded Regional Agricultural Landcare Facilitator.

LEADA reviewed the sites for the third year of the SAGIT grant looking at Copper Management for the Future. One original site and one new site were chosen. The project explores different management strategies to overcome copper deficiency in cereals, comparing the effectiveness of copper sulphate and copper chelate applied either as liquids banded at seeding or as a foliar spray.

LEADA continued to deliver the GRDC funded project establishing and running nine ‘pulse check’ groups across the Southern Region of Australia. LEADA is also facilitating the lower Eyre Peninsula group learning/discussion and practical field sessions that focus on ‘back to basics’ lentil and/or chick pea production. The delivery of the ‘Pulse check’ discussion group on lower Eyre Peninsula has been conducted by George Pedler with 4 group meetings being held in 2019. There is hope that this project will continue for an additional year to further the learnings of each of the groups and build a strong project legacy.

In 2019 LEADA’s involvement with the Warm and cool season mixed cover cropping project included two Cover Crop demonstrations being planted and the preparation for a Cover Crop plant species screening trial to be planted early 2020. LEADA participated in the successful Joel Williams Soil Knowledge Tour and visit to the cover crop demonstration site at Wangary.

LEADA were also successful in securing funding through NLP2 for a project increasing adoption of new techniques combining physical, chemical and plant based interventions to improve soils function on Eyre Peninsula. The project will increase awareness of methods to address a range of soil constraints, by demonstrating how the combination of deep incorporation of chemical amendments (lime and gypsum) and the inclusion of organic materials can address soil physical and chemical constraints that reduce plant root growth and limit soil biological function.

LEADA hosted a successful Expo in March 2019 and their annual Spring Field Walk in September 2019. Key speakers included Jason Trompf and Hamish Dickson at the Expo and Nick Poole, Jason Brand and Stuart Nagel at the Spring Field Walk.

During 2019 LEADA and EPARF representatives have been working towards a merger of both organisations due to reduced state government input and support, and the decreasing funding opportunities for research projects. Members of the two organisations will vote on the merger in early 2020.

As always, links with GRDC, the Australian Government, Rural Solutions SA, SARDI, EPARF and the Eyre Peninsula NRM Board continue to be critical to the ongoing success of LEADA.

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Committee members:
Bruce Morgan (Chair), John Richardson (Vice Chair), Daniel Adams, George Pedler, Dustin Parker, Mark Habner, Derek MacDonald, Josh Telfer, Mark Dennis, Billy Pedler, Mark Stanley, Andrew Ware, Susan Stovell/Mary Crawford (EPNRM) and David Davenport (RSSA).

An initiative of the Australian Government Department of Agriculture.

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 *LSD (P=0.05)*	$P \leq 0.05$ *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 100m)
1 acre = 0.4047 ha (1 chain (22 yards) by 10 chain)
1 ha = 2.471 acres

Mass

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

A bushel (bu) is traditionally a unit of volumetric measure defined as 8 gallons.

For grains, one bushel represents a dry mass equivalent of 8 gallons.

Wheat = 60 lb, Barley = 48 lb, Oats = 40 lb
1 bu (wheat) = 60 lb = 27.2 kg
1 bag = 3 bu = 81.6 kg (wheat)

Volume

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

Speed

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

Pressure

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

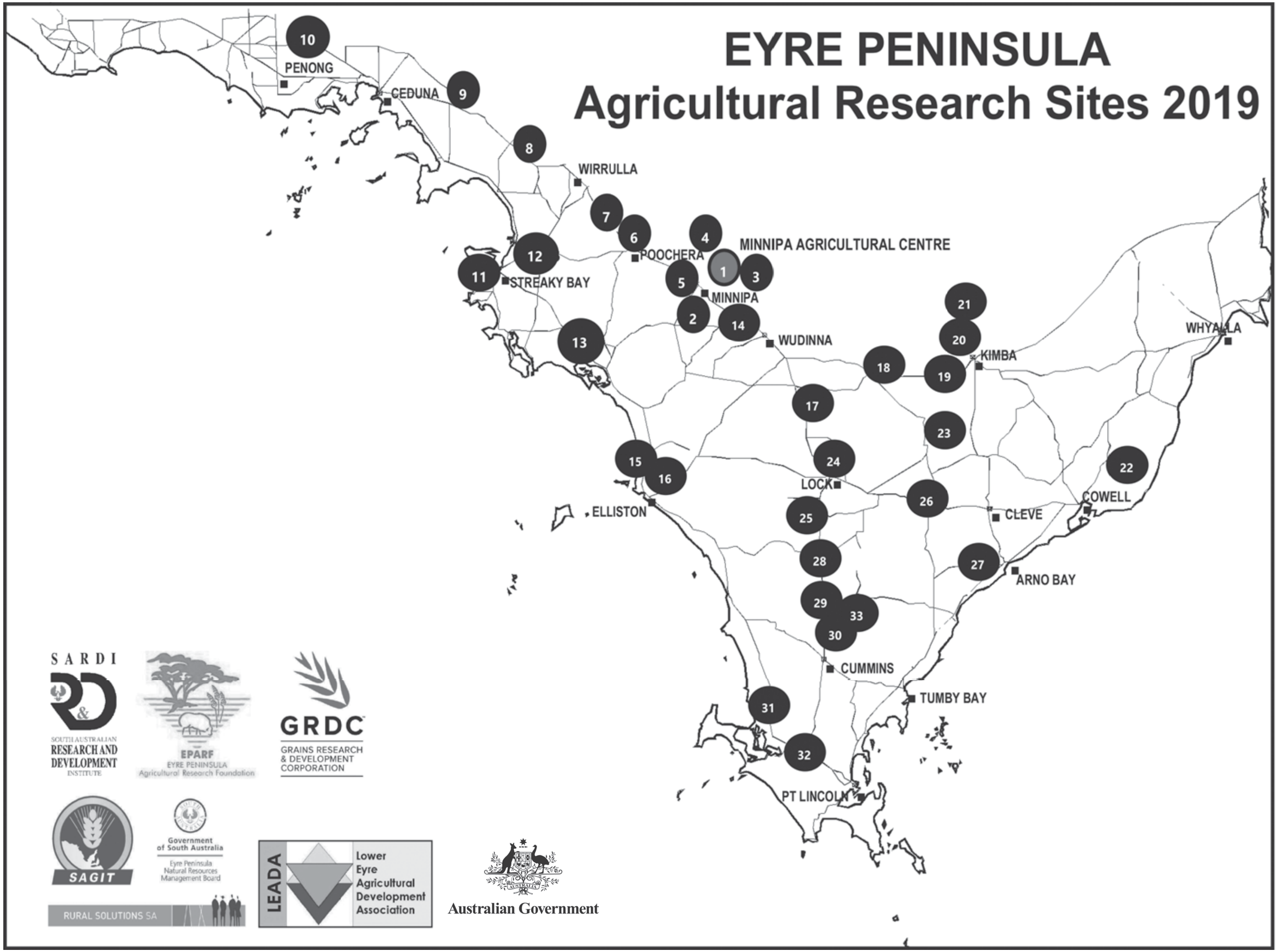
Yield

1 t/ha = 1000 kg/ha

Yield Approximations

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

EYRE PENINSULA
Agricultural Research Sites 2019



Eyre Peninsula agricultural research sites 2019 map references.

Map reference	Location	Trials	Host farm business
1	Minnipa	NVT wheat and early wheat, barley, canola. Blackspot peas. Time of sowing beans and lentils. Low rainfall zone pulses. Lentil herbicides. Pea and vetch breeding. Time of sowing wheat. Intergrain wheat and barley. AGT wheat. Russian wheat aphid Large scale annual pasture legume grazing trial. Annual pasture legume species evaluation. Nitrogen fixation annual pasture legumes. Controlled traffic. UAV monitoring grass weeds. Barley grass management strategies. Herbicide residues. Soils & plant nutrition testing.	SARDI Minnipa Agricultural Centre
2	Minnipa	Swathing crops for barley grass control. UAV monitoring grass weeds. Annual ryegrass management utilising crop competition and herbicides.	Bruce Heddle
2	Minnipa	Chafflining weed seed decay. Herbicide residue	Jerel Fromm
3	Minnipa	NVT canola. Herbicide residue	John Oswald
4	Minnipa	Phosphorous response	Gareth Scholz
5	Minnipa	Nitrogen & phosphorous response. UAV monitoring grass weeds	Matthew Cook
6	Poochera	Herbicide residue	Paul Carey
7	Cungena	Dry sowing. Nitrogen & phosphorous response	Myles Tomney
8	Nunjikompita	NVT wheat	Tim Howard
9	Mudamuckla	Soil & plant nutrition testing	Peter Kuhlmann
10	Penong	NVT wheat	Butch Dunn
11	Streaky Bay	Dry sowing. Nitrogen & phosphorous response. Lincoln weed	Phil Wheaton
12	Piednippie	NVT wheat and barley	John Montgomery
12	Piednippie	DLPS demonstration pasture species	Dion Trezona
12	Piednippie	Maximising DM production on grey soils	Brent Cronin
13	Calca	Herbicide residue	Craig Kelsh
14	Yaninee	UAV monitoring grass weeds	Gregor Wilkins
15	Elliston	Lincoln weed	Terry Williams
16	Elliston	NVT barley. Cereal pathology	Nigel & Debbie May
17	Warramboo	NVT wheat	Murphy family
18	Koongawa	Soil & plant nutrition testing	Wes Matthews
19	Kimba	NVT wheat	Shannon Mayfield
20	Kimba	Oat varieties. Pulse nutrition. Blackspot peas. Deep ripping for frost	Trevor Cliff
21	Buckleboo	Deep ripping in sandy soils	Dion Woolford Tristan Baldock
22	Cowell	NVT wheat	Kaden family
23	Darke Peak	NVT barley	Mark Edwards
24	Lock	Soil & plant nutrition testing	Andrew Polkinghorne
24	Lock	DLPS demonstration pasture species	Kerran Glover
25	Murlong	Sandy soils. Water repellence	Mark Siviour
26	Rudall	NVT wheat	Jason Burton
27	Wharminda	NVT barley. Cereal pathology	Tim Ottens

Map reference	Location	Trials	Host farm business
27	Wharminda	Chafflining weed seed decay	Ed Hunt
27	Wharminda	Chafflining weed seed decay	Ian Noble
28	Murdinga	NVT field pea	Basil Heath
29	Tooligie	Pulse validation	Bill Long
30	Yeelanna	NVT canola	Peter & Steve Glover
30	Yeelanna	Pulse and bean agronomy. NVT field pea and lentil	Chad Glover
31	Mt Hope	Sclerotina and blackleg in canola	Ashley & Sam Ness
32	Wanilla	NVT wheat, barley	Rob & Hayden McFarlane
33	Brooker	Sandy soils	Challinger Family

Photo: Michael Wilkes, Hamish Dickson, Mary Crawford, Brett Masters, Jessica Gunn and Cam Nicholson at the Lock Mixed Farming Masterclass in 2019.

Section 1

Section Editor:
Nigel Wilhelm
SARDI, Minnipa Agricultural Centre/
Waite

Farming Systems

Improving the early management of dry sown cereal crops

Amanda Cook, Ian Richter and Neil King
SARDI, Minnipa Agricultural Centre

Location
Minnipa Agricultural Centre, Paddock N1
Rainfall
Av. Annual: 324 mm
Av. GSR: 241 mm
2019 Total: 247 mm
2019 GSR: 234 mm
Soil type
Red loam
Paddock history
2019: Scepter wheat
2018: Medic pasture
2017: Medic pasture
Plot size
12 m x 2 m x 3 reps

Location
Streaky Bay
Rainfall
Av. Annual: 377 mm
Av. GSR: 303 mm
2019 Total: 278 mm
2019 GSR: 262 mm
Soil type
Grey calcareous sandy loam
Paddock history
2019: Mace wheat
2018: Medic pasture
2017: Compass barley
Plot size
12 m x 2 m x 3 reps

Key messages

- **At Streaky Bay and Cungena in 2019, establishment was similar with dry sowing or sowing at the break, and at Minnipa establishment was better with dry sowing.**
- **There was a yield penalty if no fertiliser had been applied at Minnipa.**
- **Dry sowing increased grain yield at Minnipa by 0.2 t/ha compared to waiting for the break in the season.**
- **Dry sowing at Streaky Bay and Cungena reduced grain yield, by 0.7 and 0.3 t/ha respectively, compared to waiting for the break and sowing into a moist soil bed.**
- **All three sites showed a decrease in early dry matter with dry sowing.**
- **The herbicides and fungicides evaluated in the trial did not impact on plant establishment when dry sowing.**

Why do the trial?

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

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

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

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

This article reports on field trials undertaken in 2019 at three sites.

How did we do it?

Each site had two trials with CL Razor wheat sown @ 72 kg/ha. The trials were sown with a small plot seeder on 25.5 cm (10”) row spacing with Harrington points and press wheels. The seeder had the ability to sow the fertiliser either with the seed or deeper (4-5 cm), or the fertiliser could be split (50% with seed: 50% below the seed).

Location
Cungena
Rainfall
Av. Annual: 284 mm
Av. GSR: 239 mm
2019 Total: 219 mm
2019 GSR: 185 mm
Soil type
Grey calcareous sandy loam
Paddock history
2019: Mace wheat
2018: Medic pasture
2017: Medic pasture
Plot size
12 m x 2 m x 3 reps

The treatments in the trials at each site were:
Trial 1: Sowing conditions [dry sown vs break (wet)] x fertilisers (13 treatments).

- Nil - Control (no fertiliser) - dry and break
- 60 kg/ha DAP with the seed - dry and break
- 60kg/ha DAP below the seed - dry and break
- 60 kg/ha DAP plus 50 kg/ha urea with seed - dry and break
- 60 kg/ha DAP with seed plus 50 kg/ha urea below seed (4-5 cm deeper than seed) - dry and break
- 60 kg/ha DAP with the seed and 50 kg/ha urea broadcast early - dry
- 60 kg/ha DAP split; 30 kg/ha with the seed and 30 kg/ha below the seed (deep) - dry
- Phosphoric acid (12 units) with the seed and urea (10.8 units) broadcast early - dry.

Trial 2: Management - Dry sown with 60 kg/ha DAP with the seed: 10 treatments [CL Spartacus barley, herbicides (Trifuralin @ 2 L/ha, Boxer Gold @ 2.5 L/ha or Sakura @ 118 g/ha), shallow sowing (2-3 cm), deep sowing (6-7 cm), higher seeding rate (100 kg/ha), fungicides (Baytan, EverGol, Uniform plus EverGol)].

During the growing season the trials were assessed for plant establishment, early and late dry matter, NDVI (level of ‘greenness’), plant nutrient analysis, grain yield and grain quality.

The results were analysed using GENSTAT 64, Version 20, using an ANOVA analysis.

What happened?

The 2019 season was just below average rainfall for most regions on upper EP with Streaky Bay achieving a decile 4-5 rainfall season, Minnipa a decile 4, but Cungena a decile 2-3 season. The 2019 season started with very little subsoil moisture but with good opening rains received in late April/early May which enabled seeding to be within an ideal sowing window. The first rainfall events were on the 21 April with Minnipa receiving 10 mm, Streaky Bay receiving 15 mm and Cungena receiving 6 mm. The next rain was on 1 May with 16 mm at Minnipa, 26 mm at Streaky Bay and 16 mm at Cungena. The timing of the season break meant the dry sowing treatments did not emerge before the early May rainfall events which resulted in plant establishment.

The Streaky Bay site was affected by Take-all (*Gaeumannomyces graminis var. tritici*) in spring. The most affected areas of the plots were removed (hand mown) to remove the effect on grain yield.

Trial 1: Sowing conditions

There were differences in plant establishment at Minnipa and Cungena depending on the time of sowing and fertiliser treatments. At Minnipa (break - wet only) and Cungena at both times of seeding, 60 kg/ha DAP plus 50 kg/ha urea with seed directly impacted on seed germination resulting in lower plant establishment compared to nil fertiliser (Figure 1). At Minnipa dry sowing resulted in higher plant establishment with an average of 166 plants/m^2 compared to sowing on the break with 126 plants/m^2. At Streaky Bay and Cungena there were no differences in plant germination between dry sowing or sowing after the break.

Location and timing of sowing affected early dry matter production, which was sampled on the same day. At all sites, sowing after the break of the season showed greater dry matter production than dry sowing (Table 2). Minnipa had the greatest early dry matter production overall, then Streaky Bay and Cungena. The only difference in early dry matter between fertiliser treatments over the three sites was the lowest dry matter production being the Nil Control (no fertiliser) treatment, which was similar to the 60 kg/ha DAP and 50 kg/ha urea with the seed treatment, but less than for all other treatments.

At Minnipa dry sowing compared to waiting for the break in the season and sowing into a moist seed bed increased grain yield by 0.2 t/ha (Table 3). In the highly calcareous soils at Cungena and Streaky Bay however, dry sowing decreased yield compared to sowing on the break of the season into a moist seed bed. At Streaky Bay dry sowing decreased yield by 0.7 t/ha, and at Cungena by 0.3 t/ha (Table 3).

Table 1. Sowing dates for “dry sowing” and “break” treatments at Minnipa, Cungena and Streaky Bay in 2019.

Sowing dates	Dry sowing	Break
Minnipa	15 April	3 May
Cungena	17 April	7 May
Streaky Bay	18 April	8 May

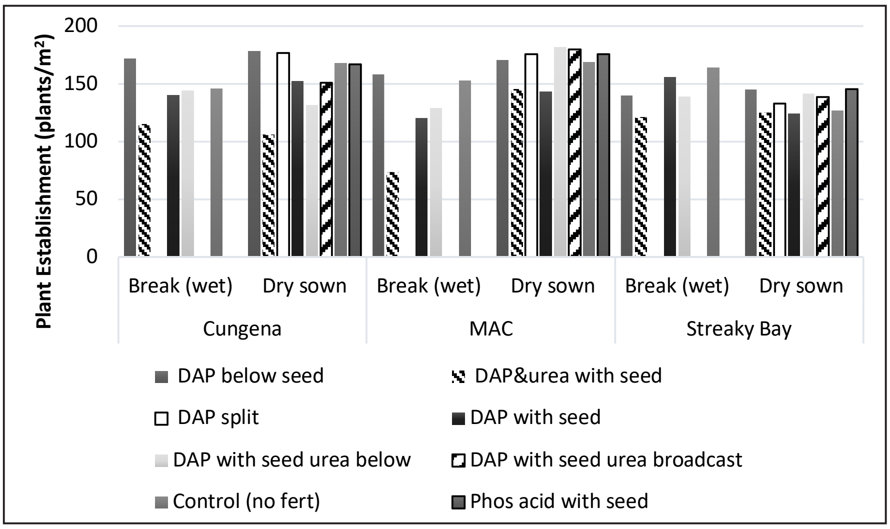


Figure 1. Plant establishment of CL Razor wheat at the three trial site locations in 2019. (LSD (P=0.05) Location*Break*Fertiliser=29)

Table 2. Early dry matter (t/ha) of CL Razor wheat at the three trial site locations in 2019.

Trial location	Dry sowing	Break
Minnipa	0.21 *a*	0.27 *a*
Streaky Bay	0.13 *b*	0.30 *a*
Cungena	0.07 *c*	0.14 *b*
LSD (P=0.05)	*0.06*	

Table 3. Grain yield (t/ha) of CL Razor wheat at different sowing times at three locations in 2019.

Trial location	Dry sowing	Break
Minnipa	1.83 *c*	1.60 *d*
Streaky Bay	2.14 *b*	2.86 *a*
Cungena	1.28 *e*	1.59 *d*
LSD (P=0.05)	*0.18*	

At Minnipa the nil fertiliser treatment was lower yielding than all other treatments except DAP fertiliser placed below the seed. At Streaky Bay higher grain yields were achieved with the addition of extra and early nitrogen as urea (Table 4).

At Cungena the addition of nitrogen did not increase grain yield (Table 4).

Trial 2: Management trial

Treatments affected both germination and early dry matter but the effects varied between locations. Streaky Bay had lower establishment than the other sites (Table 5). The highest plant establishment was with high seeding rate (207 plants/m^2) compared to the average of 150 plants/m^2 (data not shown) which was the standard seeding rate. Early dry matter was similar at Minnipa and Streaky Bay, and lowest at the Cungena site due to the seasonal conditions. High seeding rate was the only treatment which increased early dry matter production; CL Razor wheat (0.17 t/ha compared to 0.14 t/ha with the standard seeding rate) and CL Spartacus barley (0.18 t/ha compared to 0.14 t/ha of wheat with the standard seeding rate).

The management strategies evaluated in the trial did not impact on grain yield when dry sowing. The highest grain yield across the sites was achieved with CL Spartacus barley (Figure 2). Despite better plant establishment and greater early dry matter, higher seeding rate did not yield well, nor did deeper sowing.

What does this mean?

Overall, at Minnipa there were no differences in establishment with dry sowing or sowing with the break. Under good seeding conditions the Streaky Bay and Cungena soils had similar plant establishment with dry sowing, however all soil types showed a decrease in early dry matter with dry sowing. Dry sowing compared to waiting for the break of the season increased grain yield at Minnipa by 0.2 t/ha on a red loam soil. Dry sowing at Streaky Bay and Cungena in 2019 reduced the grain yield, by 0.7 and 0.3 t/ha respectively, compared to waiting for the break and sowing into a moist soil bed. Dry sowing early, especially on the grey calcareous soils, may not always result in better crop production, possibly due to fertiliser toxicity effects or lower early fertiliser uptake.

Placing 23 kg N/ha as urea with the seed reduced plant establishment on all soil types due to fertiliser toxicity effects, but placing nitrogen below the seed improved early plant dry matter compared to no fertiliser, which had the lowest early dry matter production.

Table 4. Grain yield (t/ha) of CL Razor wheat with different fertilisers at three locations in 2019.

Fertiliser	Cungena	Minnipa	Streaky Bay
DAP below seed	1.50 *gh*	1.67 *fg*	2.50 *b*
DAP & urea with seed	1.25 *i*	1.83 *cdef*	2.78 *a*
DAP split	1.31 *hi*	1.85 *cdef*	1.96 *cde*
DAP with seed	1.50 *gh*	1.81 *def*	2.41 *b*
DAP with seed, urea below	1.47 *gh*	1.77 *ef*	2.73 *a*
DAP with seed, urea broadcast	1.36 *hi*	1.83 *cdef*	2.42 *b*
Nil - Control (no fert)	1.43 *gh*	1.51 *gh*	2.04 *c*
Phosphoric acid with seed	1.46 *gh*	1.99 *cd*	2.31 *b*
LSD (P=0.05)	*0.21*		

Table 5. Site averages for crop performance of dry sown management trials in 2019.

Trial location	Establishment (plants/m²)	Early dry matter (t/ha)	Yield (t/ha)
Minnipa	165 *a*	0.17 *a*	1.85 *b*
Streaky Bay	129 *b*	0.15 *a*	2.50 *a*
Cungena	156 *a*	0.09 *b*	1.06 *c*
LSD (P=0.05)	*10*	*0.02*	*0.11*

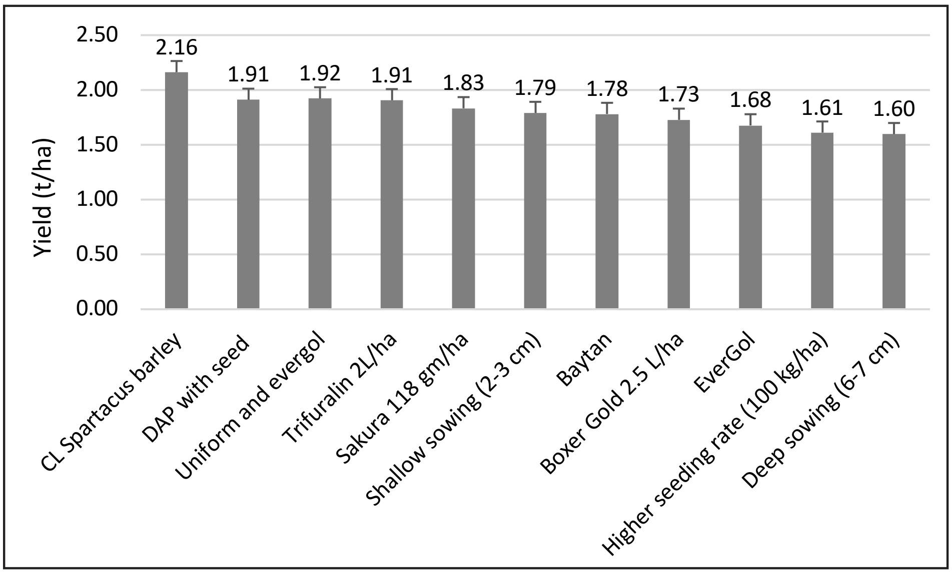


Figure 2. Average cereal yield (t/ha) of management treatments across three sites (Minnipa, Streaky Bay and Cungena) in 2019. LSD (P=0.05)=0.10.

The management trial which was dry sown showed that while increasing the seeding rate of wheat will improve plant establishment and early dry matter, it can reduce grain yield. CL Spartacus barley had improved early dry matter production compared to wheat. The herbicides and fungicides evaluated in the trial did not impact on plant establishment when dry sowing.

This research will continue for another two seasons with further trials to be established to determine the impacts of dry sowing and management on plant establishment, along with additional research on the calcareous soils.

Acknowledgements

This research was funded by SAGIT through the 'Improving the early management of dry sown cereal crops' (S419). Sincere thanks to SAGIT and their extremely valuable input into regional South Australian research and researchers. Thank you to Phil and Jan Wheaton, Myles and Kylie Tomney and MAC for having field trials on their property. Thank you to Katrina Brands, Steve Jeffs and Bradley Hutchings for field work and processing samples.

Impact of fertiliser on wheat emergence under dry conditions

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Key messages

- **Eleven days after seeding, emergence in Minnipa and Cungena soils was higher with no fertiliser or with all the DAP banded below the seed row, compared to DAP placed with the seed or split.**
- **Emergence was most affected by the presence of DAP in the Streaky Bay soil, least in the Minnipa soil and Cungena soil was intermediate.**
- **Shoot weights decreased where DAP was placed in the seed row and this occurred in all soil types. The soil EC (salinity) was higher with DAP placed in the seed row.**
- **Fertiliser toxicity may be reducing wheat emergence on grey calcareous soils, even at quite low application rates of DAP at 30 kg/ha.**

Why do the research?

With larger seeding programs, increased summer weed control to conserve soil moisture and more variable autumn rainfall patterns, more growers Australia-wide are moving toward dry sowing.

On upper Eyre Peninsula in 2017 and 2018, seed was placed in the soil for many weeks with limited soil moisture, some seed still germinated but the delayed plant emergence often resulted in a lower plant establishment. This raised questions by growers about the soil factors which reduce germination and establishment.

This article summarises a pot trial which assessed the impact of DAP placement on wheat establishment on three different soil types; a red loam (Minnipa Agricultural Centre [MAC]) and two grey calcareous soils (Streaky Bay and Cungena).

How was it done?

Soil was taken from 0-10 cm depth from three paddock research trial sites in May/June 2019 in non-sprayed and non-cropped areas. All paddocks were pastures in the 2018 season and cropped with wheat in the 2019 season. The soils were dried after collection at 70°C for 48 hours. The soil was then potted on 14 June into plastic tubs at 7.5% (w:v) soil moisture before fertiliser and seed were placed into the tubs in two seed and fertiliser rows. The tubs were placed in a glasshouse in a replicated randomized design with 3 replications.

Four placement treatments were imposed using Diammonium phosphate (DAP, 18:20:0:0). They were (i) Nil Control (no fertiliser), (ii) 60 kg/ha DAP with seed, (iii) 60 kg/ha DAP 3 cm below the seed or (iv) split application with 30 kg/ha DAP with seed and 30 kg/ha of DAP 3 cm below the seed.

The equivalent of 60 kg/ha of CL Razor wheat seed was sown at 3 cm below the soil surface, at the equivalent of 22.5 cm (9”) row spacing.

Two water rates, low (a total of 19.5%) or high (25%) were implemented on 18 June, 5 days after seeding to simulate a light or heavy rainfall event. No further watering occurred during the experiment.

Seedlings started emerging from Day 9 to Day 11 and were counted every second day from then on. The experiment was harvested 19 days after seeding on 3 July. Shoot and root dry matter were weighed after oven drying. A soil sample from around the seed at harvest from the Nil Control, 60 kg/ha DAP with seed and the split application was analysed for pH, EC, nitrate-N and ammonium-N.

What happened?

Seedling emergence after 11 days in the Minnipa soil was the same for all three placements of fertiliser and vigorous (Table 2). Emergence in the Cungena soil was highest and vigorous with no fertiliser, but was severely reduced by the presence of DAP, most severely if the DAP was all with the seed, but also when all the DAP was below the seed. Almost no plants had emerged from any treatments in the Streaky Bay soil at 11 days.

Nearly all plants had emerged from the Minnipa soil after 19 days and were vigorous (Table 3). Emergence in the Cungena soil was only lower when all the DAP had been placed with the seed. In the Streaky Bay soil, emergence was reduced by DAP all in the seed row and also when split. The lowest emergence occurred in Streaky Bay soil with DAP all in the seed row.

Table 1. Initial soil analysis results of 0-10 cm soil samples from three sites in 2019.

Soil	**Cungena**	**Streaky Bay**	**Minnipa**
Sampling date	**29 May**	**30 May**	**11 June**
DGT P (ug/L)	20	22	62
pH (water)	8.8	8.6	8.7
Texture	Clayey Sand	Sandy Clay Loam	Clayey Sand
Nitrate-N (mg/kg)	12	8	9
Ammonium-N (mg/kg)	11	33	8
*Wilting Point (vol %)	10	13	10**
*Field Capacity (%)	22	26	22**

** Based on paddock information (J Hancock, 2007). **Minnipa Ag Centre N7 paddock.*

Table 2. Soil type and fertiliser placement effect on % seedling emergence after 11 days.

Fertiliser Placement	**Cungena**	**Streaky Bay**	**Minnipa**
Nil	81	0	88
DAP below seed	63	5	94
DAP split	31	1	70
DAP with seed	10	1	71
LSD (P=0.05)		*17*	

Table 3. Soil type and fertiliser placement effect on % seedling germination after 19 days.

Fertiliser Placement	**Cungena**	**Streaky Bay**	**Minnipa**
Nil	97	96	96
DAP below seed	93	97	100
DAP split	89	85	90
DAP with seed	68	58	93
LSD (P=0.05)		*10*	

Table 4. Fertiliser placement effect on seedling dry shoot and root weight/plant after 19 days, averaged across all 3 soil types.

Fertiliser Placement	**Shoot weight (mg)**	**Root weight (mg)**
Nil	11	18
DAP below seed	10	17
DAP split	9	17
DAP with seed	9	17
LSD (P=0.05)	*1*	*ns*

Table 5. Fertiliser placement effect on salinity (EC, water) in soil averaged across the three soil types from the seed row after 19 days.

Fertiliser Placement	**EC (water)**
Nil	0.16
DAP split	0.20
DAP with seed	0.20
LSD (P=0.05)	*0.01*

DAP placed all with the seed, or split, slightly reduced early shoot dry weights (Table 4), across all soil types. DAP placed below the seed row did not reduce shoot weight of emerged plants. Root weights were the same for all placements of DAP and similar to the nil treatment.

Electrical conductivity (EC) is used to estimate salinity. With no fertiliser applied, the Minnipa soil had the lowest EC of 0.14, Cungena 0.16 and Streaky Bay 0.18. In the presence of DAP fertiliser Minnipa had an EC of 0.17, Cungena 0.21 and Streaky Bay 0.21. Salinity in soil from around the seeds was higher in the presence of DAP, regardless of whether it was split or all with the seed (Table 5).

What does this mean?

Emergence in the Minnipa and Cungena soils was higher with no fertiliser or with all the DAP banded below the seed row, compared to DAP placed with the seed or split. DAP fertiliser resulted in lower emergence in the Cungena soil than in the Minnipa soil, and the greatest impact in the Streaky Bay soil.

The Streaky Bay soil has a higher wilting point at 13% compared to the other soils at 10%, which means a greater amount of water will be tied to the soil particles in this soil type before water will become available to plant roots. The higher wilting point in the Streaky Bay soil may have affected seed swelling, germination and emergence on this soil type, however adequate water was applied in the high water treatment.

In the red loam after nineteen days nearly all seeds had emerged regardless of the placement of fertiliser. In the grey calcareous soils emergence was lower with DAP placed with the seed, and in the Streaky Bay soil type emergence was also affected with the DAP split fertiliser application, with only 30 kg/ha of DAP placed with the seed. In all soil types shoot weights decreased where DAP was placed in the seed row, but there was no effect on plant root growth with fertiliser placement. Soil testing showed the soil EC or salt level was higher with DAP placed in the seed row.

The results from this pot experiment suggest fertiliser toxicity is an issue which is reducing wheat emergence on grey calcareous soils, even at quite low application rates of 30 kg/ha DAP with the seed on some soil types. Current fertiliser guidelines would consider 30 kg/ha DAP with the seed a safe rate. On the highly calcareous soils with a high pH (8-9), adding an alkaline fertiliser product (DAP) is resulting in issues with seedling germination potentially due to salinity near the seed, especially in lower moisture conditions.

Field trials undertaken in 2019 as part of this SAGIT research on the same soil types showed plant establishment was similar at Streaky Bay and Cungena with dry sowing or sowing at the break with ideal seeding soil moisture in 2019, and at Minnipa establishment was better with dry sowing. Dry sowing increased grain yield at Minnipa by 0.2 t/ha compared to waiting for the break in the season, and there was a yield penalty if no fertiliser was applied at Minnipa. Dry sowing at Streaky Bay and Cungena reduced grain yield, by 0.7 and 0.3 t/ha respectively, compared to waiting for the break and sowing into a moist soil bed, and all three sites showed a decrease in early plant dry matter with dry sowing. The 2019 results indicate dry sowing on the grey calcareous soils using 60 kg/ha of DAP fertiliser placed with the seed is not beneficial to early dry matter production or final grain yield.

The result from this research indicate that in the grey calcareous soil types growers may want to consider the fertiliser product they are using and potentially use an acidic fertiliser product like MAP (10:22:0:0). Fertiliser placement should also be considered, as it may be beneficial to move DAP fertiliser away from the seed if this is an option. Further research on fertiliser placement and rates will be undertaken in 2020. The fertiliser placement and dry sowing effects on wheat on the red loam soils appear not to have the same negative impacts.

Further pot experiments will be conducted in 2020 to compare fertiliser types and impact on wheat emergence in calcareous soils.

Acknowledgements

This research was funded by SAGIT through the ‘Improving the early management of dry sown cereal crops’ (S419). Sincere thanks to SAGIT and their extremely valuable input into regional South Australian research and researchers. Thank you to Ian Richter, Katrina Brands, Steve Jeffs and Bradley Hutchings for their help with the experiment.

EP Soil Moisture Probe Network - summary of monitoring for three years

Andrew Ware[1], Brenton Spriggs[2], Sue Budarick[2] and Naomi Scholz[2]
[1]Formerly SARDI (now EPAG Research); [2]SARDI, Minnipa

Key messages

- **Live information for each of the soil moisture probe sites is available at: https://eparf.com.au/ then click on the yellow Soil Probe Network icon in the top right hand side and logging on using the user name: EPARF and password: EPARF.**
- **Soil moisture probes demonstrated the benefits of summer weed control.**
- **Soil moisture probes showed that pastures and pulses generally used less soil water than cereals.**
- **Soil moisture probes helped growers better understand plant water use and availability on their soils.**

Why do the trial?

This project helped to develop a network of soil moisture probes across Eyre Peninsula with the aim of providing farmers with information on how they can use the soil moisture probe data to improve their profitability through more informed decision making. Soil moisture and rainfall are key drivers of both grain and pasture yield on Eyre Peninsula. Improved understanding of how a given soil type is able to store water and then how crops or pasture can then utilise that water should provide some indication of how effective management strategies are. This article builds on the article Soil moisture probe network - using soil water information to make better decisions on Eyre Peninsula from EPFS Summary 2017, p59.

How was it done?

In September 2016 a network of soil moisture probes was created across Eyre Peninsula by linking new and existing (EPNRM and LEADA funded) soil moisture probes and providing access to the data via the EPARF website. The network currently consists of 37 probes in locations representing most major soil type/environments across Eyre Peninsula.

In addition, weather stations capable of logging temperature, humidity and wind speed have been installed at 16 soil moisture probe sites funded through contributions by EPARF, AgFarm and GRDC. This data can also be accessed by logging into the soil moisture probe network via the EPARF website.

Sites adjacent to each probe were soil tested in March/April (2017, 2018 and 2019) for soil chemistry and pre-seeding soil moisture. Further soil testing was conducted around crop maturity (October/November 2017 and 2018) to determine the amount of soil moisture left at the end of the growing season.

What happened?

This project was able to determine plant available water capacity of major soil types at 29 sites across Eyre Peninsula and created a live platform to view soil moisture and meteorological data at 37 sites.

Much of the information generated relates specifically to the part of the paddock where the soil moisture probe is located and will have most relevance to the grower whose property on which the probe is located. However, the data is also relevant to other growers with the same soil type and in similar environments to each probe.

There were many commonalities across sites and this project was able to demonstrate that soil moisture probes were able to:

1. Demonstrate the benefits of summer weed control

The soil moisture probe rainfall gauge indicated that 36 mm of rain fell between 5-7 February 2017. The soil moisture probe was able to show that all of this rainfall was removed (mostly by summer weeds) by 20 February 2017 (Figure 1).

2. Demonstrate the effectiveness of different crop types in extracting moisture

The paddock around the probe shown in Figure 2 grew wheat in 2018 and it can be seen that this crop had used the maximum amount of water ever recorded at this site, by late October. The heavy line going straight through the plot a bit below halfway was the maximum amount of soil moisture that a field pea crop was able to use in 2017. This was quite common at most of the probe sites where pulse crops and pastures did not use as much soil moisture as cereals and canola crops.

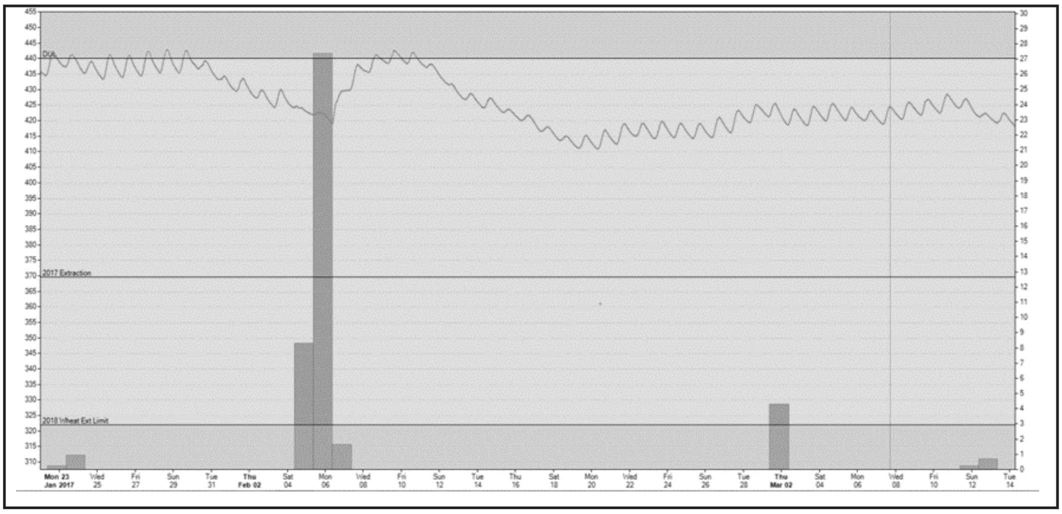

Figure 1. Total soil moisture present at a probe site (serrated line near top) during February 2017. The solid bars show rainfall.

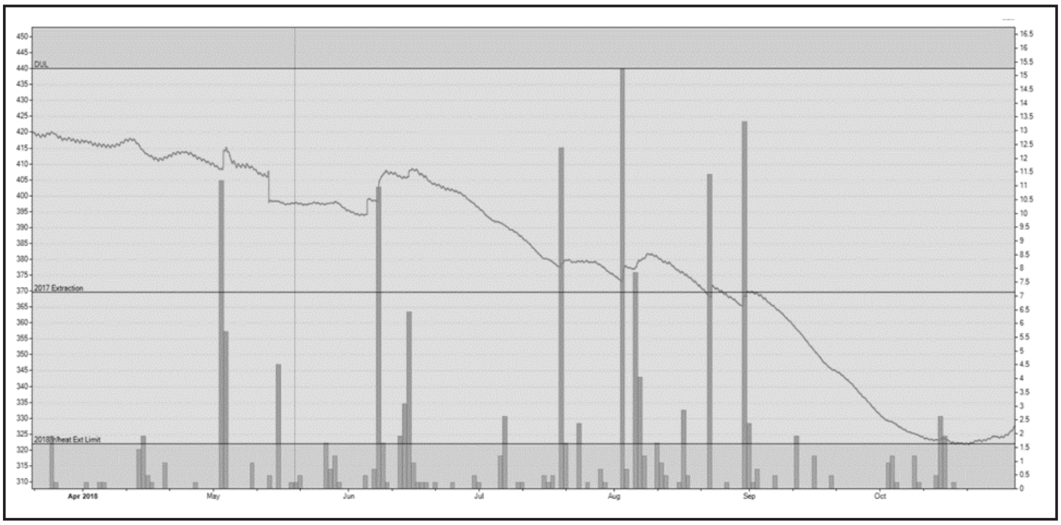

Figure 2. Graphical representation of soil water at a site in 2018 (the line gradually declining from left to right). Solid bars show rainfall events.

What does this mean?

A survey of 106 growers and advisors conducted in March 2019 indicated how they would use the information the soil moisture probes generate for decision making. A summary of their responses is listed below:

- N application x 7
- Grain marketing confidence increased x 2
- Time of sowing decisions
- Weather Stations (including FDI) x 3
- Summer weed spraying x 3
- Increased confidence of sowing
- Risk management - dry sowing knowing moisture at depth, confirm gut feel
- Target yield, knowing bucket size
- When we have enough confidence, it will help us make every decision
- Measuring WUE and stored soil moisture to know what's going on
- Know where frost has occurred (quicker decision can be made)
- Crop choice at start of season
- Towards end of season - how much is left for pasture/crop

The authors appreciate the feedback farmers and advisors have provided on how the soil moisture probe network could be improved, especially in relation to the how they can access the data, additional information they would like to see and how it is presented. These will all be addressed as part of the new Australian Government's National Landcare Program Smart Farm Project: Resilient & Profitable Farming on EP, so that the soil moisture probe network evolves to become a highly useful resource providing live, easily accessible information that will improve in-season decision making.

Acknowledgements

SAGIT for funding project EP216. EPARF, LEADA, EPNRM and Agfarm for also providing funding that has contributed to developing the soil moisture probe network. The various grower co-operators for allowing us to access to the soil moisture probes on their properties. Shane Oster, Alpha Group, for maintaining the probe network and developing the website platform so that soil moisture probe information can be viewed. Leighton Wilksch, Agbyte, for access to the data generated from the probes he installed.

Climate information for EP farmers and advisers

Peter Hayman and Dane Thomas

SARDI Climate Applications, Waite

Key messages

- **A positive phase of the Indian Ocean Dipole (IOD +ve) developed during the 2019 growing season. This phase of the IOD is associated with increased chances of warmer and drier springs.**
- **To make better sense of forecasts it is important to understand the difference between weather and climate and how multi-week forecasts are starting to blur this distinction.**

The positive IOD in 2019

The Indian Ocean Dipole is clearly explained on the Bureau of Meteorology website http://www.bom.gov.au/climate/iod/. Events usually start around May or June, peak between August and October and then decay when the monsoon arrives in the southern hemisphere. A positive phase of the IOD developed in 2019. This phase is associated with increased chances of warmer and drier springs. Figure 1 shows August to October was drier than average at Minnipa (23 mm below average of 100 mm), Kimba (70 mm below average of 110 mm) and Cummins (40 mm below average of 131 mm). Since 1960 there have been 11 IOD positive events; 8 have been below average at Minnipa and Cummins and 9 of the 11 at Kimba. As can be seen on the graph, positive IOD years change the odds, but the reduction in rainfall can be small or large. Growers and agronomists can check the historical impact of IOD and ENSO on their location using the local climate tool at a website developed by AgVic, SARDI and Federation University as part of a GRDC project https://forecasts4profit.com.au/.

The different time scales of weather, seasonal climate and climate change

Although the terms weather and climate are often used interchangeably, the distinction is important because there are differences in what is being forecast, how the forecast is made and the accuracy of the forecast. Weather is a ‘snap shot’ of the atmosphere at a particular time. Weather is determined by the timing of individual synoptic events such as a cold front or high-pressure systems and can last between a few hours to a week. Climate is some composite or average of the weather over time.

Weather forecasts are mostly based on numerical models; these are initiated from the current state of the atmosphere and used to predict future states of the atmosphere, including the timing and amount of rainfall for the coming week. Seasonal climate forecasts typically give the chance of the next 3–6 months being wetter or drier than the long-term average. Rather than being influenced from the inherently chaotic dynamics of the atmosphere, they are based on patterns of the sea surface temperature (SST) and associated atmospheric characteristics.

Up until 2013, Australian seasonal outlooks were based on statistical relationships between sea surface temperatures or the southern oscillation index. Since 2013 the Bureau of Meteorology has used dynamic models which are similar to numeric weather models but run at a coarser spatial scale and daily rather than hourly. These dynamic models can deliver multi week (2-6 weeks) forecasts that bridge the gap between weather (next week) and climate (3 months ahead). The multi-week forecasts are more usefully seen as bringing the forecast period of climate forecasts earlier rather than extending weather forecasts.

Bureau of Meteorology forecasts – more forecasts more often

Because of the access to computing power and dynamic forecasts the Bureau of Meteorology has recently started producing more climate outlooks, more often. In addition to more frequent updates on the seasonal timescale, there is information on the coming weeks, fortnights and months. The GRDC is contributing to a larger applied research project funded by the Commonwealth Department of Agriculture called Forewarned is Forearmed. This project is working with the Bureau of Meteorology to develop forecast products on weather and climate extremes at the multi-week and seasonal time scale. Products from this project will be available in coming months.

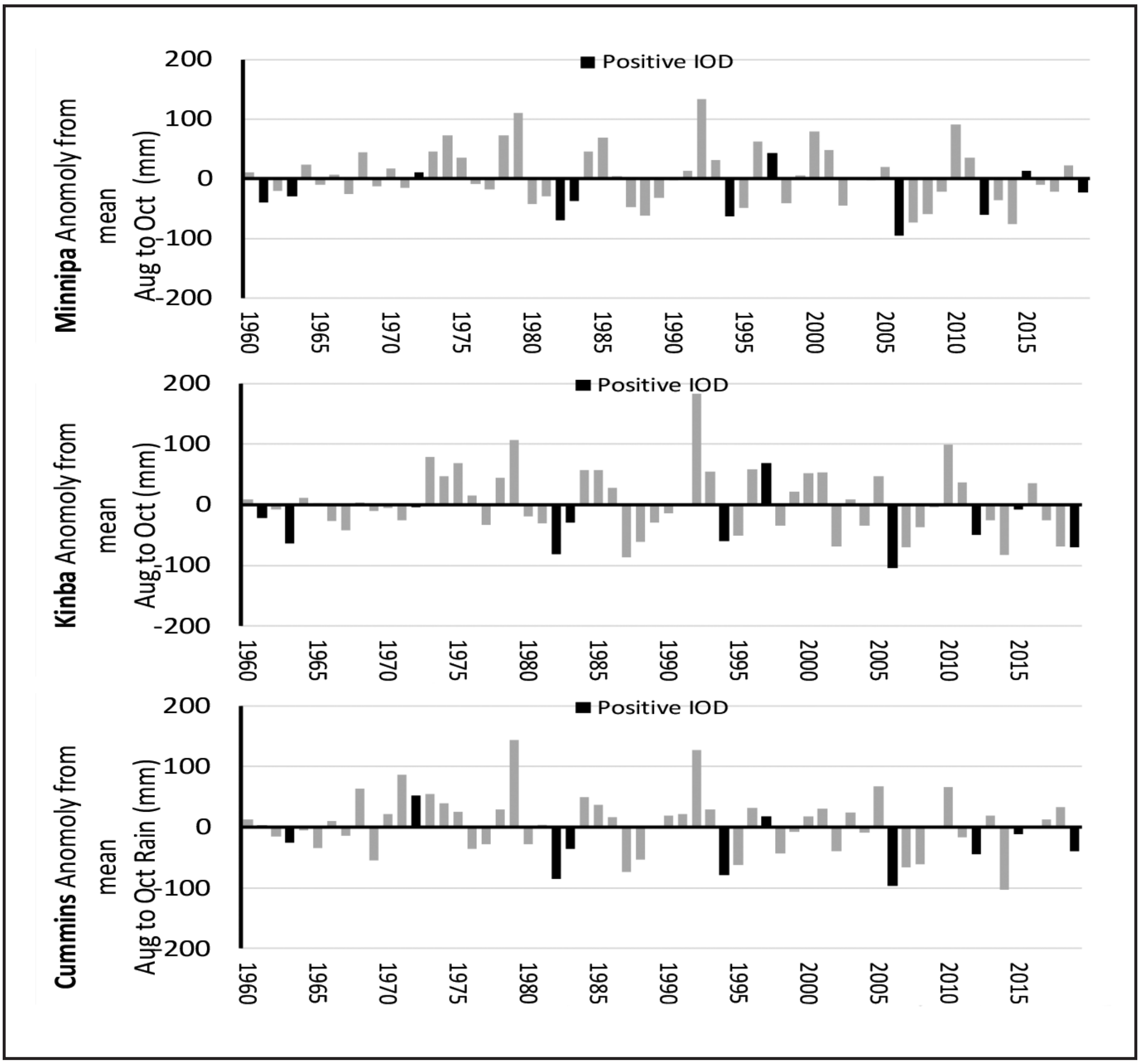

Figure 1. August to October rainfall anomalies in mm for 1960 to 2019 for Minnipa, Kimba and Cummins showing the positive IOD years in black bars.

Linking future climate information to current soil water status

Dryland farming on EP is about managing water. Successful farmers capture as much water as possible and then maximise the efficiency of water use in the crop and pasture systems. A recent development has been the network of soil moisture probes providing real time information on soil water. As part of a larger project managed by EPARF and funded through the Australian Government's Smart Farming Partnerships, SARDI Climate Applications will be working with advisers and farmers to link what is measured (water stored in the soil) with historical and forecast information about rainfall in the coming season.

While short term weather forecasts are very accurate and getting better and better, improvements in seasonal climate information are slower and harder to gauge. Seasonal forecasts still fall into the category of "too good to ignore but not good enough to be sure". Nevertheless, there is information that changes the odds on the coming season and some farmers and agronomists are incorporating the information into risk management.

Acknowledgements

Rural R&D for Profit Project 16-03-007 Forewarned is Forearmed. GRDC Project "Using seasonal forecast information and tools to manage risk and increase profitability in the southern grains region" GRDC project code 9176117. Smart Farming Program Round 2- A new paradigm for resilient and profitable dryland farming on the Eyre Peninsula using data to improve on-farm decision making.

Which oat varieties performed best for hay production at Kimba in 2019?

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SARDI, Minnipa Agricultural Centre

Location
Kimba - T, K & R Cliff
Rainfall
Av. Annual: 340 mm
Av. GSR: 220 mm
2019 Total: 149 mm
2019 GSR: 132 mm
Paddock history
2018: Scepter wheat
2017: Scepter wheat
2016: Mace wheat
2015: Peas
Soil type
Red loam
Plot size
2 m x 12 m x 3 reps

Key messages

- **All oat varieties achieved over 8% protein and estimated metabolisable energy greater than 9 MJ/kg DM in both 2018 and 2019, so would meet export hay quality.**
- **The recommended oat varieties to grow in the Kimba region are Durack, Yallara, Brusher or Wallaroo. Brusher and Wallaroo performed well in 2018.**
- **Durack is ready for hay cutting at a much earlier time than other varieties.**

Why do the trial?

Farmers in the Kimba area have been producing oaten hay for export for several years. The industry has been expanding, with dedicated storage facilities established in recent years on the outskirts of Kimba. To maximise production and quality, the Buckleboo Farm Improvement Group wanted to identify the best current oaten hay variety for the Kimba area. For the 2018 oat variety results see EPFS Summary 2018 p100.

How was it done?

Seed for seven oat varieties and one grazing barley variety were supplied by Balco. The 2019 trial was sown with SARDI small plot equipment on 2 May into moist seed bed conditions (wet to 10 cm only) with 60 kg/ha of DAP fertiliser (18:20:0:0). Seeding rates for every variety were targeted to an establishment of 180 plants/m^2. On 23 July 50 kg/ha of urea was applied to the trial. No pre-emergent herbicides were applied, and Amine 625 @ 1 L/ha was applied post emergent for broadleaved weed control.

Plant establishment was counted on 27 May, with dry matter cuts taken on 1 July, 19 July, 19 August, 23 August and 2 September. Plant height was measured on 2 September. Dry matter samples, simulating hay production, from the 2 September cut (except Durack and Yallara which were taken on 23 August) were dried for 48 hours at 40°C and sent for feed quality analysis using FeedTest. The trial was not harvested for grain yield.

The trial was a randomised complete block design with three replications. Data was analysed using Analysis of Variance in GENSTAT version 19. The least significant differences are based on F prob=0.05.

What happened?

The 2019 season was very dry for Kimba with below average rainfall for all months, and growing season rainfall was a decile 1. Despite the season, seeding soil moisture and crop establishment was reasonable by 27 May, despite being lower than targeted (Table 1).

There were differences in dry matter production between the oat varieties with Yallara performing the best in the dry conditions (Table 1). Moby barley was extremely drought stressed and was very short. Durack and Yallara matured earlier than the other varieties and the feed quality test samples at hay cutting were taken 9 days before the other varieties. There were no differences in feed quality between the oat varieties in 2019 (Table 2).

About the recommended varieties

Durack is an extremely early, moderately tall variety released in WA. It is similar in height and yield to Yallara. Durack is the earliest maturing oat variety of any variety currently available. Durack has good lodging and shattering resistance and good early vigour. Grain quality for this line is excellent. Hay yield averaged over low, medium, and high rainfall sites is lower than other longer season varieties. Care will need to be taken to cut this very early maturing variety at the correct growth stage and monitoring the crop will be the key to achieving the highest hay quality (SARDI Oat Newsletter, 2018).

Table 1. Establishment and growth of hay varieties at Kimba in 2019.

Variety	**Plant establishment (plants/m^2)**	**Dry matter (t/ha)**				**Average height (cm)**
Date	27 May	1 July	19 July	19 Aug	2 Sept	2 Sept
Brusher	142	0.26	0.59	1.16	1.05	21
Durack	144	0.32	0.93	1.28	1.40*	26
Mulgara	130	0.26	0.71	1.33	1.13	22
Swan	129	0.31	0.75	1.21	1.03	21
Wallaroo	148	0.32	0.80	1.33	1.03	24
Wintaroo	127	0.27	0.65	1.21	1.06	22
Yallara	167	0.31	0.85	1.40	1.57*	26
Moby barley	136	0.32	0.79	0.79	1.18	8
LSD (P=0.05)	*22*	*ns*	*ns*	*0.21*	*0.24*	*2*

**Sampled on 23 August*

Table 2. Feed quality of oaten hay varieties sampled on 2 September 2019 at Kimba.

Variety	**Crude protein (% of dry matter)**	**Acid detergent fibre (% of dry matter)**	**Neutral detergent fibre (% of dry matter)**	**Digestibility (DMD) (% of dry matter)**	**Est. metabolisable energy (Calculated) (MJ/kg DM)**	**Water soluble carbohydrates (% of dry matter)**
Brusher	13.3	19.7	43.3	77.9	11.8	23.3
Durack*	9.4	20.8	40.0	76.2	11.5	33.9
Mulgara	10.6	21.6	42.1	76.7	11.6	27.0
Swan	10.3	19.8	41.8	78.2	11.8	29.8
Wallaroo	10.1	21.6	45.2	74.6	11.2	23.9
Wintaroo	11.0	20.1	41.4	78.8	11.9	29.0
Yallara*	8.8	20.1	39.2	77.9	11.8	36.0

**Sampled on 23 August*

Yallara is a medium tall, early to mid-season variety. Released in SA in 2009, Yallara is a milling line. Yallara was evaluated for hay production, and hay yield is similar to popular hay varieties with excellent hay quality.

Brusher is an early to mid-season tall line which is three to seven days earlier to head than Wintaroo and this suits it well to low rainfall areas. It has good early vigour, and excellent hay yield in low to medium rainfall zones and has consistently had excellent hay quality to match the yield. Brusher is an improvement compared to Wintaroo for hay quality, stem rust, leaf rust, bacterial blight and septoria resistance. It is resistant but moderately intolerant to CCN and stem nematode.

For further information regarding other oat varieties please see EPFS Summary 2018, p100.

What does this mean?

2019 was a very tough season at Kimba. The season started well with seeding occurring after 16 mm of rainfall, but only small rainfall events followed with a dry winter and spring. Plant growth was very slow due to drought stress.

Durack and Yallara had the greatest dry matter production in a tough season and matured earlier than the other varieties. There were no differences in feed quality between the varieties at Kimba in a very dry season. Durack matures for hay cutting at a much earlier time than other varieties than growers may be used to, so this may need to be factored into seasonal work programs.

In 2019 in drought conditions, Durack and Yallara were the best hay oat varieties. In 2018 Brusher and Wallaroo also performed well. All oat varieties achieved over 8% protein and estimated metabolisable energy greater than 9 MJ/kg DM in both seasons, so would meet export quality standards. Other export standards that need to be met include colour, weather damage and weed seeds.

The recommended oat varieties to grow in the Kimba region based on these local trials would be Durack, Yallara, Brusher or Wallaroo.

Acknowledgements

The BigFIG group wish to acknowledge funding from BALCO and National Radioactive Waste Management Facility Community Benefit program.

Thanks to Trevor, Kerri and Randall Cliff for having the trial on their property and to BigFIG for the opportunity to run the trial. Thank you to Steve Jeffs and Katrina Brands for helping with the trial sowing and sampling, and Balco for providing the seed.

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Taking hay to the next level

BUCKLEBOO FARM IMPROVEMENT GROUP

SARDI
R&D
SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE

Export hay analysis for Buckleboo

Ed Hunt[1] and BigFIG[2]

[1]Consultant, Wharminda; [2]Buckleboo Farm Improvement Group

Location
Buckleboo
Rainfall
Av. Annual: 340 mm
Av. GSR: 220 mm
Soil type
Sand, red sandy loam, heavy red clay loams

Key messages

- **Including export hay in the farming system is increasing risk from a financial point of view where hay values are less than $145/t at Buckleboo.**
- **Only at higher hay prices of $210/t and above is it worth cutting hay in a decile 1 year.**
- **In a decile 1 year, if the grower is able to cut hay with their own header to reduce the costs, the breakeven price will be $170/t.**

Why do the analysis?

The hay industry has recently expanded on Eyre Peninsula into the lower rainfall areas especially in the Buckleboo area. The Buckleboo Farm Improvement Group wanted to do an economic analysis to look at the viability of hay in the rotation and whether there is an increase in financial risk.

How was it done?

A whole of farm gross margin analysis was used to look at two scenarios typical of the district:

1. Hay included in the rotation
2. No hay in the rotation

The percentage of export hay is typical of hay producers in other parts of the state. Sheep still predominate in many cropping programs and can capitalise on hay of poorer quality.

Soil types

Yields both with cereals and export hay are sensitive to soil types. A typical range of soil types (finishing ability) was used in the analysis.

These percentages were deemed representative of the Buckleboo area which has a higher percentage of heavier and loam soils compared to other areas of the Eyre Peninsula.

Hay value

Hay value is based on a number of quality parameters. One of the advantages of hay in the Buckleboo area is the quality is generally better than hay grown in higher rainfall environments.

Decile 7 yields at Buckleboo of 5 t/ha is equivalent to the amount grown in Clare in a decile 3 season. These lower yields generally have higher quality and therefore a higher price.

Weather damage will occur in 10% of years where hay value can drop to the lowest price of $80-$90/t and needs to be taken into account.

Grain values

Wheat $253/t, barley $215/t.

Source: http://agprice grainandgraze3.com.au, August 2018.

Machinery investment

Additional machinery investment was costed in as the 'no hay' example had a greater harvesting requirement due to the larger area to be harvested.

Standard machinery investment is $300 of machinery per ton of grain produced. Harvest equipment comprises approximately one-third of most farmer's machinery costs. Therefore $100/t of grain produced was used with a 10% depreciation/replacement value costed into the analysis in the 'no hay' scenario.

All hay activities were contracted at the rates given in Table 3.

Table 1. Whole farm gross margin analysis with and without export hay enterprises.

Enterprise	With export hay (%)	Without export hay (%)
Wheat	45	50
Barley	20	25
Pasture – self replacing merino	20	25
Export oaten hay	15	-
Total	100	100

Table 2. Percentage of area of different soil types used in the whole farm analysis.

Soil type	Percentage
Heavier harder finishing soils	30
Loams good finishing soils	50
Sands poorer nutrition but good finishing	20

Table 3. Contract rates for hay operations (local contracting rates in 2018-19).

Mowing/Conditioning/Raking	$60/ha
Baling	$34/t
Freight & loading to Kimba	$20/t

Grain and hay yields for each soil type for each season by crop type (t/ha)

Table 4. Wheat grain yield (t/ha) for seasonal decile by soil type.

Wheat	Season deciles				
	1	3	5	7	9
Sand	0.75	1.3	1.5	2.5	2.8
Loam	0.75	1.3	1.7	2.5	3.5
Heavy	0.3	1.1	1.6	2.8	3.6

Table 5. Barley grain yield (t/ha) for seasonal decile by soil type.

Barley	Season deciles				
	1	3	5	7	9
Sand	0.75	1.3	1.5	2.5	2.8
Loam	0.75	1.3	1.7	2.5	3.5
Heavy	0.3	1.1	1.6	2.8	3.6

Table 6. Oat hay yield (t/ha) for seasonal decile by soil type.

Oaten hay	Season deciles				
	1	3	5	7	9
Sand	1.5	3	3.5	4	5
Loam	1	2.5	3.5	5	6
Heavy	0	1.5	3	5	6.5

Fertiliser inputs

P fertiliser was costed in as a P replacement of 3.5 kg P/t for grain yields and 1.5 kg P/t for hay yields. Nitrogen was costed in on a soil type by season basis.

The urea rates are based on the N required to drive the yields for both grain and hay.

Potassium

Generally, the loam to heavy soils have adequate potassium. With only 15% of the areas going to hay, the potassium levels will take time to run down however, they should still be monitored. The sands can be more problematic for potassium issues and should definitely be monitored. Additional potassium on the sand has not been costed in due to the hay being only 15% of the program and the sandy soils comprising only 20% of the farm. However, it is an issue that may need addressing.

Chemical use

Standard chemical inputs have been costed in however, there is additional weed control when not incorporating hay. This was taken in to account and an additional $5/ha costed into the cereal years where hay is not included.

Sheep

The sheep enterprise is a self-replacing merino flock at 100% lambing. Wool value $10/kg, lamb value $120/head net, cull ewe value $100/head net, stocking rate 2.2 DSE/ha.

Table 7. Urea rate (kg/ha) for seasonal decile by soil type.

	Urea rate (kg/ha)				
Soil type	**Decile 1**	**Decile 3**	**Decile 5**	**Decile 7**	**Decile 9**
Sand	25	25	50	75	100
Loam	25	25	50	75	100
Heavy	25	25	25	50	50

Table 8. Gross margin ($/ha) at Buckleboo for seasonal decile by hay price.

		Hay value ($)/ t at Buckleboo					
Buckleboo		**90**	**130**	**145**	**170**	**210**	**250**
Decile	**No Hay**	**With Hay**					
1	42	28	30	32	35	40	**45**
3	137	113	127	132	**141**	**154**	**168**
5	186	159	179	186	**199**	**218**	**238**
7	322	282	311	322	**339**	**368**	**396**
9	434	383	419	432	**454**	**489**	**525**

The bold text highlights where hay included in this scenario has improved profitability.
Light grey indicates where profitability is similar.
Dark grey indicates where profitability is less where hay is included.

What happened?

Financial analysis

The analysis is based on a gross margin but also considers interest payable on additional expenditure and additional cost of harvest machinery in the 'no hay' scenario.

What does this mean?

Risk

To compare scenarios on a risk basis is how they perform at the lower deciles (1 & 3). Hay included in the farm system is increasing risk from a financial point of view where hay values are less than $145/t at Buckleboo. At $170/t it is only the decile 1 year where hay included is a riskier option. By choosing not to cut and bale in the decile 1 season the losses are minimised, so it is only at the higher hay prices of $210/t and above that is it worth cutting in the decile 1 year. The other factor to consider in the decile 1 year is the farmer using their own header (if suitable) to cut hay therefore reducing the costs? This brings the breakeven price down to $170/t.

There are other risk factors to consider based around experience in making good hay, availability and expertise of contractors and extending the stress period prior to harvest when hay is being made.

Acknowledgements

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Benchmarking water limited yield of cereal crops on major soil types across Eyre Peninsula

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Key messages

- **Positive relationships (R^2=0.6) were observed between water and grain yield (t/ha) across 14 Eyre Peninsula (EP) paddocks.**
- **Yeelanna (Pooh Bear paddock, clay loam over light clay) had the highest grain yield (5.8 t/ha) across the 14 EP paddocks and 100% of yield potential achieved.**
- **Karkoo, Yeelanna (South West) and Witera had similar grain yield (3.82-4.70 t/ha), but only Witera had over 100% yield potential achieved.**
- **Paddock yields were also affected by soil constraints and other abiotic stresses.**

Why do the trial?

This research aims to determine in which situations extra fertilisation can bring benefits to growers in 14 different Eyre Peninsula (EP) environments.

Every season, growers need to make choices over limited resources in order to optimise their profitability. Soil type and water represent two of the key limiting resources which define the grain yield potential of a paddock. The unpredictability of growing season rainfall patterns restricts in-season fertiliser applications for EP growers, due to the associated high economic risks. As a risk management strategy, growers often apply lower rates of nutrients than required to achieve the water limiting yield potential (Sadras and Roget 2004, Monjardino *et al*. 2013). Therefore, less than optimum nutrient rates are applied in many instances, and maximum grain yield gains are not reached on occasions where opportunities have existed. Understanding soil water and nutrient dynamics can be useful to determine when in-season extra fertiliser applications are worth the investment in EP dryland farming systems.

This study used a subset of the Eyre Peninsula Agricultural Research Foundation (EPARF) soil moisture probe network locations to benchmark the water limited yield potential and determine the achievable grain yield of cereals crops across major soil types of EP.

How was it done?

From the 37 sites, 14 sites were selected to represent major soil types of EP (Table 1). At pre-sowing and post-harvest, three soil cores per paddock were collected to 100 cm and divided in four depth intervals: 0-10, 10-30, 30-60 and 60-100 cm. Each soil core at each depth interval was split in two sub-samples. One subsample was used to calculate soil moisture and the other one was sent to the CSBP laboratory for nutrient testing. The subset of soil samples that was taken for testing nutrient content was dried in an oven (35°degrees until constant weight), sieved and sent to the CSBP laboratory.

Soil moisture was measured using the gravimetric method. A volumetric estimate was calculated considering the bulk density information from the nearest APSOIL sites, then the volumetric estimates were converted into mm of water.

Three harvest biomass cuts of 1 m^2 were collected in each paddock near the moisture probe for estimating grain yield and thousand grain weight. Benchmarking grain yield was performed following the formulae from Hunt and Kirkegaard 2012:

- Crop water use (CWU) was calculated as: CWU= Growing season rainfall + (soil moisture at sowing - soil moisture at maturity).
- Potential yield (kg/ha) = 22 (water use efficiency) x (CWU - 60* (evaporation)).
- % yield potential achieved = (Actual grain yield (kg/ha)/ Potential yield (kg/ha) x 100.

**Low evaporation rate benchmark updated by Angus and Sadras (2006) to allow for the introduction of semi-dwarf wheats, increases in atmospheric carbon dioxide and crops grown on sandy soils where evaporation is very low.*

When using this formula, care must be taken when considering particular soil types. Crops in some heavy soils will rarely come close to the benchmark or can go over the benchmark in case of some loam soils (Hancock *et al*. 2006).

Statistical analyses were performed using R software. The least significant difference (LSD) test was applied to assess differences between paddocks.

Table 1. Location, crop type, soil type, sowing date, seeding rate and harvest cut date of 14 selected paddocks across EP in 2019.

Location	Crop	Soil	Sowing date	Seeding rate (kg/ha)	Harvest cut date
Minnipa (Condada)	Scepter wheat	sand over sandy loam	22 May	65	11 Dec
Pygery	Scepter wheat	loam over clay loam	12 May	60	21 Oct
Elliston	Scepter wheat	calcareous loam	9 May	60	5 Nov
Karkoo	Emu Rock and Scepter (50:50) wheat	sandy loam over sand	6 May	100	23 Nov
Yeelanna (Pooh Bear)	Scepter wheat	clay loam over light clay	29 Apr	100	27 Nov
Yeelanna (South west)	Scepter wheat	sandy clay loam over heavy clay	6 May	100	27 Nov
Mt Damper	Scepter wheat	sandy loam over loam	29 May	65	5 Nov
Ungarra	Scepter wheat	clay loam over red sodic clay	14 May	100	27 Nov
Witera	Scepter wheat	clay loam	20 May	75	5 Nov
Port Kenny	Scepter wheat	clay loam	12 May	75	5 Nov
Minnipa (MAC)	Scepter	loam over clay loam	10 Jun	65	23 Oct
Wudinna	Spartacus barley	silty loam over loam	2 May	55	9 Oct
Cungena	Mace wheat	calcareous loam	10 May	65	23 Oct
Streaky Bay	Mace/Axe (35:35) wheat	calcareous loam	3 May	70	23 Oct

What happened?

Growing season rainfall, soil water and nutrient levels at sowing

Karkoo, Ungarra, Yeelanna South West and Pooh Bear had the highest soil moisture levels (223, 202, 149 and 125 mm) compared to the other EP sites (Table 2). As expected, growing season rainfalls were the highest at lower EP sites (Yeelanna and Karkoo) and the lowest at upper EP sites (Wudinna and Cungena). Port Kenny, Cungena, Streaky Bay, Elliston, Yelanna South West and Ungarra had moderate to high phosphorus buffer index (PBI), suggesting that phosphorus is quickly bound to the soil and thus less available to the plant.

However, high levels of Colwell P were observed in those soil profiles (Table 2). Growers' fertiliser applications and seeding rates (Table 1) reflected the regional area, soil type and nutrition, for example: Yeelanna sites and Karkoo had 100 kg/ha seeding rate and received three different urea applications during the season to increase yield potential, while Cungena had 65 kg/ha of seeding rate and 50 kg/ha of DAP blended with sulphur (Table 2).

Relationship between grain yield and water

A linear relationship between grain yield and water supply (growing season rainfall plus soil water used) was observed across all 14 sites (Figure 1). The increase of one millimetre of water either used by cereal crops during the season (Figure 1b) or from growing season rainfall (Figure 1a) was associated with an increase of 20 kg/ha of grain yield. This result underlines the importance of water as one of the drivers of grain yield in EP environments and closely matches the potential yield model of 22 kg/ha per mm.

Benchmarking water limiting yield potential

Given the moderate linear relationship between water supply and grain yield across EP sites, potential grain yield and % of potential yield achieved was also determined (Figure 2a-b). Yeelanna (Pooh Bear) paddock had the highest grain yield across the EP paddocks with 5.8 t/ha (Figure 2a) and 100% of potential yield achieved (Figure 2b).

Table 2. Location, growing season rainfall (GSR), soil moisture, N and P rates at sowing and fertilisers type applied to each paddock in 2019.

Location	GSR (Apr-Oct) (mm)	Soil moisture 0-100 cm (mm)	Soil N 0-100 cm (kg/ha)	Colwell P 0-10 cm (mg/kg)	PBI 0-10 cm	Fertiliser applications at seeding	In crop fertiliser applications
Minnipa (Condada)	234	47	44	22	*	65 kg/ha DAP + 50 kg/ha urea	
Pygery	187	83	63	25	104	60 kg/ha Granuloc ® + 40 kg/ha urea	
Elliston	283	83	117	66	254	80 kg/ha DAP	15 July and 15 September: Zn, Mn and Cu
Karkoo	346	223	56	29	20	77 kg/ha Zincstar ® (10:22:0:0:1 plus Zn) + 50 kg/ha urea	14 June: 75 kg/ha urea 9 July: 75 kg/ha urea, 27 July: 50 kg/ha urea
Yeelanna (Pooh Bear)	346	125	63	41	52	113 kg/ha Zincstar ®	7 June: 100 kg/ha urea 31 July: 100 kg/ha urea + 1% zinc
Yeelanna (South west)	346	150	90	94	174	120 kg/ha Zincstar ®	28 June: 100 kg/ha urea 27 July: 100 kg/ha urea
Mt Damper	242	61	35	27	77	80 kg/ha DAP + 40 kg/ha urea	
Ungarra	213	203	57	33	178	UAN at 20 L/ha + 55 kg/ha of Double super (0:15:10:10)	
Witera	255	100	70	23	81	80 kg/ha 50% Urea/50% Sulphur of Ammonium	20 June: 50 kg/ha urea
Port Kenny	255	89	68	46	183	80 kg/ha MAP + 40 kg/ha urea	17 July: 50 kg/ha urea
Minnipa (MAC)	234	67	77	27	77	70 kg/ha Granuloc ® and 1% zinc	
Wudinna	187	52	79	31	113	50 kg/ha MAP + 25 kg/ha urea	
Cungena	185	59	86	49	127	50 kg/ha DAP (blend 19:16:0:6 Sulphur)	
Streaky Bay	262	68.8	64.74	52	184	70 kg/ha DAP	18 August: application of Zn, Mn and Cu

** PBI was not measured*

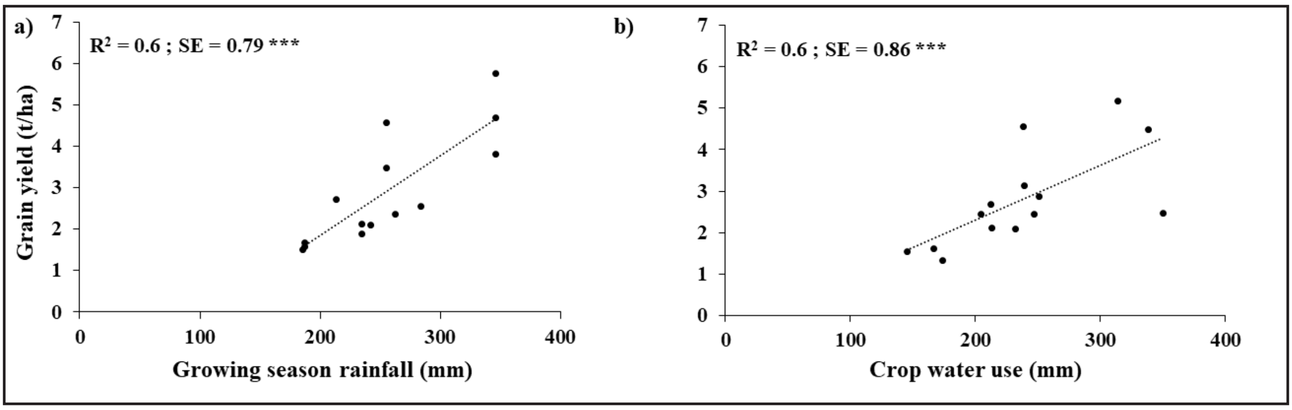

Figure 1. Relationship between wheat grain yield (t/ha) and water supply (growing season rainfall (mm))(a) and crop water use (b)) across 14 locations on Eyre Peninsula in 2019.

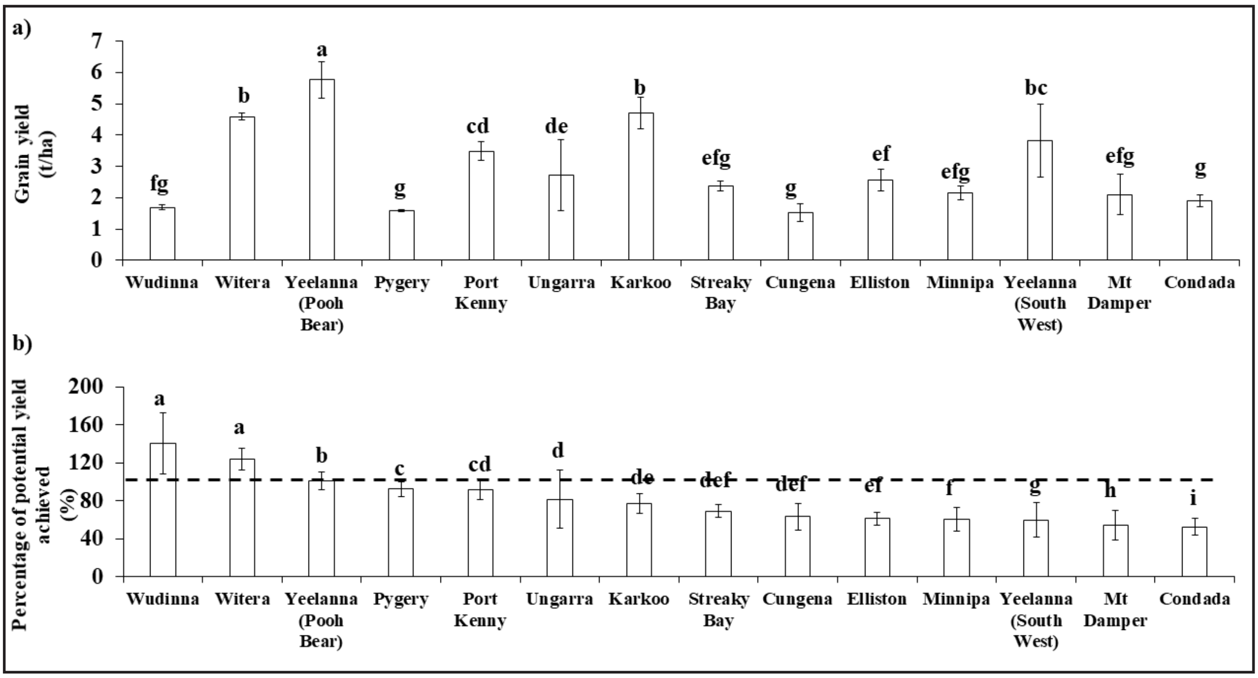

Figure 2. Grain yield (a) and percentage of potential yield achieved (b) of 14 locations on Eyre Peninsula in 2019. Dotted line indicates 100% of yield achieved. Sites followed by the same letter are not statistically different (P=0.05).

The high water input across the season was successfully matched with multiple urea applications by stem elongation (Table 2). Karkoo, Yeelanna (South West) and Witera had similar high grain yield (3.8-4.7 t/ha), however, only Witera had 123% of yield potential achieved (Figure 2b). Yeelanna (South West) and Karkoo had 60-77% of yield potential achieved, possibly due to soil constraints (Table 2, PBI) and frost during the season. Wudinna had the highest % of potential yield achieved (140%, Figure 2b) across all EP sites. However, the potential grain yield at Wudinna was associated with lower levels of grain yield (1.7 t/ha, Figure 2a), which were similar to Pygery (1.6 t/ha), Streaky Bay (2.4 t/ha), Cungena (1.5 t/ha), Minnipa (2.1 t/ha), Mt Damper (2.1 t/ha) and Condada (1.9 t/ha, Figure 2a). Port Kenny and Ungarra had comparable grain yields (2.7-3.5 t/ha) and % of potential yield achieved (82-92%, Figure 2b). At the Elliston paddock, grain yield reached 2.6 t/ha, however, the % of yield potential was only 61% (Figure 2b), possibly due to soil constraints (high levels of P fixed in the soil).

What does this mean?

In this study, our findings suggest:

1. Water supply (growing season rainfall) is one of the main drivers of grain yield. Water use explained at least 50% of the variation associated with grain yield across 14 EP paddocks. These results support the findings of Sadras *et al*. (2002).
2. An example of successful matching of water and nitrogen to maximise yield potential was observed at Yeelanna (Pooh Bear). An extra 100 kg/ha of N was added by stem elongation in three separate applications to match the seasonal water input and 100% of potential yield was achieved. These findings support the work of Sadras and Cossani on co-limitation of water and nitrogen in cereal crops (Cossani *et al*. 2019, Cossani and Sadras 2018, Sadras 2002-2006, and Arsego *et al*. 2018).
3. Water limited yield was also affected by subsoil constraints, such as moderate to high P fixation in the soils as previously observed by Sadras *et al*. (2002) and also frost damage in 2019.

Further research would need to focus on defining the soil moisture holding capacity or ‘bucket size’ of major soils of EP.

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References

Arsego, F., *et al*. “Nitrogen application at stem elongation, is it worth the investment?”. Eyre Peninsula Farming Systems Summary (2018):180-184

Cossani, Cesar Mariano, and Victor O. Sadras. “Water-nitrogen co-limitation in grain crops.” Advances in Agronomy 150 (2018): 231-274.

Cossani, C. Mariano, and Victor O. Sadras. “Increasing co-limitation of water and nitrogen drives genetic yield gain in Australian wheat.” European Journal of Agronomy 106 (2019): 23-29.

Hancock, J. “Water use efficiency of crops and pasture”. Eyre Peninsula Farming Systems Summary (2006): 87-90

Hunt, J. R., and J. A. Kirkegaard. “A guide to consistent and meaningful benchmarking of yield and reporting of water-use efficiency.” (2012).

Monjardino, M., *et al*. “Are farmers in low-rainfall cropping regions under-fertilising with nitrogen? A risk analysis.” Agricultural Systems 116 (2013): 37-51.

Sadras, Víctor. “Interaction between rainfall and nitrogen fertilisation of wheat in environments prone to terminal drought: economic and environmental risk analysis.” Field Crops Research 77.2-3 (2002): 201-215.

Sadras, Víctor O. “Yield and water-use efficiency of water-and nitrogen-stressed wheat crops increase with degree of co-limitation.” European Journal of Agronomy 21.4 (2004): 455-464.

Sadras, Víctor O., and David K. Roget. “Production and environmental aspects of cropping intensification in a semiarid environment of South eastern Australia.” Agronomy Journal 96.1 (2004): 236-246.

Sadras, Victor O., and John F. Angus. “Benchmarking water-use efficiency of rainfed wheat in dry environments.” Australian Journal of Agricultural Research 57.8 (2006): 847-856.

GRDC GRAINS RESEARCH & DEVELOPMENT CORPORATION
Government of South Australia Primary Industries and Regions SA
SARDI SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE

Characterising water limited yield potential in calcareous soils of upper Eyre Peninsula

Fabio Arsego, Amanda Cook, Ian Richter and Neil King
SARDI, Minnipa Agricultural Centre

Location
Minnipa (Condada)
Rainfall
Av. Annual: 324 mm
Av. GSR: 241 mm
2019 Total: 254 mm
2019 GSR: 234 mm
Paddock history
2019: Scepter wheat
2018: Volga vetch
2017: Fathom barley
Soil type
Red sandy loam
Plot size
12 m x 2 m x 3 reps

Location
Streaky Bay
Rainfall
Av. Annual: 377 mm
Av. GSR: 303 mm
2019 Total: 278 mm
2019 GSR: 262 mm
Paddock history
2019: Mace wheat
2018: Medic pasture
2017: Compass barley
Soil type
Grey calcareous sandy loam
Plot size
12 m x 2 m x 3 reps

Location
Cungena
Rainfall
Av. Annual: 284 mm
Av. GSR: 239 mm
2019 Total: 208 mm
2019 GSR: 185 mm
Paddock history
2019: Scepter wheat
2018: Medic pasture
2017: Mace wheat
Soil type
Grey calcareous sandy loam
Plot size
12 m x 2 m x 3 reps

Key messages

- **Current standard practices of 50 kg/ha DAP or 50 kg/ha MAP balanced with urea below the seed provides adequate P nutrition.**
- **With adequate soil moisture, no large differences in grain yield were observed in 2019 at Streaky Bay with different granular fertiliser treatments.**

Why do the trial?

On the upper Eyre Peninsula (UEP), highly calcareous soils constitute a high proportion (more than 1 million hectares) of soils used for agricultural production (Bertrand *et al*. 2000, Bertrand *et al*. 2003). The website 'Yield Gap Australia' (http://yieldgapaustralia.com.au/maps/) identifies that the average grain yield on Western Eyre Peninsula (WEP) and UEP is between 41 and 45% of the water limited yield potential (1.5 t/ha for WEP and 1.8 t/ha for UEP). Closing the grain yield gap for wheat on UEP presents a challenge to growers, particularly on highly calcareous soils where nutrient deficiencies are common (Holloway *et al*. 2001). The production of insoluble minerals through the interaction of soil calcium carbonate with soluble nutrients such as phosphorous and trace elements (Holloway *et al*. 2001), combined with low soil moisture conditions prevents these nutrients from being readily available to the plant (Lombi *et al*. 2004). Holloway *et al*. (1999-2003) demonstrated the possibility of providing phosphorus (P) to the plant in an available form by applying fluid P fertilisers instead of granular fertilisers at seeding.

The majority of landholders in Australia, including the western and upper Eyre Peninsula currently use granular fertilisers which require good soil moisture conditions to enable uptake of nutrients by crops. Growers and advisors have noted that highly calcareous top soils dry out quickly after rainfall events, which may contribute to poor water use and nutrient extraction efficiency, and may also be a reason why diseases such as *Rhizoctonia solani* have greater impact in these soils. In addition, as a risk management strategy, growers often apply lower rates of nutrients than required to achieve the water limiting yield potential (Sadras and Roget 2004, Monjardino *et al*. 2013). A better understanding of soil moisture, root disease and factors which influence nutrient availability and the efficacy of fertilisers are needed to increase the water limited yield potential of the highly calcareous soils (McLaughlin *et al*. 2013).

Field trials were conducted in 2019 to investigate these factors on the nutrition of wheat on highly calcareous soils.

How was it done?

Trial 1: Fertiliser Trial

In trial 1, a randomised block design fertiliser trial was sown at three sites to test the effects of soil moisture on nutrient uptake and yield of wheat. The trials were located at Streaky Bay and Cungena on grey calcareous soils with differing calcium carbonate levels, and Minnipa, a red loam with low calcium carbonate. The treatments applied to Scepter wheat sown at 60 kg/ha were:

- Nil fertiliser (control)
- Nil fertiliser with a high seeding rate of 80 kg/ha
- 50 kg/ha DAP (di-ammonium phosphate)
- 50 kg/ha MAP (mono-ammonium phosphate) balanced with urea
- 50 kg/ha DAP with fluid trace elements (TE) (Zn Cu, Mn)
- 50 kg/ha DAP with a high seeding rate of 80 kg/ha
- 50 kg/ha MAP balanced with urea and fluid TE (Zn Cu, Mn)
- 5 kg P/ha as fluid fertiliser (phosphoric acid) with fluid TE (Zn Cu, Mn)
- 100 kg/ha DAP
- 100 kg/ha MAP balanced with urea
- 200 kg/ha MAP balanced with urea
- 200 kg/ha DAP with a high seeding rate of 80 kg/ha.

Trial 2: Phosphorus and Nitrogen Interaction Trial

A factorial trial was conducted to evaluate the interaction between phosphorous and nitrogen at Streaky Bay, Cungena and Minnipa (Table 1), and was used to interpret the response of commercial fertilisers in Trial 1. In this trial, Scepter wheat was sown at 60 kg/ha.

At each site, twenty plants per plot were randomly sampled to estimate root dry weight and rhizoctonia on roots within the top 10 cm soil layer at 6 weeks and 12 weeks after sowing. Root rhizoctonia disease measurements consisted of 1) counting the number of seminal roots and 2) calculating a percentage of infected crown roots.

Gravimetric soil moisture was measured in increments to 100 cm depth at sowing for each replicate, and for each plot at maturity. Soil fertility was also measured before sowing . Volumetric soil water was estimated using bulk density from the nearest APSOIL sites. Statistical analyses were performed using R software and the R package ASREML to estimate treatment variability and adjust for spatial trends in the trials. Tukey's tests were applied to assess differences between treatments.

What happened?

Soil water and fertility at sowing

Cungena and Streaky Bay had higher soil moisture (65 and 77 mm) to 100 cm than Minnipa (Table 2). Although all three sites had pasture as a previous crop, Minnipa had the lowest mineral N, organic C and Colwell P of the three sites (Table 2). Cungena and Streaky Bay sites had moderate phosphorus buffer index (PBI) values but high Colwell P (Table 2). The organic carbon levels measured at Streaky Bay and Cungena could have been due to the presence of higher calcium carbonate levels affecting the measurements (Table 2).

Table 1. Treatment details and application time (Trial 2) at Streaky Bay, Cungena and Minnipa in 2019.

Timing of treatment	Treatment details
Seeding	Phosphoric acid (water rate of 80 L/ha): 0, 5, 10 and 40 P kg/ha
Emergence	Granular urea: 0, 10, 30, and 60 kg N/ha

Table 2 Soil N, P, organic C content and soil moisture at sowing, sowing date and growing season rainfall. Plant available water capacity (PAWC) information taken from Hancock* et al.*, 2007.

Trials 2019	Mineral N 0-100 cm (kg/ha)	Colwell P 0-10 cm (mg/kg)	PBI 0-10 cm	Soil moisture 0-100 cm (mm)	Organic carbon 0-10 cm (%)	Sowing date	Growing season rainfall (Apr-Oct) (mm)	PAWC (mm)
Minnipa (Condada)	44	22	76*	41	0.61	6 May	234	126
Cungena	86	49	127	65	0.96	7 May	185	38
Streaky Bay	65	52	184	77	2.28	8 May	262	96

**Data collected in the neighbouring paddock next to a soil moisture probe*

Water limited grain yield (Trial 2)

The phosphorus and nitrogen interaction fluid fertiliser trials showed grain yield increases were associated with 40 kg/ha of P at Minnipa and Cungena (Figure 1). Minnipa and Cungena had the highest increases compared to the nil treatment with 11 and 12% increase in grain yield compared to the nil respectively (Figure a-b). Streaky Bay had no yield difference across treatments (Figure c). These results may be explained by the higher solubility of P and other nutrients due to the higher growing season rainfall (Table 2) with 262 mm at Streaky Bay compared to Minnipa (234 mm) and Cungena (185 mm).

Water limited grain yield (Trial 1)

The granular trials performed similarly to the fluid trials in terms of average grain yield (Figures 1-2). Minnipa had 200 kg/ha of MAP balanced with urea and DAP with high seeding rate as the best fertiliser treatments with 16-18 % increase in grain yield compared to the nil (Figure 2a). However, similar grain yields were also achieved with growers' standard practices such as: 50 kg/ha of DAP or MAP balanced with urea at seeding (Figure 2a).

At Cungena, 200 kg/ha of MAP balanced with urea was also the best treatment, with a grain yield increase of 22% compared to the nil with high seeding rate, and 50 kg/ha of DAP with trace elements (Figure 2b). Although 200 kg/ha of MAP balanced with urea had the highest increase in grain yield, similar grain yields were found for the nil fertiliser with normal seeding rate and growers' standard practice of 50 kg/ha DAP at Cungena (Figure 2b). This result may be due to low soil moisture at Cungena (Table 2) that affected soil P availability and uptake.

At Streaky Bay, there were no significant differences in grain yield responses to fertiliser treatments applied at sowing (Figure 2c). The high growing season rainfall, and increased soil nutrient availability at sowing (Table 2) may have reduced the responsiveness of Streaky Bay soil to fertiliser rates.

Although Trial 2 results supported the grain yield responses to 40 units of P at Trial 1 (Figure 1 and 2), no drastic grain yield increases have been detected that justified replacing standard practices of 50 kg/ha of DAP or MAP balanced with urea.

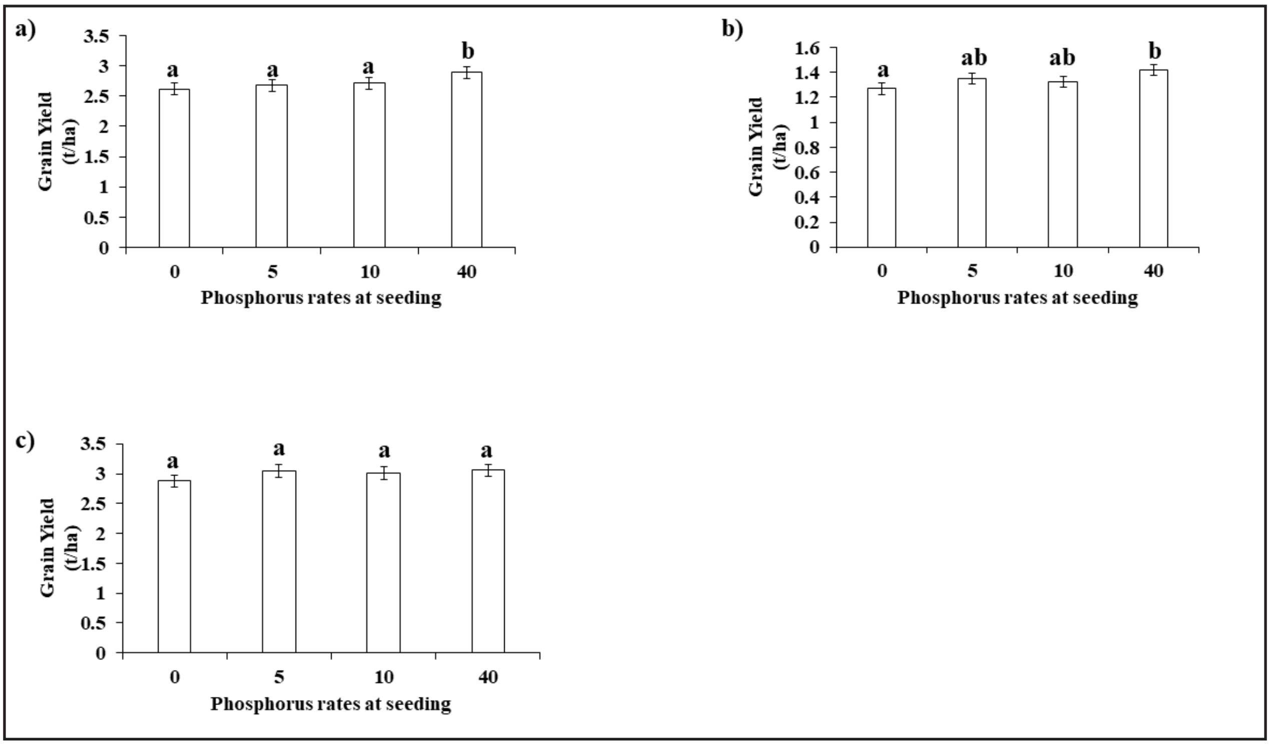

Figure 1. Grain yield (t/ha) across fluid fertiliser trials at Minnipa (Condada (a), Cungena (b) and Streaky Bay (c).

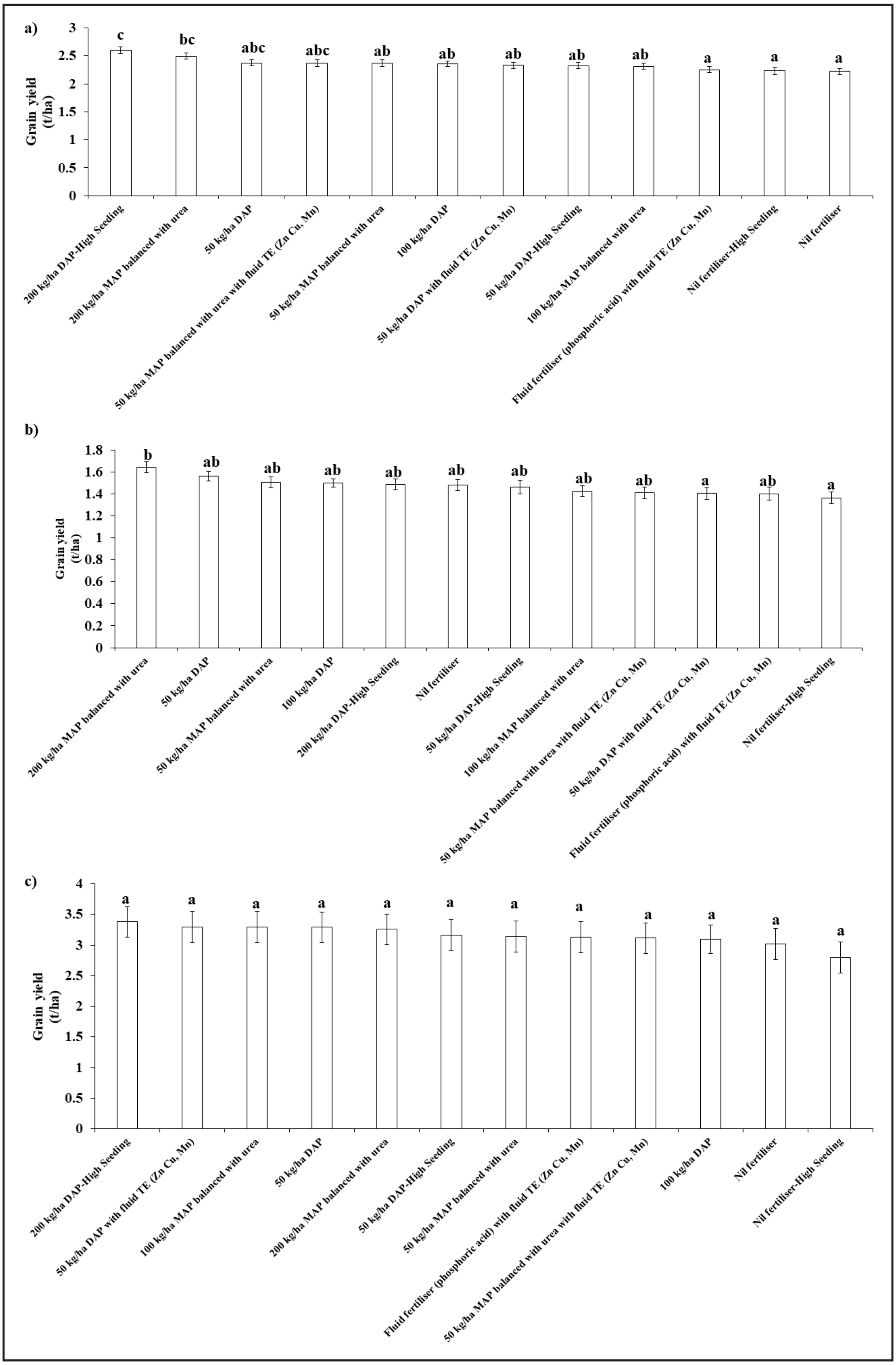

Figure 2. Grain yield (t/ha) across granular fertiliser trials at Minnipa (Condada, a), Cungena (b) and Streaky Bay (c).

Rhizoctonia infection of crown roots (Trial 2)

At Cungena and Minnipa, there were differences in rhizoctonia infection of crown roots between treatments at both sampling times (data not shown). Interactions of N and P rates were detected in response to rhizoctonia incidence. The delay in the application of N (at emergence) compared to P (at sowing) may have been responsible for an increase in rhizoctonia incidence in crown root infection across treatments.

What does this mean?

In 2019, our findings suggest:

1. 0.3-0.4 t/ha increases in grain yield compared to nil fertiliser were observed across higher input fertiliser treatments in 2019. No improved fertiliser strategies have been found to replace the current standard practices of 50 kg/ha of DAP or MAP balanced with urea below the seed applied at seeding.
2. Soil moisture and P dynamics contributed to increase grain yield of wheat in dryland farming systems. This research confirmed the findings of McBeath *et al*. 2012 where P fertiliser use efficiency was strongly affected by water input (soil moisture and growing season rainfall). The combination of soil moisture, seasonally applied P and N fertiliser inputs at Streaky Bay and Minnipa favoured high levels of grain yield.
3. Rhizoctonia crown root infection was triggered by an interaction between N and P treatments. This may have been due to soil nutrient deficiencies caused by the delayed N application (after emergence instead of at seeding). These results supported the conclusions from Cook *et al*. 2009, where nitrogen deficiencies at seeding increased Rhizoctonia incidence. Additionally, reduced rhizoctonia incidence across high input treatments in good seasons was also observed by Cook *et al*. 2011 at Streaky Bay.

Future research should focus on the soil chemistry and the development of new fertiliser formulations to unlock the soil P already fixed in calcareous soils.

Acknowledgements

This project was part of the strategic partnership between SARDI and GRDC (scoping study DAS00157). Special thanks to Matthew Cook, Myles Tomney and Phil Wheaton and families for providing the field trial sites. Thank you to Katrina Brands, Steve Jeffs and Bradley Hutchings for their collaboration with field activities. Thank you to Nigel Wilhelm and Amanda Cook for feedback and suggestions throughout the season.

References

Arsego, F., *et al*. “Nitrogen application at stem elongation, is it worth the investment?” Eyre Peninsula Farming Systems Summary 2018, p. 180-184

Bertrand, I., *et al*. “Understanding Fertiliser Chemistry: necessity for efficient fertiliser application and formulation”. Eyre Peninsula Farming Systems Summary 2000, p. 79-80

Bertrand, I., *et al*. “Chemical characteristics of phosphorus in alkaline soils from southern Australia.” Soil Research 41.1 (2003): 61-76.

Cook, A., *et al*. “Understanding the impact of soil mineral nitrogen on disease suppression”. Eyre Peninsula Farming Systems Summary 2009, p. 63-65.

Cook, A., *et al*. “Long term disease suppression at Streaky Bay”. Eyre Peninsula Farming Systems Summary 2011, p. 76-77.

Hancock, J., *et al*., “Soil Characterisation Data” (2007): 1-181.

Holloway, R. E., *et al*. “Improving fertiliser efficiency on calcareous and alkaline soils with fluid sources of P, N and Zn.” Plant and Soil 236.2 (2001): 209-219.

McBeath, T. M., *et al*. “The effect of soil water status on fertiliser, topsoil and subsoil phosphorus utilisation by wheat.” Plant and Soil 358.1-2 (2012): 337-348.

McLaughlin, Mike J., *et al*. “The chemical nature of P accumulation in agricultural soils - implications for fertiliser management and design: an Australian perspective.” Plant and Soil 349.1-2 (2011): 69-87.

Monjardino, M., *et al*. “Are farmers in low-rainfall cropping regions under-fertilising with nitrogen? A risk analysis.” Agricultural Systems 116 (2013): 37-51.

Sadras, Víctor O., and David K. Roget. “Production and environmental aspects of cropping intensification in a semiarid environment of South eastern Australia.” Agronomy Journal 96.1 (2004): 236-246.

Mixed cover crops for sustainable farming

Fiona Tomney[1] **and Mark Stanley**[2]
[1]SARDI, Minnipa Agricultural Centre; [2]Ag Excellence Alliance

Location
Minnipa Agricultural Centre,
paddock S8
Rainfall
Av. Annual: 324 mm
Av. GSR: 241 mm
2019 Total: 254 mm
2019 GSR: 234 mm
Paddock history
2018: Medic pasture
2017: Scepter wheat
2016: Medic pasture
Soil type
Red sandy loam
Plot size
12 m x 1.5 m x 4 reps

Key messages

- **Crop intensive farming systems are running down soil carbon.**
- **Mixed species cover cropping offers a new approach that may address the issue.**
- **Local guidelines need to be developed so that farmers can make informed decisions about incorporating cover crops into their farming systems.**

Why do the project?

Crop intensive farming systems are running down soil carbon, requiring increased inputs to maintain or increase yield without necessarily improving profitability. Mixed species cover cropping offers a new approach to reverse this trend in the Australian context. It is a key component of some farming systems overseas but is yet to be adopted widely in southern Australia. In the context of this project, mixed species cover crops refers to a diverse mix of plant species grown together but often outside the main growing season to build fertile and resilient soils.

Potential benefits of cover crops include improving soil organic carbon, structure and health, while decreasing weed and disease levels for following crops, but these must be balanced against the cost of growing the cover crop and the water and nutrients it will use. Many potential cover crop options exist and while growers are beginning to investigate these, local guidelines are yet to be developed to inform decisions.

A trial at Minnipa is investigating mixed species cover crops grown over winter. The principle behind growing a mixture of species rather than a monoculture is that it mimics naturally occurring diverse ecosystems. Different root systems host different microorganisms, fungi and soil biota that improve the dynamic properties of soil leading to healthier soil that has higher infiltration rates for water and are better able to retain that moisture. This retained water can potentially be used for the following cereal crops. Different root systems also inhabit different parts of the soil profile and therefore access water and nutrients more completely, so no single section is severely depleted. Organic matter is distributed more evenly throughout the soil profile and more carbon is available to soil organisms. The qualities of two or more different species may also improve the overall productivity. Legumes fix nitrogen that can be used by other plants. Tall plants provide shade for emerging seedlings, reducing their exposure to water and temperature stress. Climbing plants such as peas will often use the taller plants as a trellis. The fibrous root systems of many cereals and grasses bind the soil to protect it from wind erosion, particularly under dry conditions. Brassicas can function as biofumigants, suppressing soil pests, especially root pathogens and plant-parasitic nematodes. Leaving residue on the soil surface lowers the soil temperature, reducing soil water loss through evaporation and providing protection from erosion. A diverse cover crop also offers a more balanced diet to livestock.

How was it done?

Ten species were selected as potential components of a winter cover crop based on their suitability for the local rainfall and soil type, seed availability, ability to be included in mixes and existing district practices. The species were also selected to include a range of legumes, brassicas, cereals and grasses. A mix including all ten species in equal amounts, four other mixes composed of subsets of these species and each species as a monoculture were sown. As a control there was a fallow treatment where the plots were left unsown (Table 1). The trial was sown into moist soil on 31 May 2019 with 60 kg/ha DAP.

Table 1. Winter cover crop species sown at Minnipa on 31 May 2019.

Cover Crop Species	Sowing Rate
PM-250 Strand medic	7.5 kg/ha
Volga vetch	40 kg/ha
Field peas	100 kg/ha
Mulgara oats	60 kg/ha
Safeguard annual ryegrass	5 kg/ha
Cereal rye	40 kg/ha
Triticale	70 kg/ha
Stingray canola	2 kg/ha
Tillage radish	5 kg/ha
Narbon beans	120 kg/ha
Ten Species Mix	10% of the sowing rate of each species as a monoculture
Control (fallow)	NA
Jake's Party Mix (oats, vetch & canola)	40 kg/ha oats, 20 kg/ha vetch, 1.5 kg/ha canola
Mandy's Mix (oats & medic)	40 kg/ha oats, 7.5 kg/ha medic
Fluff's Mix (canola & field peas)	2.5 kg/ha canola, 30 kg/ha field peas
Fi's Mix (tillage radish, ryegrass, cereal rye, oats, field peas & vetch)	18% of the sowing rate of each species as a monoculture

PM-250 strand medic was included to represent the common district practice of regenerating medic pastures being used in rotation with cereal crops. As a legume species it fixes nitrogen.

Volga vetch is a legume so has the benefit of adding nitrogen to the soil. It can be grown in the lower rainfall areas of southern Australia where no other legume crops perform consistently well. It can also be grazed or cut for hay. Its dense, spreading structure provides shade to the soil.

Field peas are legumes so fix nitrogen. They can be grown in most cropping regions of southern Australia.

Mulgara oats are a hay variety that we had available, which can produce a highly competitive crop canopy that can compete well with weeds when sown early. Oats were included as a treatment to represent a common district practice of sowing oats to provide grazing and ground cover, with the option of later cutting for hay or harvesting the grain.

Safeguard annual ryegrass can mature rapidly in drought conditions, producing abundant winter forage in marginal areas. It has no herbicide resistance and is resistant to annual ryegrass toxicity.

Cereal rye is suited to infertile, sandy soils and is drought resistant. It has the ability to produce a soil-binding cover on land where other cereals grow poorly.

Triticale can make good use of land that is marginal for other cereals and is adapted to alkaline soils. It has an aggressive, fibrous root system that binds light soils reducing erosion and builds soil organic matter. It also provides excellent residual ground cover and can be grazed.

Stingray canola is a brassica commonly included in crop rotations in low rainfall southern Australia.

Tillage radish is a brassica bred specifically for its large tuberous taproot, which is claimed to reduce soil issues such as compaction. It is drought hardy with the ability to access subsoil moisture and nutrients. It also produces very palatable feed.

Narbon beans (*Vicia narbonensis*) are a legume suited to low rainfall and alkaline soils, with resistance to aphids. They can be grazed, cut for hay or used for green manure.

Jake's Party Mix was included because this same mix was sown on the MAC Farm by Jake Hull in 2019 to provide grazing for the MAC sheep.

Mandy's Mix was included because oats and medic produced the most dry matter of the mixes included in Amanda Cook's 2018 trial 'Maximising dry matter production for grazing systems on alkaline soils'.

Fluff's Mix was suggested by Ian Richter as canola and field pea had the greatest benefit to subsequent cereal crops in Suzanne Holbery and Roy Latta's 2011-2014 'Crop Sequences' trial.

Fi's Mix was selected to represent a balance of species from cereals/grasses, legumes and brassicas. Retrospectively I would have replaced Safeguard annual ryegrass with canola to provide an extra brassica species.

Table 2. Dry matter measurements at Minnipa 13 September 2019.

Cover crop species	Shoot dry matter (t/ha)
PM-250 Strand medic	0.48 de
Volga vetch	0.89 d
Field peas	1.15 cd
Mulgara oats	2.94 a
Safeguard annual ryegrass	1.24 cd
Cereal rye	2.44 ab
Triticale	2.52 ab
Stingray canola	1.50 cd
Tillage radish	1.41 cd
Narbon beans	1.14 cd
Control (fallow)	NA
Ten Species Mix	2.24 b
Jake's Party Mix (oats, vetch & canola)	2.42 ab
Mandy's Mix (oats & medic)	2.40 ab
Fluff's Mix (canola & field peas)	1.57 c
Fi's Mix (tillage radish, ryegrass, cereal rye, oats, field peas & vetch)	2.60 ab
LSD (P=0.05)	*0.62*

What happened?

Plants began to emerge and establish vigorously two weeks post seeding. The performance of PM-250 Strand medic was compromised by being sown too deep and struggled all season with low plant numbers. Dry matter cuts were taken on 13 September 2019 (Table 2) at early grain fill, as a measure of maximum biomass.

Despite triticale and Jake's Party Mix producing the best early vigour, Mulgara oats produced the most dry matter of all treatments by the end of the season; 2.94 t/ha at early grain fill.

Of the mixes, Fi's Mix produced the most dry matter with 2.60 t/ha. As expected the PM-250 Strand medic produced the lowest amount of dry matter with 0.48 t/ha.

The trial was terminated with glyphosate on 2 October 2019 to prevent seed set and further water use.

What does this mean?

Whilst some species were shown to grow more vigorously and/or produce more biomass, this is only one measure of the effectiveness of cover crops. The most important factor to consider is their benefits to the following crop. Cover crops can improve soil health, nutrient cycling, organic carbon, and soil moisture; decrease weed populations and increase the population of beneficial insects, however these benefits may not be measurable after only one phase.

The trial will be sown to wheat in 2020 to evaluate the impact of each cover crop option on crop performance. The amount of crop residue and ground cover will be assessed prior to seeding, as will soil moisture, organic carbon and chemical fertility.

Acknowledgements

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Thank you to Dot and Reg Brace for donating the triticale seed, and to Gareth and Roanne Scholz for donating the tillage radish and cereal rye seed.

The growing problem of seeps across SA - what can be done about it?

Dr Chris McDonough
Insight Extension for Agriculture, Loxton SA

Location
Various demonstrations/ monitoring sites across the SA Murray Mallee.
Bow Hill: Kevin & Geoff Bond
Wynarka: Peter Rose, Andrew Thomas, David Arbon
Karoonda: Stuart Pope, Simon Martin
Alawoona: Lachie Singh
Rainfall
Av. Annual: 285-342 mm
Av. GSR: 194-235 mm

Key messages

- **Seeps are rapidly growing as a result of modern farming systems, landscape and seasonal factors (both very wet and extended dry periods).**
- **Early identification and action is imperative and can be assisted through satellite NDVI imaging.**
- **Specific management strategies must be applied within Recharge, Discharge and Interception Zones to prevent this initial unused fresh water problem resulting in large unproductive saline scalds.**
- **Take action early to keep land productive and prevent degradation occurring.**

Why do this trial work?

This work aims to give farmers practical solutions for managing the growing problem of Mallee Seeps, and is based on 5 years of investigative monitoring and trial work in the SA Murray Mallee.

Seeps resulting from localised perched water tables have become a degradation issue across the cropping zones of SA and Victoria over the last 20 years, and have rapidly increased over the last decade. This was highlighted in a recent survey involving 80 landholders across the Mallee region (McDonough 2017). The emergence of a seep is due to a combination of landscape, seasonal and farming system factors that led to waterlogging, scalding and salinisation of farmer's most productive cropping ground. They also reduce paddock efficiencies and increase risks of damage to machinery.

Modern farming systems which are dominated by no-till and intensive cropping have led to almost complete control of deep rooted/perennial summer weeds such as skeleton weed which once dominated mallee sand dunes. This has led to a greater amount of summer rainfall passing through sandy rises that have very low water holding capacity. This results in the formation of perched water tables above areas of impervious clay layers (such as Blanchetown clays) and water moving laterally toward lower lying areas (as demonstrated in Figure 1) to find surface expression where the clay comes close to the soil surface in mid-slopes or at the base of swales. This leads to waterlogging, capillary rise, evaporation and a process of surface salinisation over time.

These seeps generally begin as areas inundated with too much fresh water but this will lead to permanent salinisation and land degradation if no remediation takes place. The key to managing seeps is to identify the problem early, assess and apply appropriate management into the three key zones of Recharge, Intercept and Discharge areas (Figure 1).

How was it done?

This article presents findings and strategies resulting from a number of seep monitoring projects conducted over the last five years funded through the Australian Government's National Landcare Program (NLP), the South Australian Murray Darling Basin Natural Resource Management Board (SAMDB), GRDC and Mallee Sustainable Farming (MSF), involving seven sites over six farms. Each site has involved the use of moisture probes, piezometers and rain gauges with continuous data loggers, along with detailed landscape soil testing and treatment monitoring to more accurately assess the dynamics of the catchments and impacts of rainfall events and various management strategies. The farmers have been directly involved in developing and applying practical strategies to remediate the problems in each catchment.

While results and new approaches will continue to develop, there are already many important understandings, outcomes and strategies that farmers and advisors can use now to deal with this growing land degradation issue.

What happened and what can be done?

Identifying the problem

There are a number of key indicators that a seep area may be forming. Initially, and often more evident through drought years, the crop below a sandy rise or lower in a catchment area may produce substantially higher growth or yield, due to accessing the extra moisture from the beginnings of a perched fresh water table. It is not uncommon to find a distinct saturated layer of soil within the top 1m (sometimes slightly deeper) where this is happening. Ideally, this is the time to commence remedial action, well before it turns into an expanding and degraded soil area.

This early phase is usually succeeded by ryegrass becoming very thick and dominant through cereal or pastures. Ryegrass tends to be more tolerant and responsive to these conditions, persisting well into summer with a very large seed set (likely to have a high percentage of hard seed). It is not uncommon for farmers to find tractors suddenly sinking to their axles and major operational disruptions occurring around these sites by this stage.

As the seep area grows and the perched water table gets closer to the surface, bare scalded areas will start to emerge, essentially due to anaerobic soil conditions that are detrimental to most plant growth. Depending on rainfall and landscape factors, it is possible that surface ponding may occur for extended periods after rainfall events. This is a critical phase, as these bare soil conditions, particularly over the heat of summer, will lead to capillary rise of the moisture, evaporation and accumulation of salt at the soil surface to levels too toxic for crop growth.

In recent years it has become evident that while the wet years (such as 2010/11 and 2016) have resulted in much of the excess water issues occurring in these catchments, it is the drier years with less plant growth and longer periods of heat and evaporation that greatly exacerbate the spread of surface salt accumulation.

Viewing images throughout the growing season may also identify specific areas of poor crop growth which may be directly contributing to recharge after rainfall. These areas can then be targeted for specific management options. Ground truthing of images, along with local farmer knowledge is vital in ensuring an accurate assessment of the satellite images is made. For instance, frost events can lead to crops reshooting late and staying greener longer in low lying areas. Summer crops or uncontrolled summer weeds may also lead to similar NDVI image colours as seeps, as can trees or other perennial vegetation. Cloud cover and shadows from clouds can also cause distortions and misinterpretations, which is why it is often important to view multiple images.

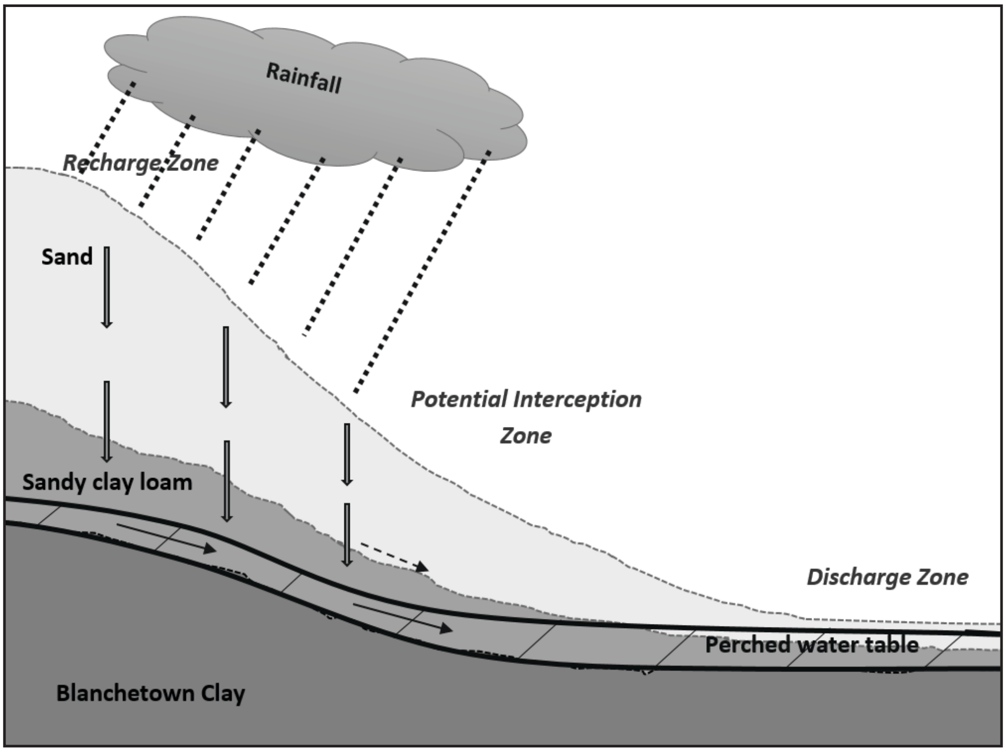

Figure 1. The formation of Mallee Dune Seeps, adapted from Hall (2017) p31, showing the three key zones of recharge, interception and discharge.

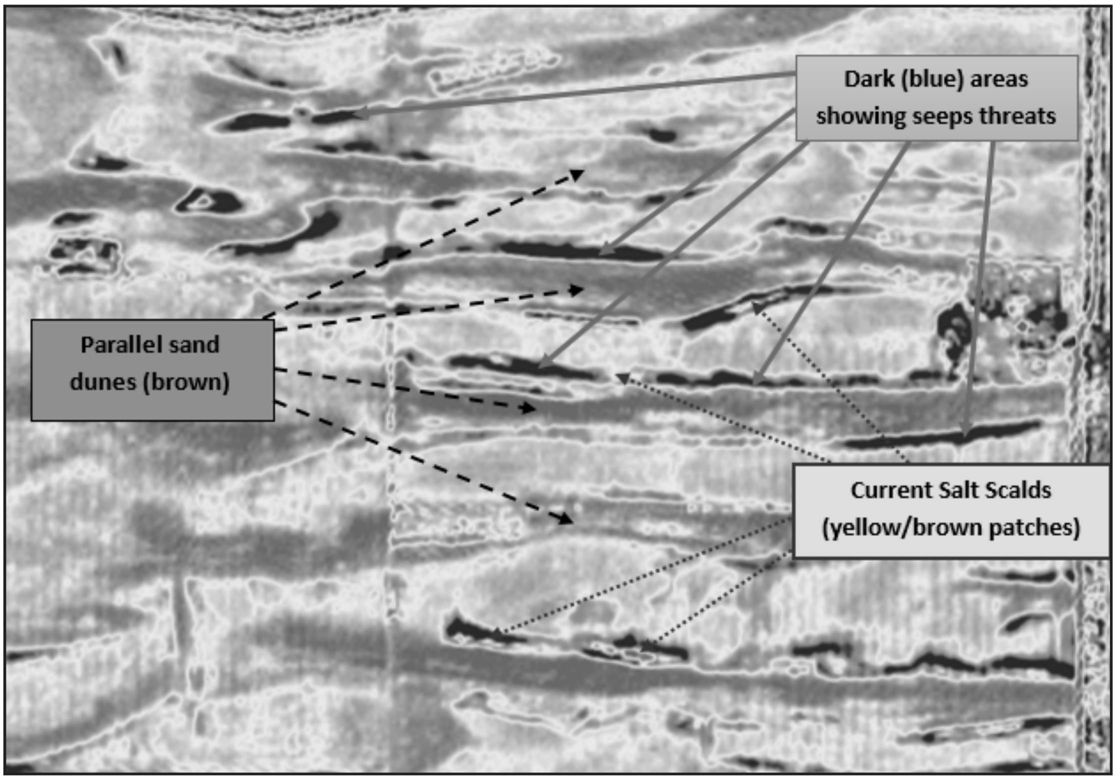

Figure 2. NDVI Map 16 October 2017 showing large areas under threat from seep degradation, as well as indicating original image colours that assist in understanding landscape features.

Key management zone strategies

Once areas with seeps and those areas threatened by seep formation have been identified, it is important that management strategies are implemented as soon as possible. Ideally, these should be designed to best fit within the farmer's systems with minimal disturbance to the normal paddock activities. Some strategies may even lead to higher paddock productivity. However, some less convenient changes may be necessary in order to protect a greater area of productive land heading towards problems and total degradation if nothing is done.

There are three main areas within these local catchment systems that need to be identified (Figure 1). These are:

1. Recharge Zones - where most of the excess water is entering the system;
2. Discharge Zones - where the problems are developing at the soil surface (often in midslope or lower lying areas); and
3. Potential Interception Zones - where higher water use strategies can utilise the excess water before it reaches the discharge zones.

It is generally a combination of management strategies targeted in each zone that is required to stop the spread of these seeps and possibly bringing these areas back into normal production.

Recharge Zones

Deep sands (often non-wetting) are the main source of extra water moving into the discharge zone. This is because they have very low water holding capacity and soil fertility, and are often suffering compaction to levels that prevent plant root penetration below 20 cm. This means that even relatively small rainfall events can quickly pass through the root zones to contribute to the perched water table below.

Figure 3 shows rises in the water table at a mid-slope piezometer between November 2015 and May 2018 (including the wet Spring of 2016 of 130 mm) at Wynarka. The perched water table at this site is below the crop root zone, so any rise is a direct impact of rainfall contributing recharge from the 60 m of sandhill slope above the piezometer. Any fall in levels is likely due to discharge, evaporation or transpiration of the water lower in the system (particularly in the hotter summer periods), or in some cases a bulge of water may be moving down the slope after a larger rainfall event. It reveals that a 40 mm rainfall event raised this midslope water table by over 40 cm. Smaller events of 12 mm and 15 mm during the 2017 growing season led to rises of 15-20 cm. Even a sudden 7 mm rainfall event in Dec 2016 caused a 10-15 cm water table rise.

The key principles for managing these areas is firstly to break any soil compaction, as this will increase plant root zones from around 20 cm of depth to as much as 150 cm (as observed at one site). This also allows crops to dry out these new root zones to wilting point, meaning that any summer rainfall will have a larger bucket to fill before it starts contributing to recharge. This will also lead to greater crop yields and water utilisation.

Further to this, any soil amelioration that incorporates clay or nutritious forms of organic matter such as manures into the top 40 cm has been shown to greatly improve soil water holding capacity within this root zone. This was clearly evident at a Karoonda seep monitoring site, where the spading in of chicken manure has produced well over double the crop yields over a 4 year period, and soil moisture probes showed excellent soil water retention within the 40 cm spading depth which was utilised by the crop. This was in direct contrast to the control plot which had low yields, very little soil moisture use by crops below 30 cm depth and numerous rainfall events contributing to recharge (McDonough 2018b).

Any practical, effective and safe method of achieving sand amelioration through deep ripping, delving, spading, clay spreading or manure/organic matter/nutrition incorporation will be beneficial in remediating these sandy recharge zones. Current research is developing more options for farmers in this pursuit.

Some farmers have decided their deep sands are not worth cropping and have chosen to establish them with permanent perennial, deep rooted pasture options such as lucerne or veldt grass. This becomes more of a viable option for farmers with livestock in their systems, providing valuable feed options at critical times. However, care is needed in establishing these pastures into adequate soil cover within favourable seasons. One cooperating farmer in 2019 chemically fallowed his sandhill until sowing lucerne in August, avoiding the dry May-June period with high wind events, and achieved an excellent stand as the soil warmed up in Spring.

Discharge Zones

The main principle for discharge zones is maintaining living soil cover all year around if possible. This greatly reduces capillary rise of moisture to the surface, and evaporation leading to surface salt accumulation, because plant roots will be drawing the moisture from deeper in the profile. Bare soil, over the summer months and dry seasons, will lead to a rapid deterioration of these soils into unproductive saline scalds. However, the strategies used to best manage this will depend on the development stage of the seep.

When a perched watertable is in its early stages and is mainly resulting in increased yields with some patches suffering from saturation, it is important to maintain cropping through these areas, without getting machinery bogged. As soon as practical after harvest a summer crop should be sown in these zones. A mixture of sorghum and millet has been successfully used over 3 seasons by farmers at the monitoring site near Mannum. These crops will only grow well where the excess moisture is accumulating, and soon die out in the dry sandy soils surrounding the seeps (there has been very little summer rainfall through this period). The summer crops are either cut or harvested prior to seeding the winter crop. This has not led to any loss of crop yield as a saturated soil layer is still evident despite the growth of the summer crop. While this technique does not address the problem at its source, it does greatly reduce the soil degradation, with minimal impact on the farmer maintaining their normal cropping program. However, this method will only be affective long term if management strategies are also employed to address the excess water emanating from the recharge and moving through interception zones.

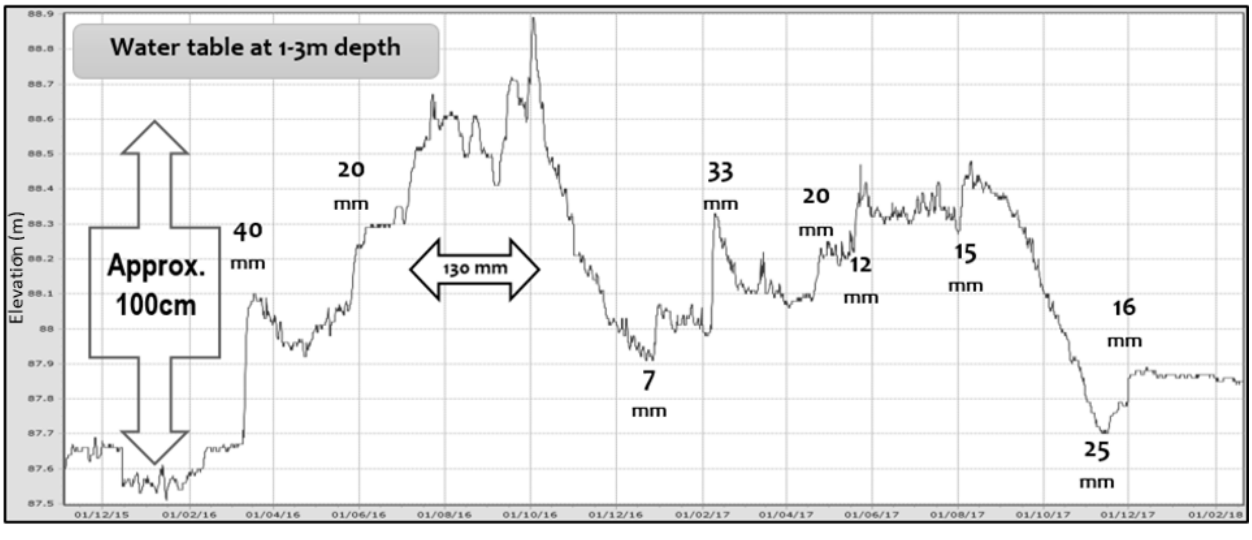

Figure 3. Midslope (RO2 Piezometer) water table rises after specific rainfall events in mm, as stated along the line (November 2015-May 2018) at Wynarka.

It is important that all sites are soil tested to guide the type of remediation action appropriate for each specific site. If the scald is already established surface salinity or waterlogging to severe for crop growth, then perennial salt tolerant pastures such as puccinellia or tall wheat grass should be established. Success has been achieved using airseeders where possible. Dragging harrows behind a four wheeled motorbike and seed spread through a rabbit baitlayer has been used successfully where heavier machinery has been too risky. While it has been reported that puccinellia is suitable for areas with moderately high to very high soil salinity of 8 to >32 dS/m, and tall wheat grass being slightly less salt tolerant at low to moderate levels of 0-8 dS/m (Liddicoat and McFarlane 2007), current trial demonstrations have shown good and poor establishment in a variety of sites and salinity levels, highlighted by some excellent puccinellia establishment on a crystalline salt covered scald at Wynarka. In some cases, tall wheat grass has established later in the season where puccinellia has not grown, even though they were sown together in the same seed mixture. The salt tolerant annual legume variety Messina has also been tried but has generally not established well on bare scalded sites. Saltbush has been grown and grazed successfully in some seep areas, but has not survived well in the most saturated areas that are subject to periodic water inundation.

It is becoming apparent that successful establishment of these pastures can sometimes be dependent on seasonal factors and more specific soil parameters, which may not have been considered in previous work based more on saline water table sites. Even slight raises in surface soil levels or organic matter content have been shown to make a difference. For example, current monitoring of scald sites have been found some to have extremely high pH, approaching 11, which is toxic to most plant growth.

The MSF Seeps project is aiming to better understand these various parameters. This will provide more accurate and relevant information for managing these scalded areas. Soil qualities at different times throughout seasons, and where plants have and have not established need to be measured. The surface crust (often black) is being measured along with 0-10 cm samples, as they may provide important insights into critical soil issues. Initial success has been achieved with a front end loader to add 10 cm layers of sand, straw and manures to bare scalds and to get salt tolerant grasses established and even a cereal crop at one site. These sites will be monitored over coming seasons to see if they deteriorate over time, or continue towards greater soil improvements.

In areas that already have salt scalds and are too toxic for re-establishing crop growth, it is still important to employ these strategies on the edge areas to help stop the growth of these bare seep scalds.

Potential Interception Zones

There are often areas below recharge zones where there is lateral subsoil flow of excess water above the impervious clay layers (Figure 1). They provide the opportunity for water interception and utilisation before it causes problems in the discharge areas. The most successful strategy applied within all monitoring sites has been the strategic establishment of lucerne in this zone to produce hay or pasture, as its roots penetrate deep into the perched water table layer throughout the year. Lucerne especially takes advantage of large summer rainfall events that are usually a key source of recharge water and is a versatile option that is familiar to many. Figure 4 shows that each major rainfall event in a lucerne area was quickly utilised and there was no evidence of recharge happening. This is in contrast to the continuously cropped side which regularly has 60-70 mm more water in the top 1 m soil profile and water passing beyond the root zone. In the extremely wet season of 2016, the mid-slope piezometer in the lucerne was the only site to experience a reduction in water table.

Farmers are targeting strips of lucerne (often 30-50 m wide) above seep areas to intercept the lateral water flows. Even cropping farmers can gain profits from this by selling lucerne hay and through prevention of seeps to maintain crop yields. Crops can be sown through these lucerne strips, so establishing lucerne in the same direction as cereal sowing may be worthwhile, even if it takes more initial effort. While encompassing these lucerne strips within cropping paddocks will present some compromises, it is still better than losing greater areas of highly productive land to spreading seeps.

While most farmers do not wish to plant trees in the middle of cropping paddocks, it may still be an option to consider, particularly where a fenceline or laneway already exists, and where a large amount of water use is required to reduce an emerging seep. If planting close to seeps, it may be worth testing the water quality to assess whether more salt tolerant species may be required. This project found greater success where tree guards protected the seedlings from vermin and some early watering was done to ensure summer survival on the deeper non-wetting sandy soils.

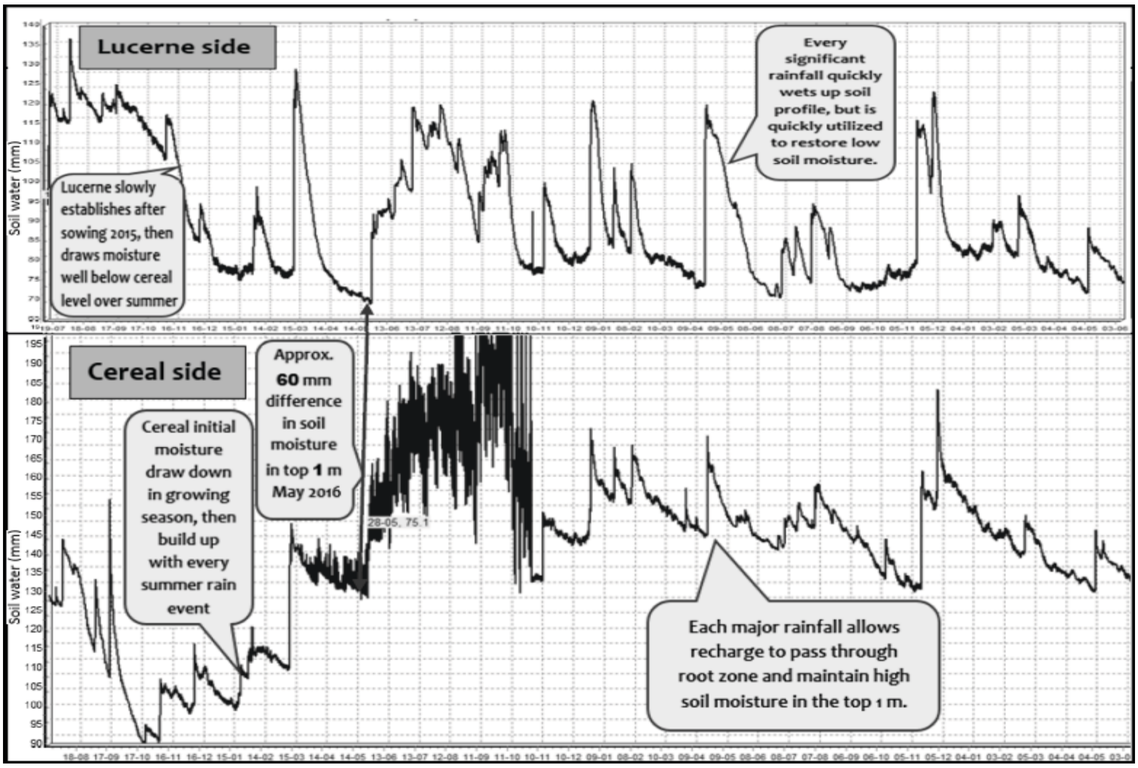

Figure 4. Top 1 m soil moisture level comparisons of lucerne and cereal treatment areas (July 2015-May 2018).

New innovative strategies being tested

The MSF Seeps Project is currently exploring a number of trials and demonstrations including the use of a subsoil extruder on deep sands above a seep at Alawoona. This machine profiles a manure slurry behind its multiple deep ripping tines. This is much safer for wind erosion than spading in manure, and initial results have been promising for improving crop production and water use. Other trials are assessing the use of other subsoil amelioration techniques, alternative pasture species, methods to maximise crop water use and longer season varieties.

Another site will assess the practicality of establishing an in-ground sump just above a seep scald area to pump water out to be stored and used for either spraying, livestock or liquid fertiliser application. Early water quality measurements at the particular site has presented some challenges, but work is ongoing

What does this mean?

Localised seeps are a growing land degradation issue across cropping zones of southern Australia, and come about through a combination of landscape and seasonal factors as well and changes associated with modern farming systems. New technologies such as NDVI satellite imaging are providing important resources for the identification of developing seeps and the potential threat posed to farmers' paddocks if left unmanaged.

There are a variety of strategies that have been identified though a number of seep projects in the SA Murray Mallee in recent years that provide practical options for farmers to apply into the three critical areas of Recharge, Discharge and Intercept Zones. More work is currently refining these strategies through the MSF Mallee Seeps project that aims to improve water use efficiencies and remediation of these issues.

This information is highly relevant and adaptable to seep forming areas of the Eyre Peninsula. However, it is important to make a distinction between the more localised perched water table issues associated with mallee seeps, and the salinity issues directly caused with often saline water tables within existing river systems. The latter can be very different in cause and effect, with the source of the problem often emanating from much further up the catchment.

There is currently an application to apply monitoring and demonstration sites within local EP areas to assist in providing local answers to the early detection and management of seeps in that region.

References

Hall , J. (2017). Mallee Dune Seepage in the SA Murray Mallee - Summary Report. Natural Resources SA Murray Darling Basin, Dept of Environment, Water & Natural Resources, Government of South Australia, Murray Bridge. https://data.environment.sa.gov.au/Content/Publications/REPORT_NRSAMDB_Mallee%20Dune%20Seepage_Summary%20Report_2017.pdf

Liddicoat, C. and J. McFarlane (2007). Saltland Pastures for South Australia, Dept of Water, Land and Biodiversity Conservation (South Australia). https://www.environment.sa.gov.au/files/sharedassets/public/science/kb-saltlandpasturessamanual.pdf

McDonough, C. (2017). Mallee Seeps Farmer Survey 2017 Report for Mallee Sustainable Farming. https://www.naturalresources.sa.gov.au/files/sharedassets/sa_murray-darling_basin/land/reports_and_case_studies/mallee-seeps-farmer-survey-2017-rep.pdf

McDonough, C. (2018a). The Use of Normalised Difference Vegetation Index (NDVI) to Manage Seeps. Martins Report, Karoonda. SA Murray Darling Basin Natural Resources Management Board https://www.naturalresources.sa.gov.au/samurraydarlingbasin/land-and-farming/soils/mallee-seeps.

McDonough, C. (2018b). Monitoring Mallee Seeps Summary, Project 1569C for the South Australian Murray Darling Basin Natural Resources Management Board. https://www.naturalresources.sa.gov.au/files/sharedassets/sa_murray-darling_basin/land/reports_and_case_studies/monitoring-mallee-seeps-jun18-rep.pdf

Acknowledgements

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Section 2

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Soils

Ameliorating a deep repellent sand at Murlong in 2018 increased barley performance in 2019

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Location
Murlong
Rainfall
Av. Annual: 385 mm
Av. GSR: 270 mm (May - Oct)
2019 Total: 223 mm
2019 GSR: 209 mm (May - Oct)
Yield
Water-limited yield potential: 4.2 t/ha barley
Long term average yield: 1.7 t/ha barley (yield gap = 2.5 t/ha)
Actual: 1.8 t/ha
Paddock history
2018: Razor CL wheat
2017: Scope CL barley
2016: Pasture
2015: Mace wheat
Soil type
Deep sand over clay
Soil profile: 0-5 cm water repellent, light brown/grey sand; 5-15 cm grey sand; 15-40 cm white sand; 40-70 cm yellow sand; 70-80 cm yellow light clay
Plot size
25 m x 2.3 m x 4 reps
Trial design
Experimental: randomised complete block
Yield limiting factors
Severe water repellence, low rainfall, frost.

Key messages

- **Physically disrupting compacted layers down the profile of a repellent deep sand by ripping with inclusion plates or spading produced large performance gains in cereals over two years. Spading was the most effective but deep ripping was very cost-competitive.**
- **Deep ripping compared to spading creates less erosion risk but the ameliorated sand is still vulnerable.**
- **Five t/ha of incorporated lucerne pellets or high rates of fertiliser only increased grain yields in the first year and the gains were not profitable.**

Why do the trial?

Previous research has shown that physical intervention on compacted sandy soils can deliver large yield increases. However, there is still a lot of uncertainty whether adding amendments to the intervention operation or thorough mixing/inverting of the topsoil is effective or profitable. The development of inclusion plates attached to deep ripping tines is a low-cost option for increased mixing of surface applied amendments and/or topsoil with less risk of soil erosion than spading or mouldboard ploughs. This trial aimed to:

- Determine if physical intervention and soil mixing improved yield on a sandy soil on eastern EP.
- Compare deep ripping with inclusion plates to spading.
- Identify if the addition of fertilisers or organic material provided additional benefits.

See the article in the EP Farming Systems Summary 2018 for more details of results from this trial in 2018 (“Ameliorating a deep repellent sand at Murlong increased wheat performance substantially in 2018,” p111).

How was it done?

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

Table 1. Trial establishment and cropping details for 2019 (trial was sown with Razor CL wheat in 2018)

19 April 2018	OM and nutrient packages applied	• OM: Lucerne pellets at 5 t/ha • Nutrient Package: nutrients applied to match lucerne - N 167, P 14, K 105, S 12, Cu 0.03, Zn 17, Mn 0.18 kg/ha. NPKS applied as granular and trace elements as fluids. Treatments applied evenly across the surface on spaded plots or in bands to correspond with ripper tine spacings, immediately prior to spading and ripping.
	Soil treatments imposed	• Spading to 30 cm at 5 km/h • Ripped: 4 tines at 64 cm spacings with inclusion plates, positioned 10 cm below the soil surface and operated at 5 km/h • Shallow ripped (corresponding to the depth of spading) to 30 cm with 20 cm tall inclusion plates • Deep ripped to 41 cm with 30 cm tall inclusion plates
10 May 2019	Sowing, inter-row on 2018 crop rows	63 kg/ha Scope CL barley at 25.4 cm row spacing + DAP at 60 kg/ha (all treatments). In addition, urea at 55 kg/ha and SOA at 42 kg/ha were banded below seed rows for non OM and nutrient package treatments only.
20 August 2019		Foliar spray of Zn, Mn and Cu. No other nutrients during the season.

Crop performance of an unmodified control is being compared to spading to 30 cm or ripping with inclusion plates (IP) to 2 depths (30 cm or 41 cm) with and without the addition of high rates of mineral fertiliser or lucerne pellets (Table 1).

Measurements taken include: Pre-seeding soil water and mineral nitrogen, crop establishment, biomass at flowering, yield, yield components and grain quality, and post-harvest soil water.

What happened?

- In both years, severe water repellence resulted in low plant numbers where there was no soil disturbance treatment. Only a few barley plants/m^2 initially established in the unamended controls in 2019, the impact of water repellency being exacerbated by inter-row seeding and a pump breakdown which meant a wetting agent was not applied into the seed row as had been intended. Deep ripping improved crop establishment, but spading was the most effective treatment in both years. The addition of nutrients, or lucerne pellets, further improved crop establishment only in 2018. Ripping or spading from 2018 resulted in initial establishment of barley in 2019 of 35-46 plants/m^2.
- Crop growth in 2019 was very poor in unamended controls due to both low plant numbers and also due to poor vigour in the plants which had established. This is despite more N, P and S fertiliser having been applied to these plots at seeding (in both years). At flowering, controls only averaged 840 kg DM/ha while interventions varied between 2450 and 3920 kg DM/ha with spading having higher DM than ripping to 30 cm (ripping to 41 cm was intermediate between the two). Amendments had no consistent effect on barley DM.
- Flowering DM of wheat was increased by both physical interventions and amendments in 2018.
- The 2019 season at Murlong was poor with rainfall for the year up until harvest being just better than decile 1 and several frost events damaging barley yields. The controls averaged 720 kg/ha but yields after interventions in 2018 varied between 1250 and 1800 kg/ha (Figure 1). Spading and ripping to 41 cm resulted in the highest yields with ripping to 30 cm not quite as good. Neither amendment produced any grain yield increases in 2019.
- Wheat grain yields in 2018 were improved by ripping to 41 cm which was better than ripping to 30 cm. Spading yielded more than either ripping treatment and the addition of nutrients or lucerne further increased yield.
- Combined over the two years, ripping to 30 cm in 2018 has improved cereal yields from the control by 1100 kg/ha, ripping to 41 cm by 1800 kg/ha and spading by 2400 kg/ha. Incorporated lucerne hay or a multi-nutrient fertiliser package increased yields only in the first year (by about 300 kg/ha).

What does this mean?

Physical interventions on this deep, water repellent sand at Murlong delivered large economic responses to cereals over the two years monitored so far. Even with deep ripping typically costing between $50 and $80/ha and spading at least double those costs, these physical interventions have already made a good return on their investment in the first two seasons following implementation. There are also good prospects for benefits continuing into at least a third season.

Spading has proven to be the most effective type of disturbance so far, but ripping to 40 cm with inclusion plates and wide rows (60 cm) is proving very competitive in terms of economic return.

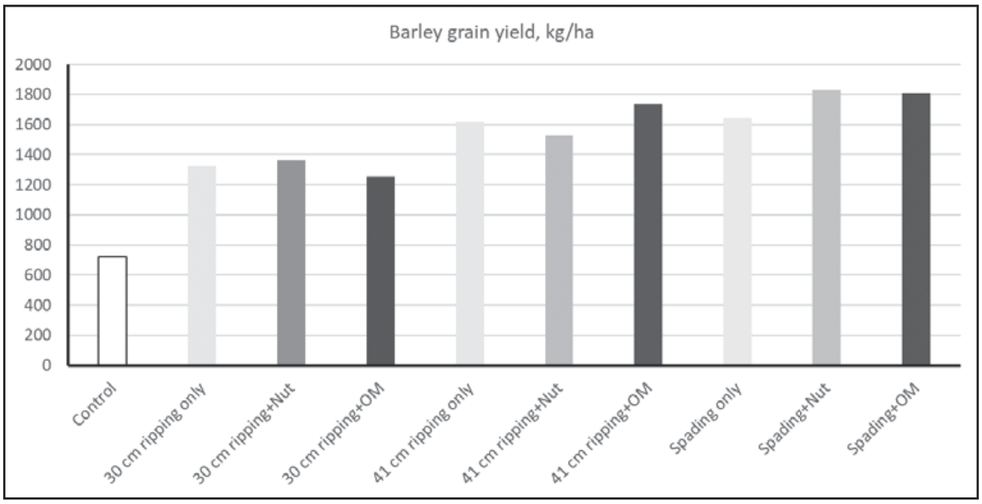

Figure 1. Grain yield of barley (kg/ha) at Murlong 2019 (LSD, P=0.05, 260 kg/ha).

Ripping has the additional benefit that it does not leave the ground as vulnerable to wind erosion as spading. Increased erosion is a factor with physically disturbing these fragile sands.

One of the reasons that interventions have produced better crops at this site is that they have improved early crop establishment despite severe water repellency. Spading is more effective than ripping in this aspect. However, seeder strategy trials conducted by the University of SA (see their articles in this edition and in the Eyre Peninsula Farming Systems Summary 2018) have shown that there are low cost options at seeding which can substantially improve early crop establishment on this severely repellent sand. A combination of those approaches with deep ripping could improve outcomes even further.

While incorporating lucerne hay or a multi-nutrient fertiliser package increased crop performance in 2018, the cost of these amendments will have to come down substantially before they are going to be economically attractive.

The general pattern of these results at Murlong are consistent with a lot of the current research into poorly performing sands. These messages include:

- Where sand is compacted, physical disturbance is providing very good returns in both crop performance and economics. Compaction in sandy soils is common in paddocks which have a substantial cropping history.
- Disturbing sands increases erosion risk.
- Incorporating amendments (especially high rates of N rich organic matter) with these physical disturbance operations often produce much better crops, but rarely have those amendments been financially attractive so far. There is currently a lot of activity into refining amendment strategies to improve their cost-effectiveness.

Further paddock scale validation trials and farmer demonstrations were established at Kimba, Mount Damper, Karkoo and Cummins in 2019 in partnership with EPARF and LEADA; see report in this edition by Brett Masters for details of those complementary trials.

Impact of rate of incorporated lucerne on wheat production. In a new trial set up in 2019 at Brooker on the Lower Eyre Peninsula, lucerne hay incorporated by spading had little impact on wheat performance at rates equal to or below 2 t/ha, there was little further increase in crop productivity above 15 t/ha but between these two rates, for every 1 t/ha increase in lucerne, wheat grain yield increased by 0.2 t/ha.

This site was also on a deep, unproductive and severely repellent siliceous sand.

Acknowledgements

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Seeder-based approaches to reduce the impact of water repellence on crop productivity: Soil wetter evaluation

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Location
Murlong
-33.691295S, 135.944050E
Mark and Amy Siviour
Rainfall
Av. Annual: 385 mm
Av. GSR: 270 mm
2019 Total: 223 mm
2019 GSR: 209 mm
Yield
Potential: 2.7 t/ha for decile 1(W)
Actual: 2.4 t/ha (B)
Paddock history
2018: CL Razor wheat
2017: CL Scope barley
2016: Pasture
2015: Mace wheat
Soil type
Grey, non-wetting deep sand
Soil test
$\text{pH}_{(\text{Water})}$: 7.7
Plot size
25 m x 1.68 m (6 rows) x 4 reps
Yield limiting factors
Water repellence

Key messages

- **A soil wetter evaluation trial conducted over 2 years at the same site compared 15 different treatments.**
- **Six wetter treatments provided large crop establishment benefits (up to 55-60 plants/m^2 at 36 days after sowing) over two years, while 7 wetter treatments achieved no early impact.**
- **In Year 1, five of the better wetters produced an extra wheat grain yield (up to 0.22 t/ha), while in Year 2, all 13 wetters achieved a grain yield increase (0.5-1.07 t/ha).**
- **The best soil wetter treatment achieved only 66% of the establishment number and 85% of the grain yield of an on-row (no-wetter) sowing reference in 2019.**
- **The early impact of a soil wetter chemistry is likely to be site-specific.**

Why do the trial?

Non-wetting sands have low fertility and suffer from delayed and uneven wetting, which leads to erratic crop establishment, staggered weed germination and generally poor crop productivity due to low plant densities, low nutrient access, poor weed control and crop damage in areas prone to wind erosion. A range of trials in the GRDC funded Sandy Soils Project (CSP00203) are investigating effective solutions available at seeding time to mitigate the impacts of water repellence.

Soil wetter chemistries are varied and complex and little is known of their individual suitability to local water repellence. Modern soil wetters typically have both surfactant and humectant properties. Surfactant chemistry lowers the surface tension between the liquid and non-wetting sand, which allows the liquid to more readily infiltrate. Humectant chemistries are designed to counter the potential for excessive drainage of the surfactant in sandy soils through the use of co-polymers to promote a horizontal spread of the liquid increasing the quantity of liquid retained within the furrow seed zone. Ten years of research testing soil wetters applied at seeding time in WA was recently summarised by Davies *et al*. (2019) and found that:

- Banded soil wetters were most beneficial for dry sown cereals on repellent forest gravels, with less reliable benefits for break-crops.
- Benefits of banded wetters were minimal or at best sporadic for dry sown crops on deep sands, with no benefit under wet sowing of any crop or in any soil type.
- Benefits are larger in seasons with low and sporadic germinating rains in autumn.

Previous SA research at Wharminda on EP (Ward *et al*. 2019) conducted over 2015-2017 found that two soil wetting agents evaluated among other strategies could significantly improve wheat, barley and lupin establishment and had a positive impact on grain yield, in two years out of three. Building on the above, the Murlong soil wetter evaluation trial aimed to broaden the range of soil wetter types and combinations being evaluated under contrasting furrow placement scenarios.

How was it done?

During 2018-2019 soil wetter evaluation trials were conducted at Murlong on Eyre Peninsula (EP) (see 2018 results in the EPFS Summary 2018, P114).

Table 1. Soil wetter treatments evaluated at the Murlong site over 2018-2019.

Product names	Supplier	Rate (L/ha)	Placement zone*	$/ha (2018)
H2Pro® TriSmart	ICL Specialty Fertilisers	2	FS	15
H2Flo™	ICL Specialty Fertilisers	2	FS	16
Soak-n-Wet	Victorian Chemicals	4	FS	14
Aquaforce	SST Australia	2.5	FS	20
SeedWet	SST Australia	2	FS	17
RainDrover	SACOA	2	SZ	12
SE14®	SACOA	3	SZ	21
Aquaboost AG30 FB+AG30NWS	Bio Central Lab	2+2	FS+SZ	24
Precision Wetter + Nutri-Wet	Chemsol GLE	2+2	FS+SZ	21
Divine® Integrate/Agri mix	BASF	1+1	FS+SZ	20
H2Flo™ + RainDrover	ICL Specialty Fertilisers + SACOA	2+2	FS+SZ	28
Bi-Agra Band	SST Australia	1.5+1.5	FS+SZ	22
Aquaforce + SE14®	SST Australia+ SACOA	2+3	FS+SZ	41

**SZ=Seed Zone; FS=Furrow Surface*

In Year 2 (2019), 6 row x 25 m long plots set to 0.28 m row spacing were sown at 6 km/h using a deep banding knife point operating at 110 mm depth, followed by twin seeding discs and a furrow stabilising V press wheel, 140 mm wide. Plots were sown at 3-5 cm depth on the 15-17 May with CL Scope barley treated with Vibrance and Cruiser 350 at a seed rate of 68 kg/ha. Uniform fungicide at 400 mL/ha and Intake Hi-Load Gold fungicide at 250 mL/ha were also applied in furrow in 80 L/ha volume to address medium/high risks of rhizoctonia/yellow leaf spot and take-all, respectively. All plots were inter-row sown to barley in the standing wheat stubble, under a randomised complete block experimental design. There was an additional on-row sowing treatment with no wetter applied. All treatments were replicated 4 times and the 2018 treatments were re-applied to the same plots in 2019.

A stable consolidated furrow surface is often deemed critical to secure the efficacy of furrow surface applied soil wetters, which must be sprayed onto a firm, settled soil, and not mixed into loose backfill. Soil wetter treatments were applied in 100 L/ha volume of rainwater with foam suppressant at 0.05% v/v, using a Teejet TPU1501 low angle flat fan nozzle behind press-wheels to produce a 25-30 mm wide band footprint on the furrow surface (FS). In contrast, seed zone (SZ) applications were delivered with a Keeton in-furrow seed firmer to achieve accurate co-location with the seeds. Nutrition was supplied at 28 kg N/ha, 12 kg P/ha, 6 kg S/ha, 1.5 kg Zn/ha deep banded at furrow depth. There was also a foliar application of Zn, Cu and Mn at tillering.

What happened?

Barley crop establishment at 5 weeks after sowing is shown in Figure 1 (top). The inter-row control established at 12% of seeds sown (27 plants/m^2, respectively), indicating poor conditions for crop establishment in this severely water repellent sand, while the on-row sowing treatment (with no wetter) offered a significant establishment benefit in excess of 400% (+85 plants/m^2). In contrast, the wetters on inter-row sown treatments showed a variable early impact, and increased barley crop establishment by 17 plants/m^2 on average, with a range of 0-56 plants/m^2.

The impact of soil wetter treatments on crop establishment was similar in both years of the trial, as confirmed by a strongly positive correlation between results in each year (data not shown). Interestingly, all treatments with only furrow surface applied wetters had a limited effect on crop establishment at Murlong, while the two treatments with a seed zone applied humectant (SE14® or RainDrover) performed well. Overall, 4 out of 6 seed zone + furrow surface wetter combinations provided a significant establishment benefit compared with the control.

Combining a surfactant on the furrow surface (FS, Aquaforce) with a humectant in the seed zone (SZ, SE14®) provided a synergistic response in 2019 (where the treatment combining wetters had a greater effect than adding the effects of the two separate wetter treatments independently), possibly due to the effective water harvesting furrows kept intact over that season. A similar combination based on H2Flo™ (FS) and Raindrover (SZ) did not synergise, with the performance driven mostly by the seed zone wetter.

In 2019 (decile 1 GSR) under inter-row sowing there were barley grain yield responses to all soil wetters (Figure 1, bottom). The grain yield in the inter-row sown control averaged 1.10 t/ha.

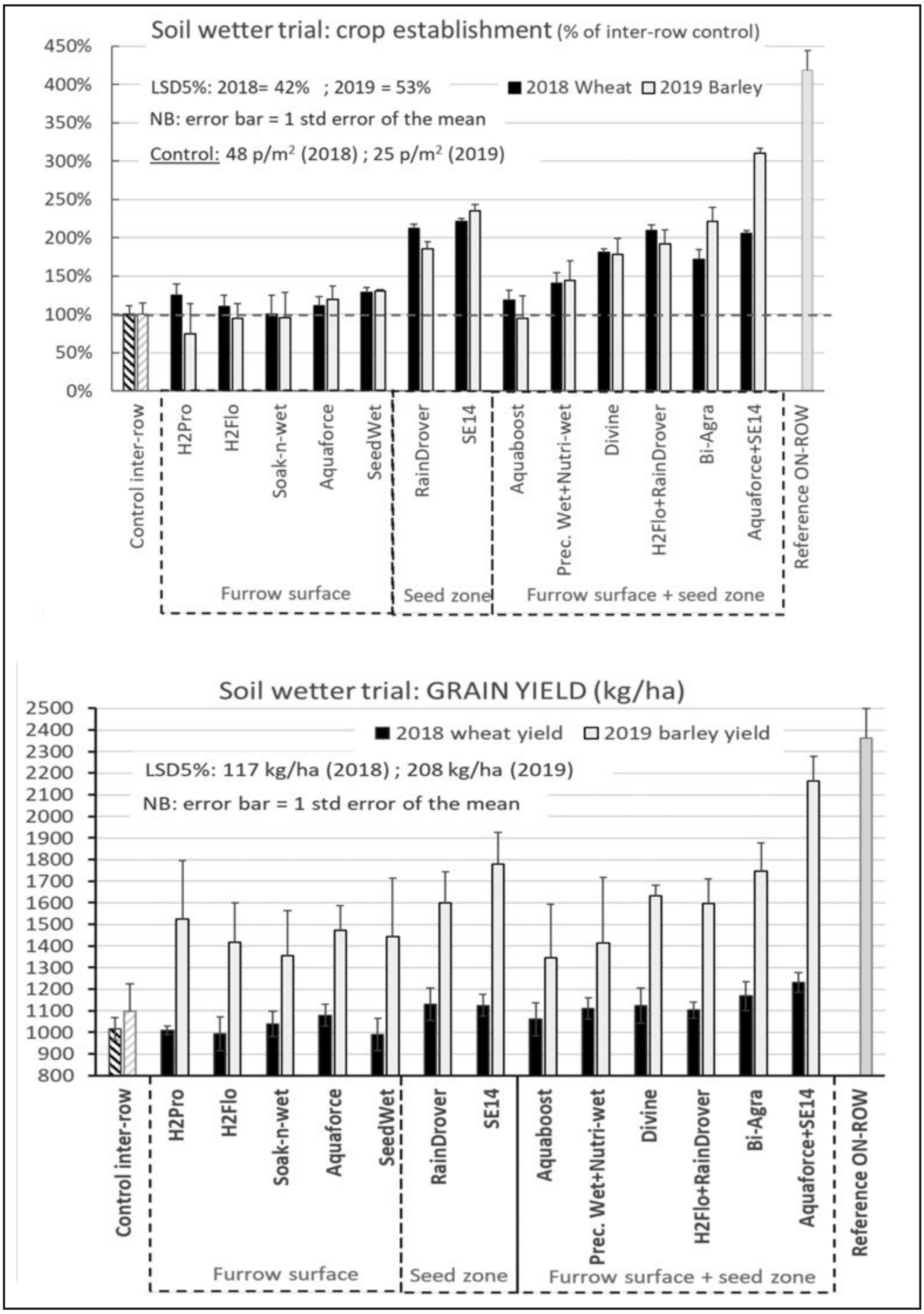

Figure 1. Effect of the 13 soil wetter treatments on: (top) crop establishment over 2 seasons (at 38 and 35 days after sowing) relative to no wetter control (control=100%) and: (bottom) grain yield (kg/ha), relative to a no-wetter control (left, 2018/19) or on-row (right, 2019). The error bars are the standard error of the mean. The 2019 soil wetter treatments and control were sown on the inter-row, with an additional on-row no-wetter reference. The wetter treatments are detailed in Table 1 and their placement varied as indicated.

On the inter-row sown plots, soil wetter treatment yield increases ranged from +23-97%, with a maximum response of +1.07 t/ha. The water harvesting furrows kept intact over the 2019 season are thought to have driven a blanket yield response to soil wetters (with total response also product specific), while in 2018, the furrows backfilled early from drift and limited wheat grain yield responses (up to 0.22 t/ha) were measured, while the early impacts on crop establishment was similar.

In comparison, the on-row control yielded the highest (x2.15 the inter-row control), providing a 1.26 t/ha grain yield benefit. A strong positive correlation (data not shown) was obtained between grain yield and plant density at 36 days after sowing (DAS), which means the soil wetters which achieved a greater early impact secured the maximum yield. Overall, the treatment grain yield responses across the two seasons were strongly correlated (data not shown). This is encouraging and suggest that an effective wetter with consistent effects across multiple years, once identified, may be safely recommended to farmers in that environment.

Table 2. Top 6 soil wetter products and placement (SZ seed zone or FS furrow surface) with significant yield outcomes. Some treatments might not be significantly from others in the ranking.

Rank	**2018 wheat yield**	**2019 barley yield**
1st	SE14® (SZ)+ Aquaforce (FS)	SE14® (SZ) + Aquaforce (FS)
2nd	Bi-Agra Band (SZ+FS)	SE14®(SZ)
3rd	Rain Drover (SZ)	Bi-Agra Band (SZ+FS)
4th	SE14® (SZ)	Divine® Integrate/Agri mix (SZ+FS)
5th	Divine® Integrate/Agri mix (SZ+FS)	RainDrover (SZ)
6th	n/a	RainDrover (SZ)+ H2Flo™ (FS)
Treatment/control	111-121 %	145-197 %
Control yield	1.02 t/ha	1.10 t/ha

Table 2 provides a synopsis identifying the top 6 performers overall for both crop establishment and grain yield at Murlong. This evaluation was conducted using a precise split seeding system (knife point + independent dual seeding discs) where co-location of seed zone wetter and seed was assured and a stable wide furrow was provided for furrow surface wetters, applied with a nozzle over a 30 mm wide band.

What does this mean?

- The top 6 soil wetter treatments used at Murlong were consistent across both years. The findings that i) the 13 product chemistries had a consistent early impact on crop establishment at this site over two years and, ii) that maximum grain yield response correlated strongly with greater early impact, are encouraging. Once a suitable product is found for a particular sand environment, it may prove reliable over many seasons and may be recommended to farmers.
- An additional factor likely influencing the cost-effectiveness of a soil wetter is the water harvesting capacity of press wheel furrows, ensuring that capacity is maximised and maintained for as long a period as possible during the season.
- The optimum furrow location, application rate and water volume per ha may require further experimentation on a product by product basis.
- The crop establishment and grain yield benefits achieved with wetters applied under inter-row sowing were not as great as those delivered with an on-row seeded crop without wetters. Analysis of the combined effects of the seeding system and wetters is available in the next article (Seeder Based Strategies).

Acknowledgements

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References

Davies *et al*. (2019). Ten years of managing water repellent soils research in Western Australia – a review of current progress and future opportunities. GRDC Grains Research Update, 25-26Feb2019, Perth WA. www.giwa.org.au/2019researchupdates.

Ward P *et al*. (2019) Low-risk management strategies for crop production on water repellent sands. Agronomy Conference, Wagga Wagga (25-29 August 2019) - http://agronomyaustraliaproceedings.org/index.php/2019/48-2019/761-2019-soil-management-and-constraints.

Seeder-based approaches to reduce the impact of water repellence on crop productivity: Seeder-based strategies

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Location
Murlong
-33.691295S, 135.944050E
Mark and Amy Siviour
Rainfall
Av. Annual: 385 mm
Av. GSR: 270 mm
2019 Total: 223 mm
2019 GSR: 209 mm
Yield
Potential: 2.7 t/ha for decile 1(W)
Actual: 2.4 t/ha (B)
Paddock history
2018: CL Razor wheat
2017: CL Scope barley
2016: Pasture
2015: Mace wheat
Soil type
Grey, non-wetting deep sand
Soil test
$pH_{(Water)}$: 7.7
Plot size
25 m x 1.68 m (6 rows) x 4 reps
Yield limiting factors
Water repellence

Key messages

- **Low-cost, low risk seeder-based strategies achieved valuable wheat/barley crop establishment and grain yield benefits in a severely water repellent sand in two below-average rainfall seasons.**
- **Edge-row/on-row sowing and 230 mm deep furrow till achieved the greatest crop benefits by exploiting existing in-furrow moisture (via guided sowing) and deeper moisture (via lifting by furrow opener), respectively.**
- **While adoption of these strategies involve Real Time Kinematic (RTK) guidance, liquid dispensing and compatible seeding system technologies, scope for simplified solutions to reduce practical challenges exist and their performance should be tested in farm scale demonstrations.**

Why do the trial?

Non-wetting sands have low fertility and suffer from delayed and uneven wetting, which leads to erratic crop establishment, staggered weed germination and generally poor crop productivity due to low plant densities, low nutrient access, poor weed control and crop damage in areas prone to wind erosion. A range of trials in the GRDC funded Sandy Soils Project (CSP00203) are investigating effective solutions available at seeding time to mitigate the impacts of water repellence. A range of seeder strategy experiments in the SA Mallee and in WA have demonstrated the potential for edge-row, on-row, paired-row and deep furrow till sowing to deliver establishment and yield benefits in water repellent sands. Another project trial conducted in a non-wetting deep sand at Lameroo during 2017-2019, quantified significant benefits of edge-row and on-row sowing on wheat and barley crop establishment and grain yield, while significant biomass and grain yield responses to 230 mm deep furrow till were also measured (Desbiolles *et al*. 2019). In addition, experiments at Murlong have demonstrated some consistency in crop responses to wetters on water repellent sand (see Soil Wetter Evaluation article).

The aim of this work was to test the impact of single and combined strategies that could be available to farmers around seed row location relative to stubble row (using RTK guidance), soil wetter (using liquid application), depth of furrow till (adjusting furrow opener to suit), opener type (knife point vs inverted T) and paired row sowing (vs single row baseline), with the aim to recommend a seeding strategy that maximises crop establishment and yield in a water repellent sand.

How was it done?

A trial was set up at Murlong on EP in 2019. This trial was sown with barley on 20-22 May 2019 into 6 row wheat stubble plots established in 2018 on an RTK AB-line to ensure high accuracy when implementing row guided sowing treatments. The soil wetter (SACOA SE14 at 3 L/ha) was applied to the seed zone into 100 L/ha water volume. The seeding agronomy is summarised in the Soil Wetter Evaluation article. Two separate double shoot tine seeding systems were used, namely knife point side banding to achieve edge-row sowing and a baseline knife point centre row banding to achieve inter-row and on-row sowing, both followed by a 100 mm wide banked press wheel.

The 230 mm depth of furrow-till contrast was achieved by using a 120 mm longer knife point (side banding) or by operating 120 mm deeper and setting the seed boot 120 mm higher (centre-row banding).

Eleven experimental treatments with 4 replicates were organised in a randomised complete block design and consisted of: a) six treatments assessing the impact of a selected seed-zone soil wetter under inter-row, edge row and on-row sowing configurations at a reference 110 mm depth of furrow till, b) two soil wetter treatments assessing the additional impact of a 230 mm deep furrow till under inter-row and edge row sowing, c) two soil wetter treatments contrasting the impact of an inverted T opener (95 mm wide) and of paired row sowing (75 mm spread) at the reference 110 mm depth of furrow till under on-row sowing and, d) an additional contrast to the no-wetter control under inter-row sowing, assessing the impact of a proportion of in-furrow fertiliser (6N+12P) applied with the seeds. The treatment factors are listed in Table 1 and illustrated in Figure 1.

Table 1. Key treatment factors and the combinations tested in the seeder strategy evaluation trial at Murlong in 2019.

Treatment label	Seed row placement	Wetter (W)	Furrow Tillage (mm)	Fertiliser (28N, 12P+6S+1.5Zn)
IR+Fert	Inter-row	nil	110	6N+12P with seed
Inter-Row (IR)	Inter-row	nil	110	Deep banded
IR+W	Inter-row	SE14	110	Deep banded
IR+W+Deep-Till	Inter-row	SE14	230	Deep banded
Edge row (ER)	Edge-row	nil	110	Deep banded
ER+W	Edge-row	SE14	110	Deep banded
ER+W+ Deep-Till	Edge-row	SE14	230	Deep banded
On-Row (OR)	On-row	nil	110	Deep banded
OR+W	On-row	SE14	110	Deep banded
OR+W+Paired row	On-row, Paired-row	SE14	110	Deep banded
OR+W+Inv.T	On-row, Inverted T	SE14	110	Deep banded

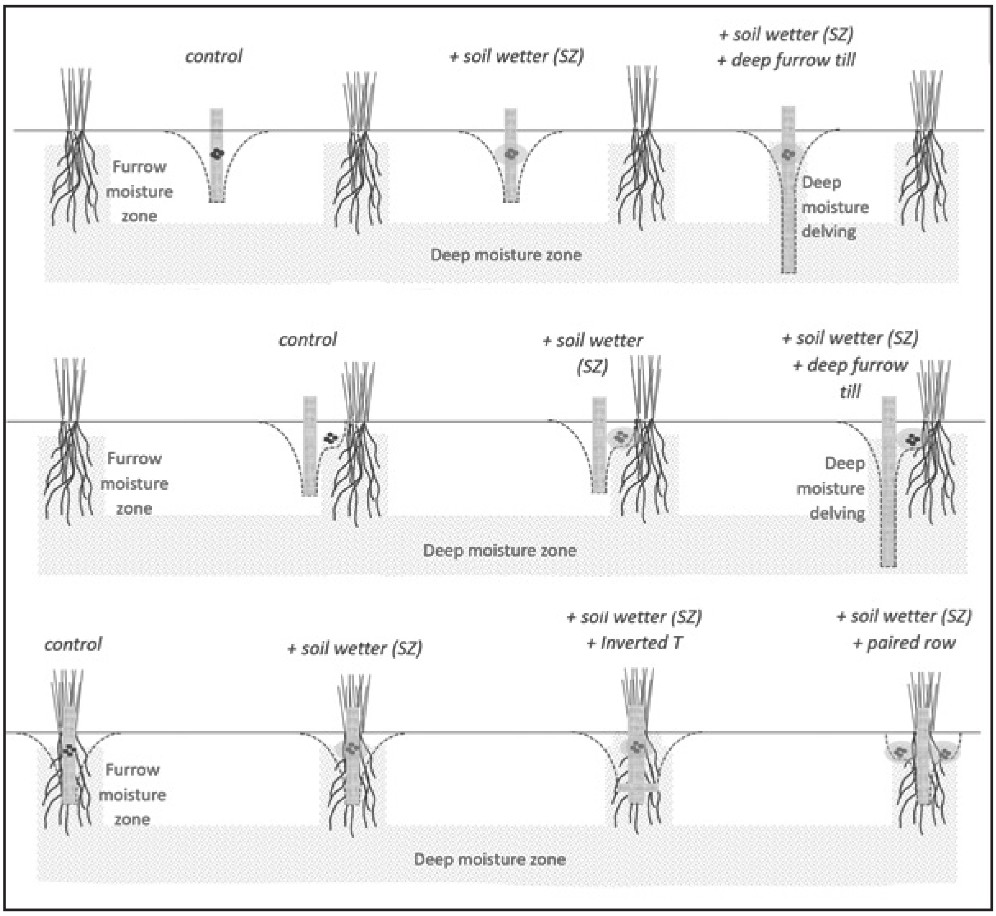

Figure 1. Visual representation of seeder-based strategies for non-wetting sands evaluated at Murlong: Top: inter-row sowing; Centre: edge-row sowing; Bottom: on-row sowing. The schematic highlights the previous year stubble rows; the seeding opener and co-placement of seeds and wetting agent; the moisture zones in furrow and at depth.

What happened?

A dry 11-12 cm thick repellent top layer was present in the inter-row zone at seeding but with consistent moisture below 16-17 cm, which was separated by a patchy transition zone. In contrast, the existing stubble row zone had good moisture below 4-5 cm dry top layer. Measurements quantified 9 mm more water stored in the 0-40 cm layer in the stubble row zone compared to the inter-row zone, with the majority occurring in the top 25 cm layer. This moisture benefit in the stubble row was consistent with observations made in water repellent sands at Lameroo during 2018/19, which ranged between 7-9 mm of extra water stored on the 0-40 cm layer in both seasons.

On-row sowing alone increased plant density by 39 plants/m^2 over edge-row sowing and by 95 plants/m^2 over inter-row sowing (Figure 2). Edge-row sowing results were much more variable indicating the sensitivity of this strategy to an optimum position relative to the stubble row and representing a greater difficulty for farm adoption. Inter-row sowing crop establishment was 21 plants/m^2 worse than the equivalent control under the soil wetter evaluation trial (see Soil Wetter Evaluation article), which had used a more accurate seeding system. The placement of 6N+12P fertiliser with the seed created a small additional loss to an already very poor control crop establishment (at 0.28 m row spacing, approximately 10% seedbed utilisation).

The addition of soil wetter increased plant density by 22 and 29 plants/m^2 in inter-row and edge-row sowing, respectively (Figure 2). In contrast, no soil wetter benefits were measured under on-row sowing, where the stubble row soil was already sufficiently moist to achieve good germination on its own. The benefit of the soil wetter (SACOA SE14 at 3 L/ha) under inter-row sowing was slightly less (i.e. 22 plants/m^2 vs 36 plants/m^2) than that measured in the Soil Wetter Evaluation trial, which may be due to the better seed and wetter co-placement and water harvesting furrow quality obtained by the tine-disc-wide press wheel seeding system of that trial. This perhaps emphasises the importance of considering seeder set-up issues in combination with wetter application to extract the best possible response from the wetter.

Deep furrow till to 230 mm depth had a major positive impact (extra 74 plants/m^2) under inter-row sowing with soil wetter, where deeper moisture delving most benefited an otherwise dry seed zone (Figure 2). Deep furrow till did not improve establishment under edge-row sowing where a 26 plants/m^2 decrease was recorded. This may be due to the long steep knife point to reach 230 mm depth likely less effective at delving moisture up and the extra disturbance also affecting seed placement uniformity with this compact side banding unit. Deep furrow till was not evaluated under on-row sowing. However, a positive response to inverted T opener (+20 plants/m^2) was measured, indicating that the extra quantity of moist furrow soil lifting and mixing benefited seed germination.

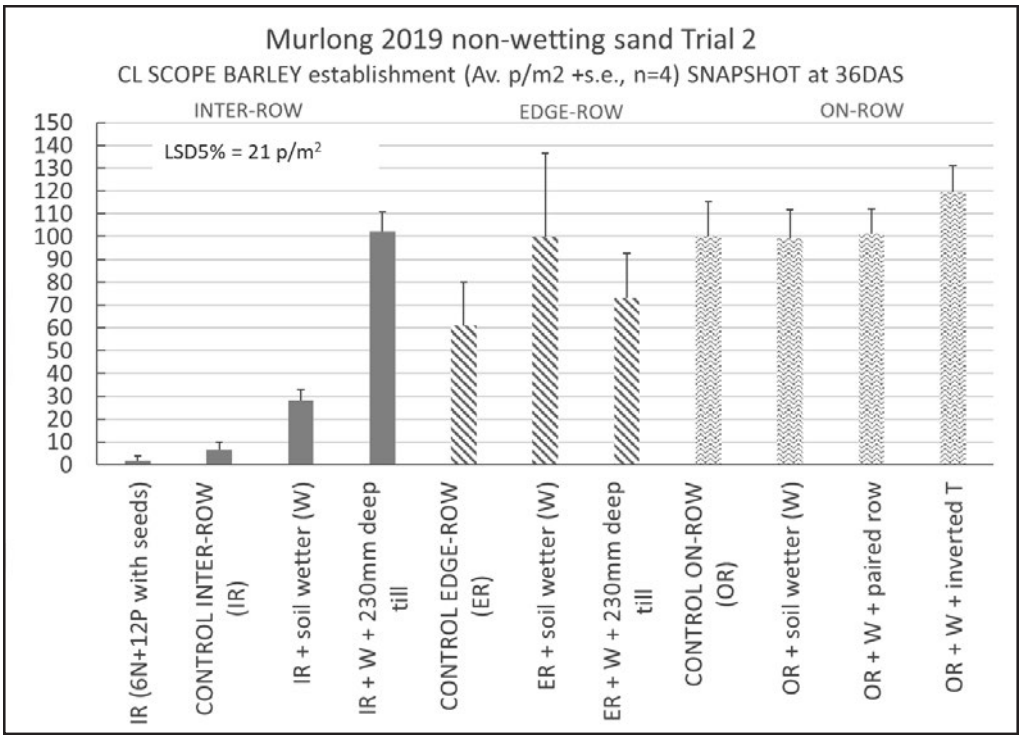

Figure 2. Impacts of various inter-row, edge-row and on-row sowing strategies on crop establishment at 5 weeks after sowing in barley at Murlong in 2019. The error bars represent the standard errors of the treatment means.

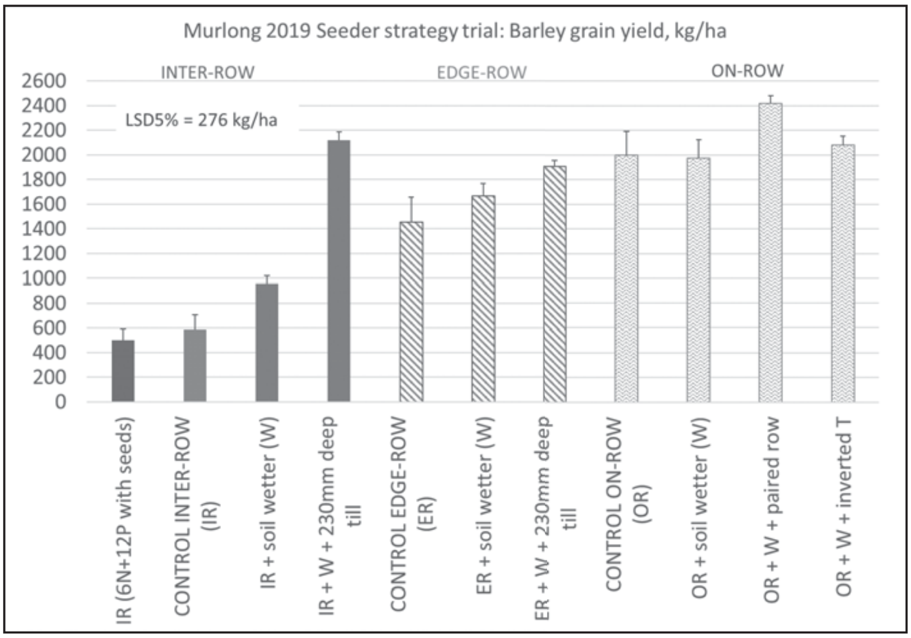

Figure 3. Impacts of various inter-row, edge-row and on-row sowing strategies on barley grain yield in 2019 at Murlong. The error bars represent the standard errors of the treatment means.

Under on-row sowing with soil wetter, the paired row system did not improve crop establishment over the single row equivalent, both using a knife point opener.

Figure 3 shows grain yields ranged from 0.5-2.42 t/ha. Inter-row, edge-row and on-row sowing controls yielded 0.59, 1.45 and 2.0 t/ha, respectively. All on-row treatments yielded at or above 2 t/ha, with paired row sowing yielding the highest (2.42 t/ha). Inter-row sowing benefited from the soil wetter (0.37 t/ha gain), and even more drastically from the 230 mm deep furrow till (1.16 t/ha additional gain). The soil wetter had no effect on grain yield when applied on-row where furrow moisture was sufficient to achieve good germination. Overall, grain yield responses to treatments were highly correlated with their established plant densities, indicating higher plant numbers was a key factor driving barley grain yield under the trial conditions. The inter-row control in the soil wetter evaluation trial (see Soil Wetter Evaluation article) yielded more (0.5 t/ha) than in this trial, which may be explained by the combined benefits of 5 days earlier sowing, greater water harvesting and more stable furrows, more precise seed placement and soil wetter co-location achieved by the tine-disc-wide press wheel seeding system.

What does this mean?

Seeder-based strategies for reducing the impact of water repellence can deliver large benefits on crop establishment and productivity in terms of grain yield. The strategies evaluated focussed on accessing the stored moisture within existing stubble rows, the deeper moisture found below a dry non-wetting top layer and maximising in-season rainfall infiltration and use.

Specific technologies were required to implement these strategies, such as: precision guidance (on-row, edge-row sowing), liquid dispensing (soil wetters), seeding system attributes (adjustable depth of furrow till, stable water-harvesting furrows, precision placement of seed and liquids in furrow, paired row seeding, seed-fertiliser separation).

Combining technologies can deliver additive crop establishment and productivity benefits, thus have the potential to form the basis of best-practice on-farm. Adoption of some strategies, however, is likely to be limited if major investments are required by the grain grower. Other complications include issues such as water repellent sands only occupying part of larger paddocks and larger scale machinery with variable tracking accuracy.

Some of the benefits summarised above could be achieved with low-technology options such as upgrading seeders for deeper moisture delving capability and seeding (without RTK guidance) at a small angle to existing stubble rows, in order to maximise the benefits of furrow moisture access. Project validation activities in 2020 will work with growers to evaluate which seeder-based strategies can be effectively implemented at farmer scale in different sand environments.

Acknowledgements

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Cereal responses to ripping, seeding and nutrition across the SA Mallee in 2019

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Location
Lameroo
Pocock Family

Rainfall
Av. GSR: 205 mm
2019 GSR: 270 mm

Paddock history
2018: Scope CL barley
2017: Scepter wheat
2016: Medic based pasture

Soil type
Non-wetting slightly acidic deep sand

Plot size
20 m x 2 m 4 reps

Trial design
Experimental: randomised complete block

Yield limiting factors
Non-wetting, nitrogen, moderate soil strength

Location
Waikerie
Schmidt family

Rainfall
Av. GSR: 164 mm
2019 GSR: 119 mm

Paddock history
2018: Scepter wheat
2017: Vetch/canola mix

Soil type
Deep alkaline sand

Plot size
20 m x 2 m 4 reps

Trial design
Experimental: randomised complete block

Yield limiting factors
High soil strength, nitrogen, phosphorus

Key messages

- **Soil strengths high enough to hurt crop performance are apparent at all our Mallee sandy sites, with non-wetting also occurring at some sites depending on season.**
- **The average gain from ripping across the Mallee has been 0.5 t/ha, but higher wheat yield gains of 0.75 and 1.3 t/ha depending on depth (40 cm, 60 cm) were demonstrated at Lowaldie in 2019.**
- **However, very dry years can also lead to yield penalties in years subsequent to ripping. Sand at Waikerie that was ripped in 2018 yielded 0.5 t/ha less than unripped soil in 2019.**
- **Deep tillage (20 cm) as part of the seeding pass improved crop yield in 2017 and 2018 but not in 2019, suggesting shallow ripping responses are quite sensitive to placement relative to previous rows.**
- **Permanent fertility strips, aiming to improve a narrow area of the furrow through targeted and repeated sowing with/without amendments (clay, organic matter, fertiliser), have not generated a significant yield advantage over a 3-year cycle.**

Why do the trials?

The aim of this work is to increase crop water use on sandy soils in the Southern cropping region by improving diagnosis and management of constraints in underperforming sands. Water-use and yields on sandy soils are commonly limited by a range of soil constraints that limit root growth. Constraints can include a non-wetting topsoil-layer with poor crop establishment, soil pH issues (both acidity and alkalinity), poor nutrient supply and compaction. To achieve the best possible profit-risk outcomes, we are testing strategies implemented with the seeder (e.g. guided row sowing, seed placement, wetting agents, fertiliser placement, furrow management, permanent fertility strips), through to high soil disturbance interventions (e.g. deep ripping, spading, deep ploughing with and without nutrient inputs) that require specialised machinery at nine research sites across the Southern region.

How was it done?

Lameroo

A permanent fertility strip (FS) was established near Lameroo where crops were sown in very close proximity to previous crop rows with and without amendments using a side-banding knife point system. The row was sown to the left of the 2017 row in 2018 and on top of the 2017 row in 2019. Additional to mineral nutrition inputs to the furrow, a number of contrasting amendments (compost, clay or biochar) were applied every year for three years (rather than in one high-rate application), one of which included placement at 20 cm depth, in contrast to the baseline 10 cm furrow depth.

Location
Lowaldie
Loller Family
Rainfall
Av. GSR: 237 mm
2019 GSR: 184 mm
Paddock history
2018: Stingray canola
2017: Scepter wheat
2016: Stingray canola
Soil type
Deep neutral pH sand
Plot size
20 m x 2 m 4 reps
Trial design
Experimental: randomised complete block
Yield limiting factors
Non-wetting, nitrogen, moderate soil strength, root disease

The 2019 trials (Year 3) were sown to fertility strip treatments or inter-row (control with no amendment) positions with CL Scope barley at 61 kg/ha on 30 May. At sowing the base nutrient inputs were 21 kg/ha N, 12 kg/ha P and 6 kg/ha S with a subset of treatments receiving higher nutrient inputs of 48 kg/ha N, 12 kg/ha P and 16 kg/ha S. All plots were top-dressed with a further 25 kg/ha N in two applications in-season due to tissue tests revealing N deficiency after the first topdressing event.

Waikerie

A range of more intensive interventions were implemented at Waikerie in 2018 to evaluate the value of increasing the depth of physical treatments (ripping) and/or amendments (chicken litter @ 2.5 t/ha or nutrient inputs from fertiliser to match chicken litter) (Table 1). The shallow fertiliser treatment was banded at 8 cm depth prior to sowing while chicken litter was spread on the soil surface. In 2019 we measured the residual (1 year old) responses to these treatments. Adjacent to the intensive treatments was a trial testing nutrient packages applied with the seeder including combinations of N (20 kg/ha) and P (10 kg/ha) supplied on the surface, 3, 6 or 10 cm deep. The trials were sown with Spartacus CL barley on 22 May with 20 kg N/ha and 15 kg P/ha as urea and MAP.

Lowaldie

A small trial was established at Lowaldie in 2019 testing the response to nil, 40 cm or 60 cm ripping depth. The plots were ripped on 1 May under dry conditions with only 6-10 mm of plant available water in the top 100 cm. The plots were sown with Scepter wheat on 30 May.

What happened?

All sites experienced below average growing season rainfall in 2019 with 184 mm at Lowaldie (average 237 mm) and 205 mm at Lameroo (average 270 mm), but despite average conditions in May and June Waikerie experienced the worst season with 119 mm (average 164 mm). This followed a very dry fallow period for all sites.

Lameroo

Barley was sown into 89-93 mm of stored water on the sandy soil types, but more than half of this water was stored in the 60-100 cm layer. Independent of treatment there was 39-41 kg/ha of soil mineral N at sowing in the sands. There was a 7 mm soil water advantage at 0-40 cm depth for crops sown edge-row (fertility strip) compared with the inter-row position. However, this year, no fertiliser was applied with the seed, with all deep banded at full furrow depth (avoiding the possible toxicity that was experienced in 2018). The FS treatments in this Year 3 were edge-row sown into the Year 2 stubble rows (rather than the old Year 1 stubble rows, as initially planned), in order to access the furrow moisture benefits measured at sowing. While all treatments achieved an excess of 100 plants/m^2, the barley crop establishment under inter-row sowing achieved an extra 18 plants/m^2, significantly higher than their equivalent edge-row sowing FS treatments. This is explained by the likely impact of significant residue clumping that occurred in most edge-row sown plots, from the uprooting of the Year 1 stubble rows when edge row sowing into the adjacent Year 2 stubble rows. The Lameroo site was depleted for soil N after two cereal crops in the seasons prior and both GS31 biomass and tissue tests (not shown) during tillering indicated N deficiency. The response to high nutrient input observed for inter-row treatments at first node was not significant at grain yield, which was in part due to dry conditions late in the season and high levels of variation in yield across all plots (Table 2).

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

Site (Year)	Treatment (depth cm)	Amendment Type	Amendment Placement
Lameroo (2017)	Seeder (10 vs. 20)	Compost (up to 200 kg/ha), clay (up to 200 kg/ha), biochar (up to 60 kg/ha) annual	At furrow depth
Waikerie (2018)	Rip (30), Rip (60)	Chicken litter (2.5 t/ha), fertiliser matched at ripping time	Deep, surface
Waikerie (2019)	Seeder (8,15)	Fertiliser (N, P)	At furrow depth
Lowaldie (2019)	Rip (40), Rip (60)	Nil	

Table 2. Barley responses to inter-row and edge-row (fertility strip) sowing positions with base and high levels of sowing nutrient inputs along with a range of amendments at Lameroo in 2019. Clay is 100 kg/ha as Ca bentonite, compost is 100 kg/ha TailorMadeTM Prills, biochar is 60 kg/ha Cool Terra. Within a column different letters represent a significantly different treatment at P=0.05.

Treatment	Nutrient input	Establishment (plants/m^2)	GS31 biomass (t/ha)	Grain yield (t/ha)
Inter-row sowing	Base	132a	0.69c	1.83
Fertility strip	Base	114bcd	0.89bc	1.81
Fertility strip with clay	Base	122ab	0.76c	1.89
Fertility strip with compost	Base	121ab	0.83bc	2.07
Fertility strip with clay + compost	Base	118bc	0.84bc	1.95
Fertility strip with x2 clay + compost	Base	101e	0.77bc	1.94
Deep (200 mm)* fertility strip with clay + compost	Base	101e	0.68c	1.99
Fertility strip	High	108cde	0.83bc	2.06
Fertility strip with biochar	High	102e	1.01ab	2.32
Inter-row sowing	High	126ab	1.13a	2.05
LSD (P=0.05)		*13*	*0.24*	*ns, P=0.15*

In contrast to these results a small sub-trial on the lower yielding South facing slope showed a large establishment delay for inter-row sown plots at 21 days after sowing relative to on-row sown plots (40 vs. 120 + plants/m^2) which translated to an early (GS31) biomass effect (0.3-0.4 t/ha inter-row vs 0.63-0.71 t/ha edge-row). These effects carried through to harvest and resulted in a 0.3 t/ha yield advantage of on-row sowing (1.5 edge-row vs. 1.2 t/ha inter-row) in the sub-trial. Some buffer strips also indicated a potential response to deep-till (200 mm) with edge-row sowing that was not detected in the main trial despite this treatment showing significant yield advantage in the previous two years.

Waikerie

The Waikerie site has high soil strength at 15-55 cm depth and based on soil test results is potentially deficient for P, Zn and Mn. At the time of sowing there was 65-83 mm of water (but more than half of this was below 60 cm depth), and strong carryover of N from the dry season of 2018 with 100-159 kg /ha mineral N. The fertiliser experiment lacked consistent trends. The lowest yielding treatments in this season of high N carryover were where fertiliser N was closest to the seedling early in the season while the highest yielding treatment was where fertiliser N was at 10 cm depth with significant separation from the seed.

In the ripping experiment, no treatment performed better than the control in 2019 which had no disturbance and was fertilised with 20 kg/ha N and 10 kg/ha P. While the 30 cm deep ripping treatments did not cause a barley yield penalty, the 60 cm deep treatments caused a 0.5 t/ha yield penalty (averaging 0.2 t/ha compared with the control of 0.7 t/ha) (Figure 1). This result is in contrast with 2018, the year when the plots were ripped and the 60 cm rip treatment offered a 0.3 t/ha yield advantage over the control. The experiment will continue for a further 3 years to evaluate the longevity of physical and nutrient carry-over effects.

Table 3. Barley responses to fertiliser treatments at Waikerie. Treatments with a different letter are significantly different from each other (P=0.05) for yield.

Treatment	GS31 biomass (t/ha)	Grain yield (t/ha)
Nil	0.91	0.91bc
MAP broadcast	0.87	1.05bc
MAP with seed	0.93	1.10ab
MAP at 6 cm	0.84	0.95bc
MAP at 10 cm	1.02	1.02bc
MAP + Urea at 10 cm	1.01	1.27a
MAP at 6 cm + Urea topdress early	0.84	0.86c
MAP with seed + Urea at 6 cm	0.85	0.84c
MAP at 10 cm + Urea topdress early	0.99	0.93bc
MAP with seed + Urea at 10 cm	0.94	1.11ab
LSD (P=0.05)	*ns*	*0.22*

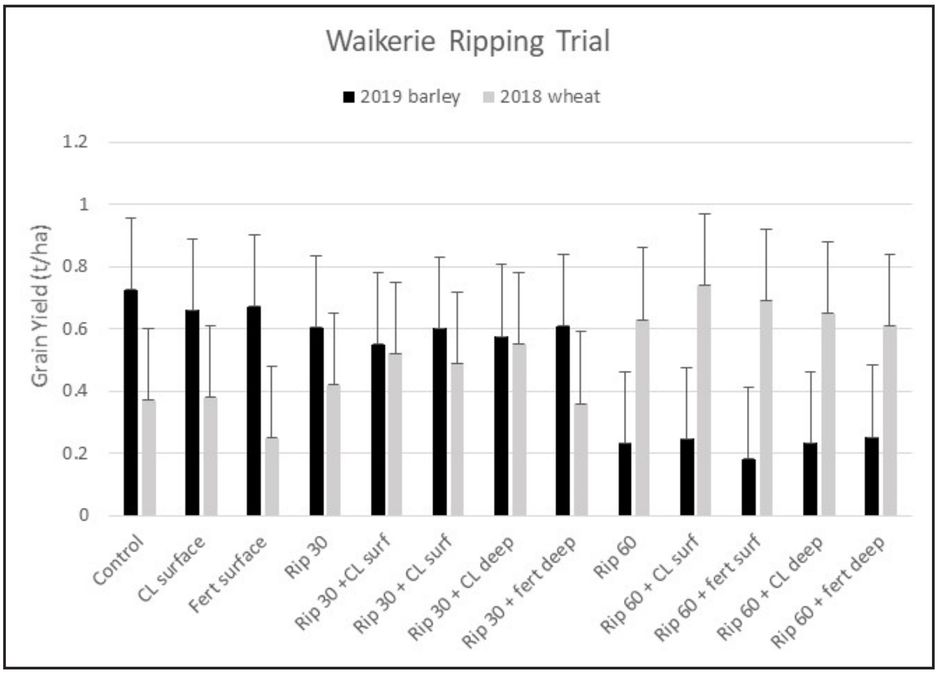

Figure 1. 2018 wheat and 2019 barley yields (t/ha) at Waikerie in response to treatments implemented in 2018; ripping (Rip30, Rip60) with and without 2.5 t/ha chicken litter (CL) or matched nutrients from fertiliser (fert) applied at the surface (surf) or deep. Error bars represent least significant difference (P=0.05, LSD 0.23 t/ha in both years).

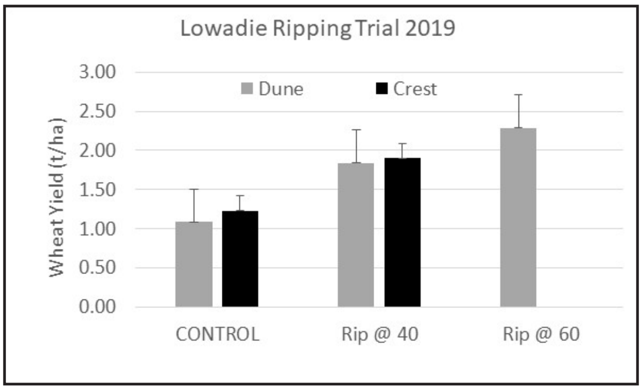

Figure 2. Wheat yields at Lowaldie in response to ripping treatments where the error bars represent least significant difference (P=0.05, LSD 0.19 crest and 0.42 dune t/ha). Yield not presented for crest 60 cm rip due to spray damage of 2 reps.

Lowaldie

Ripping in 2019 generated large wheat yield benefits: 0.7-0.8 t/ha extra with ripping to 40 cm and 1.3 t/ha extra with ripping to 60 cm on the dune (Figure 2).

What does this mean?

The fertility strip treatments implemented at Lameroo showed benefits of edge-row sowing plus deep tillage in year 1 and year 2 but not in year 3 when the row position returned to that of year 1. The addition of amendments with the fertility strip treatments did not generate consistent yield benefits. Experiments with fertiliser packages at Waikerie have not revealed new options over two very dry seasons. Year 1 benefits from deep ripping have been measured at Waikerie (2018) and Lowaldie (2019). However, 60 cm rip treatments at Waikerie have revealed a significant risk in the year after ripping with a 0.5 t/ha yield penalty in the very dry season of 2019.

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The how's and why's for deep ripping sandy soils

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Location
Lameroo
Pocock Family
Rainfall
Av. GSR: 205 mm
2019 GSR: 270 mm
Paddock history
2018: Scope CL barley
2017: Scepter wheat
2016: Medic based pasture
Soil type
Non-wetting slightly acidic deep sand
Plot size
20 m x 2 m 4 reps
Trial design
Experimental: randomised complete block
Yield limiting factors
Non-wetting, nitrogen, moderate soil strength

Location
Waikerie
Schmidt family
Rainfall
Av. GSR: 164 mm
2019 GSR: 119 mm
Paddock history
2018: Scepter wheat
2017: Scepter wheat
2016: Stingray canola
Soil type
Deep neutral pH sand
Plot size
20 m x 2 m 4 reps
Trial design
Experimental: randomised complete block
Yield limiting factors
Non-wetting, nitrogen, high soil strength, root disease

Key messages

- **Deep ripping is most effective in deep sandy-textured soils, and when the ripper tines go beyond the compacted layer. Large grain yield increases over at least several years are common on deep sands.**
- **Deep ripping with ripper tines spaced less than 60 cm did not increase final grain yield therefore wider (up to 60 cm) tine spacing can be considered in order to use less machinery horsepower.**
- **The risk of wind erosion is very high when deep ripping is done in legume stubble and in cereal paddocks with very low stubble cover.**
- **The largest potential downside associated with deep ripping in low rainfall areas is that it increases the risk of haying off when soil water reserves are low and the finish to the season is harsh and dry.**
- **Controlled traffic should increase the longevity of the deep ripping benefit and reduce the need to repeat the deep ripping with its associated cost.**
- **Overcoming multiple soil constraints (compaction, sodicity, acidity, etc.) can improve the longevity of benefits and overall return on investment in the long-term.**

Why do the trials?

Sandy soils dominate the landscape across the low rainfall region of south-eastern Australia, and there is increasing evidence that compaction is widespread on these soils. Soil compaction is one of many problems facing modern farming systems on coarse textured soils mainly because of the widespread use of heavy machinery and intensive cropping. Subsoil compaction is a subsoil constraint that can adversely affect soil biological activity and soil physical condition, particularly storage and supply of water and nutrients. Compaction increases soil bulk density and soil strength, while decreasing porosity, soil water infiltration and water holding capacity. Sandy soils have a natural tendency to form hard layers just below the soil surface, hence deep ripping is becoming a common strategy for addressing soil compaction, hard pans and ameliorating hard setting soils.

Deep ripping is most effective in deep sandy-textured soils (Paterson and Sheppard, 2008) where roots need to grow deep to access subsoil moisture and nutrients. However, not all soil and crop types respond positively to deep ripping every season. Isbister *et al*. (2018) have reported that responses to deep ripping in WA were greater in sandy soils (20-37% yield increase) than loamy duplex >30 cm deep (22%) or shallow duplex soils (4%).

Location
Lowaldie
Loller Family
Rainfall
Av. GSR: 237 mm
2019 GSR: 184 mm
Paddock history
2018: Stingray canola
2017: Scepter wheat
2016: Stingray canola
Soil type
Deep neutral pH sand
Plot size
20 m x 2 m 4 reps
Trial design
Experimental: randomised complete block
Yield limiting factors
Non-wetting, nitrogen, moderate soil strength

Tine spacing, working depth, shallow leading tines or discs, soil moisture content, timing and soil type all need to be taken into account in order to maximise productivity gains and also to make this strategy cost effective. Research by the Department of Agriculture and Food Western Australia (DAFWA), funded by GRDC, estimates that the costs associated with deep ripping can range from $50-60 per hectare for standard ripping (to a depth of 30-40 cm) and up to $70-90/ha for ripping to a depth of 50-70 cm (depending on machinery and soil conditions). Therefore, the challenge that growers face is refining how best to ameliorate compacted soils while keeping costs down but at the same time, maximising and prolonging the benefits. It is important to note that if the soil in, or below, the ripping depth contains other constraints such as acidity, poor structure from sodicity or subsoil salinity, the benefits of deep ripping may not be fully realised.

To gain insight into how deep ripping is impacting crop performance and how best to conduct it on different soil types, this paper summarises the results from replicated trials conducted in different low–medium rainfall cropping regions of Australia. The expectation is that collation of data from these trials will assist in making sound guidelines for growers which address key questions around if and why they should be considering deep ripping as a soil amelioration strategy, and how best to undertake it to achieve sustainable and improved crop yields and good returns for every dollar invested.

Justification for deep ripping

Research conducted in the 1970s and 80s demonstrated that on deep sands and sandy earths in WA, wheat roots can extract water from depths ranging from 1.4 to 2.5 metres (Hamblin *et al*. 1982, Hamblin *et a*l. 1988). The capacity of roots to extract water and nitrogen from such depths is critical on these soil types, in moisture limited environments. These soils tend to have relatively low water holding capacity, and the use of deeper subsoil moisture is critical for grain filling. In compacted sandy soils where penetration resistance exceeds 2500 kPa, crop root growth is severely restricted and these crop potentials cannot be realised. In these situations, deep ripping can be a strategy to break up that compaction, improve root penetration and ultimately crop performance.

Historically peak soil strength in deep sands and sandy earths typically occurred at depths of 30-35 cm and reached strengths of 2000–2500 kPa as shown in Figure 1b. However, as machinery sizes and axle loads have increased, the severity of the compaction problem has continued to worsen. Recent soil strength measurements indicate that peak soil strength now occurs at depths as shallow as 20 cm, with strengths ranging from 3000-3500 kPa (Figure 1 a and b). Therefore, when considering shattering compaction, deeper ripping past the compacted layer is recommended in order to maximise the benefits.

Crop responses to deep ripping

Reviews of historic deep ripping trials have shown substantial benefits with cereal yield increases of 22-37% in the first year (Crabtree 1989, Davies *et a*l. 2006, Jarvis 2000). In recent experiments conducted in WA (Davies *et al*. 2017) during 2014-16, ripping increased average wheat yields by 8% for shallow 30-40 cm ripping, 35% for deeper ripping to depths of 50 cm or more, and 53% for deeper ripping with topsoil slotting (Table 1).

Similar results of significantly improved grain yields when ripping was deeper (+60 cm) were reported at Waikerie recently (McBeath *et al*. 2018). However, deeper intervention to 60 cm did not provide any significant yield benefits over a depth of 30 cm at several other SA and Vic sites (Moodie *et al*. 2018, McBeath *et al*. 2019).

What happened?

SA Mallee trials

Five replicated field trials (Table 2) were conducted during the 2018 and 2019 cropping seasons on sandy soils across the northern and southern Australian Mallee, and the upper Eyre Peninsula (UEP). Trial 1 (depth x spacing) was set up at Peebinga (2018 and 2019) and at Buckleboo (2019) to investigate the impact of depth of ripping on crop productivity, to evaluate whether narrow or wide tine spacing changed crop responses and to estimate the longevity of the amelioration benefits.

Trial 2 was set up at Loxton as a crop rotation experiment with three different crop types (wheat, barley and field peas each year), with the aim of assessing which crop types respond better to deep ripping in the first, second and third year after amelioration.

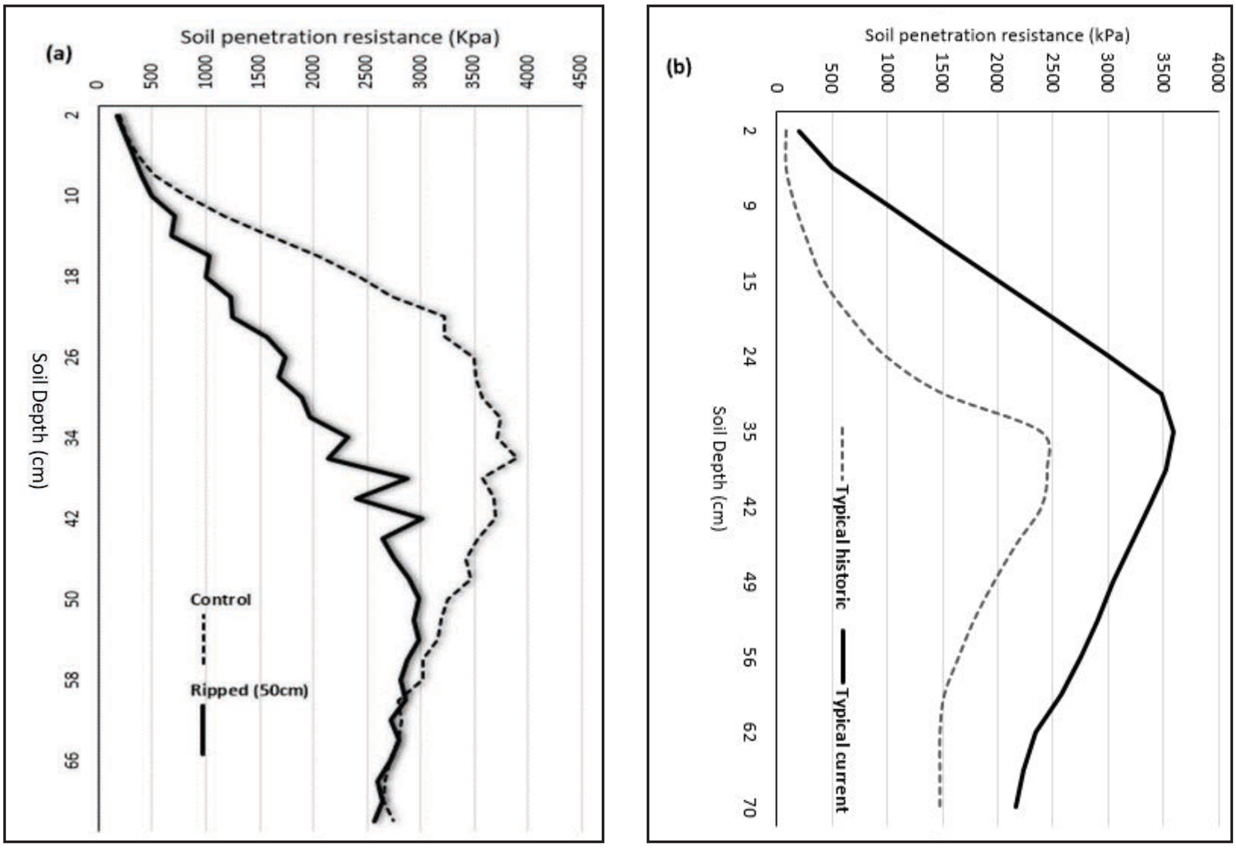

Figure 1. Plots showing penetration resistance for a SA sandy soil at Loxton (a), and typical historical and current soil penetration resistance measures for deep WA sandy soils (b). Values of 1500-2500 kPa are considered moderate compaction, 2500-3500 kPa severe compaction and >3500 kPa extreme compaction.

Table 1. Crop responses to deep ripping at different depths and the impact of topsoil slotting (with inclusion plates). Trials conducted in WA during 2014-2016 (Davies** et al. **2017).

Location, crop	**Soil type**	**GSR (mm)**	**Control yield (t/ha)**	**Ripped 30-40 cm**		**Ripped 50-70 cm**		**Ripped 50-70 cm + topsoil slotting**	
				Yield	**%**	**Yield**	**%**	**Yield**	**%**
Moora, canola	Loamy sand	177	1.9	2.2	**16**	2.8	**47**	2.9	**53**
Wubin, wheat	Deep sand	228	2.1	2.7	**29**	3.0	**43**	-	**-**
Binnu, wheat	Deep sand	219	0.8	0.8	**0**	1.4	**75**	1.8	**123**
Binnu, wheat	Loamy sand	219	2.1	2.1	**0**	2.8	**33**	3.6	**71**
Beacon, wheat	Sandy duplex	240	3.8	3.9	**3**	3.5	**-11**	4.5	**15**
Broomehill, wheat	Sandy duplex	227	1.8	2	**11**	3	**67**	-	**-**
Munglinup, wheat	Sandy duplex	280	3.6	3.6	**0**	3.6	**0**	4.2	**17**
Meckering, wheat	Sand over gravel	323	2.7	-	**-**	3.4	**26**	-	**-**
Meckering, wheat	Deep sand	323	2.4	-	**-**	3.4	**46**	-	**-**
Meckering, wheat	Sand over gravel	323	2.2	2.5	**15**	3	**38**	3	**38**
Walkaway, lupin	Deep sand	219	1.2	-	**-**	2.3	**92**	-	**-**

Table 2. Deep ripping locations and treatment details for 2018 and 2019 cropping seasons.

Year	Trial	Location (crop)	Region	Treatments
2018	Trial 1	**Peebinga** (barley)	southern Mallee	Depths (0, 20, 40, 60, 70 cm) Tine spacings (Narrow=30 cm and wide=60 cm)
	Trial 2	**Loxton** (wheat, barley, peas)	northern Mallee	Ripped (50 cm) vs compacted (control) Tine spacing 50 cm
2019	Trial 1	**Peebinga** (wheat)	southern Mallee	Depths (0, 20, 40, 60, 70 cm) Tine spacings (Narrow=30 cm and wide=60 cm)
		Buckleboo (barley)	upper EP	
	Trial 2	**Loxton** (wheat, barley, peas)	northern Mallee	Ripped (50 cm) vs compacted (control) Tine spacing 50 cm

GSR: 2018 Loxton (105 mm), Peebinga (116 mm); 2019 Loxton (93 mm), Peebinga (152 mm), Buckleboo (143 mm).

Deep ripping treatments were imposed using a straight tine ripper on 11 May and 21 May 2018 at Loxton and Peebinga respectively, and at Buckleboo on 10 April 2019. Penetration resistance readings were taken on 7 August 2018 at both Mallee sites using a Rimik CP40 (II) cone penetrometer to estimate the magnitude and depth of compaction. In season assessments of crop density, dry matter (DM) production, grain yield and quality were undertaken to help understand the effect of ameliorating compaction in typical deep sands of the SA mallee.

With total growing season rainfall (GSR) ranging from only 93–152 mm crop growth and productivity were severely limited at all sites. However, visual and positive responses in crop establishment and biomass to ripping were evident throughout the growing season in all trials. No grain yield was achieved in field peas at the Loxton site for 2018 and 2019 because of severe frost which resulted in pod damage. Overall, our trials have demonstrated that ameliorating compacted sandy soils in low rainfall environments can lead to substantially improved crop biomass (data not shown) and grain yield over at least 2 seasons. Deep ripping increased wheat yields by up to 135% for shallow 20-40 cm ripping and up to 235% for deeper ripping to depths of 50 cm or more. Barley grain yield was increased by up to 93% for shallow 20-40 cm ripping and up to 193% for deeper ripping to depths of 50 cm or more (Table 3). Only shallow ripping did not cause large grain yield gains.

Averaged over all ripping depths, deep ripping with tines spaced narrowly at 30 cm resulted in an increase in early and late shoot DM (data not shown). However, this benefit did not carry through to grain yield (Figure 2). Deep ripping has the potential to promote early biomass growth but in moisture limited environments, one of the largest potential downsides associated with deep ripping is that it increases the risk of haying off when soil water reserves are low and the finish to the season is dry (Davies *et al*. 2017). In some situations, faster water use and increased vegetative biomass caused by deep ripping can leave inadequate stored soil water for grain filling resulting in haying off and reduced yields.

Our trials also show that when the compacted soil in question is compacted to depth, then ripping deeper is better for grain yield, provided there are no other chemical constraints below the compaction zone. There was a consistent general trend of increasing grain yield with increasing ripping depth across all sites in 2 years of conducting these trials (Figure 3). Cumulative grain yields over the 2 seasons have shown that the deepest ripping treatment (70 cm) is achieving the highest yield. This could be attributed to increased plant root growth, access to nutrients and water down the soil profile, and similar results of better grain yields with deeper ripping have been reported by several authors (Davies *et al*. 2017, Isbister *et al*. 2018, McBeath *et al*. 2018, McBeath *et al*. 2019, Moodie *et al*. 2018). However, it is important to note that the highest yielding ripping treatment does not necessarily translate to the most profitable and most sustainable tillage strategy. Apart from these productivity gains from deeper tillage, there are also natural resource benefits such as nitrate leaching can be reduced through deeper rooting and greater water and nitrogen uptake by the higher-yielding cereal crops and in the long-term should reduce saline seeps developing in lower parts of the landscapes.

Table 3. Summary of deep ripping trials conducted during 2018 and 2019, showing crop responses to deep ripping at different depths and tine spacing on grain yields.

Year	Location	Crop	Tine spacing (cm)	Control	Ripped 20 cm		Ripped 40 cm		Ripped 50 cm		Ripped 60-70 cm	
				Yield (t/ha)	Yield (t/ha)	% change	Yield (t/ha)	% change	Yield (t/ha)	% change	Yield (t/ha)	% change
2018	Loxton	Wheat	50	0.58	-	**-**	-	**-**	0.69	**19**	-	**-**
	Loxton	Barley	50	0.54	-	**-**	-	**-**	1.08	**100**	-	**-**
	Peebinga	Barley	30	0.27	0.46	**70**	0.52	**93**	-	**-**	0.79	**193**
	Peebinga		60		0.23	**-15**	0.43	**59**	-	**-**	0.77	**185**
2019	Loxton	Barley	50	0.13	-	**-**	-	**-**	0.18	**38**	-	**-**
	Loxton	Wheat	50	0.22	-	**-**	-	**-**	0.56	**155**	-	**-**
	Peebinga	Wheat	30	0.20	0.20	**0**	0.47	**135**	-	**-**	0.67	**235**
	Peebinga		60		0.28	**40**	0.29	**45**	-	**-**	0.62	**210**
	Buckleboo	Barley	30	2.13	2.79	**31**	2.88	**35**	-	**-**	3.35	**57**
	Buckleboo		60		2.38	**12**	3.46	**62**	-	**-**	3.33	**56**

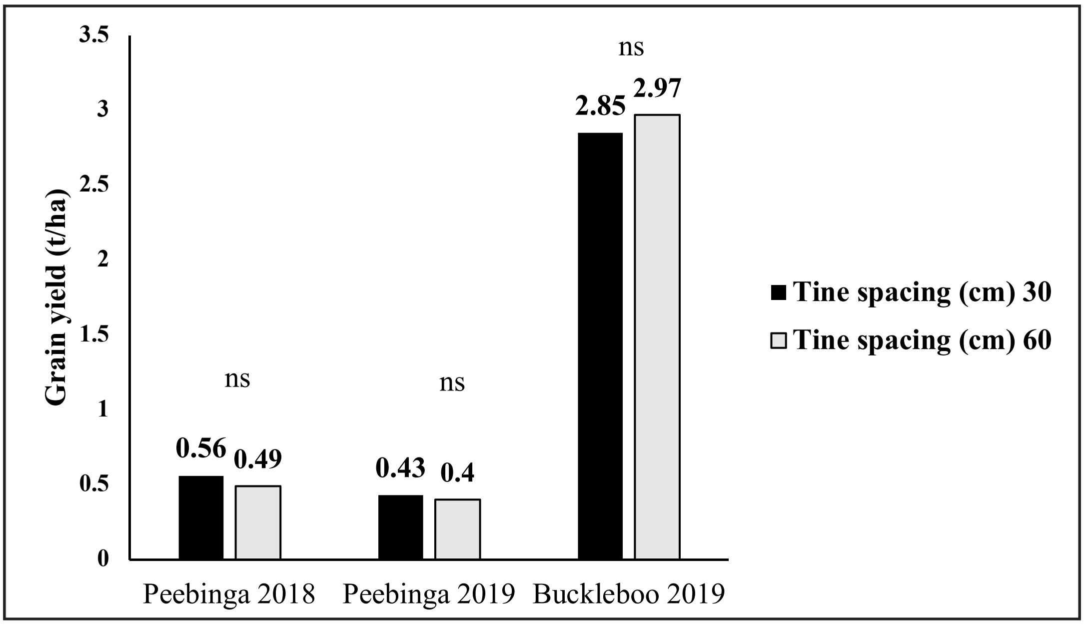

Figure 2. Cereal grain yield (t/ha) on 30 cm and 60 cm tine spacing at Peebinga and Buckleboo.

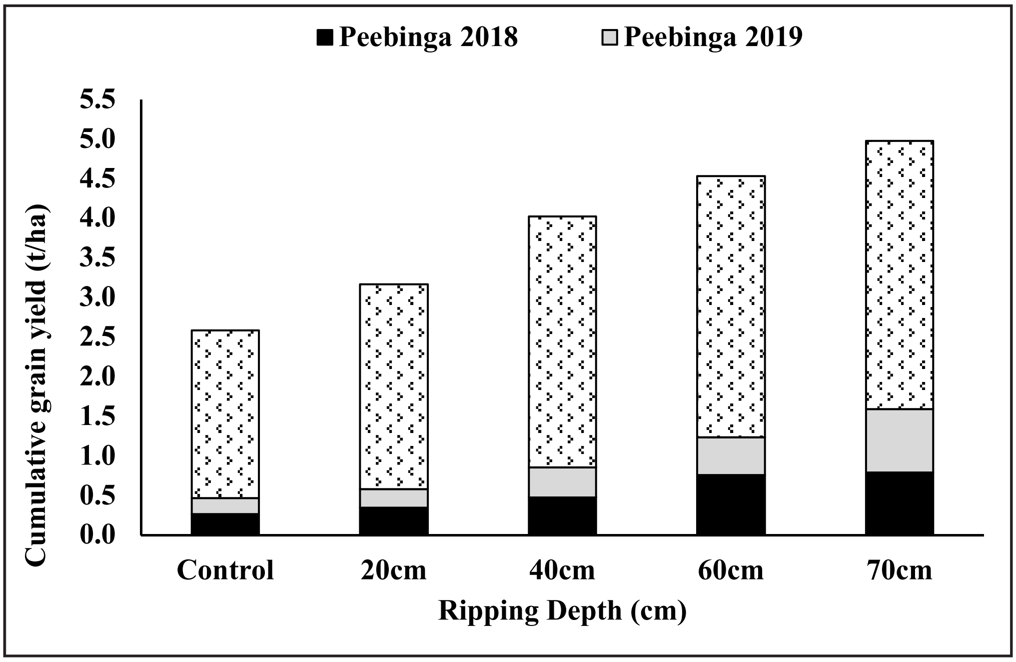

Figure 3. Cumulative cereal grain yield (t/ha) at Peebinga (2018, 2019) and Buckleboo (2019).

Economics of deep ripping

Economics are an important factor when evaluating whether an amelioration strategy should be implemented or not. Soil amelioration is slow and costly, so it is necessary to have long-term benefits to achieve a good return on investment. Large physical interventions like deep ripping have the potential to improve crop productivity in compacted sandy soils, but there is a risk of low returns in low rainfall seasons. Our results from 2 years (Table 4) of conducting the “ripping depth x tine spacing” trials, are showing that better returns are achieved when deep ripping below 60 cm. When narrower tine spacing is considered, going deeper than 60 cm will not give the best economical return in the first year because the yield gain does not economically justify the extra cost of ripping further down the soil profile. However, the data for Peebinga is showing that the marginal benefits in year 2 significantly improve by more than 100% by ripping down to 70 cm. There is no evidence from our data of a drop off in yield in the second year after ripping, which implies that the benefits of deep ripping could extend into year 3, improving the economic returns even more.

Tackling more than just one constraint

Our experiments have focused only on the physical intervention of ripping to ameliorate subsoil compaction, however, other research has acknowledged that tackling more than one constraint is better in the long run to improve and sustain crop yields, particularly on sands in medium to low rainfall environments. Trials in the Western Australian wheat belt have found deep ripping combined with topsoil slotting with inclusion plates can increase yields from sandy soils by more than deep ripping alone. At Meckering, WA in 2016 shallow ripping of pale sand over gravel increased wheat grain yield by 11% (320 kg/ha) over the control with the addition of topsoil slotting increasing the yield by 26% (560 kg/ha) (Davies *et al*. 2017). Research is continuing to investigate if topsoil slotting will improve the longevity of the benefits of deep ripping.

Ripped soil can be very soft and more susceptible to re-compaction which can cause trafficking issues for field operations. To maximise the benefits of deep ripping and minimise risks of re-compaction, adopting a controlled traffic farming (CTF) system should be considered. CTF is a farming system built on permanent wheel tracks where the crop zone and traffic lanes are permanently separated. For many deep sandplain soils, deep ripped areas can remain soft for at least 4 to 5 years in controlled traffic situations (Davies et al. 2017), and the benefits can be maximised by adopting CTF (Wilhelm *et al*. 2018). CTF should ultimately result in a much improved return on investment through increased longevity of the deep ripping benefit and a reduced need to repeat the deep ripping with its associated cost.

Other research activities are also investigating how best to overcome subsoil constraints to further improve and sustain grain yield with cost effective soil modification and ameliorants (Masters and Davenport 2015, McBeath *et al*. 2018). However, it is important to take into consideration the risk of wind erosion when soil renovation is done in legume stubble and in cereal paddocks with very low stubble cover. Common modifications and ameliorants being investigated include delving and spading, and incorporating gypsum, lime, clay, fertilisers or organic matter.

Table 4. Summary of marginal benefits from deep ripping at Peebinga (2018, 2019) and Buckleboo (2019).

	Tine spacing (30 cm)				**Tine spacing (60 cm)**				
	Depth (cm)	**20**	**40**	**60**	**70**	**20**	**40**	**60**	**70**
	Estimated cost ($/ha)*	**40**	**60**	**90**	**100**	**30**	**50**	**70**	**80**
Peebinga 2018	Yield change from control (t/ha)	0.19	0.25	0.56	0.48	-0.04	0.16	0.42	0.57
	Value of extra yield ($/ha)	42	55	123	106	-9	35	92	125
	Marginal benefit ($/ha)	**2**	**-5**	**33**	**6**	**-39**	**-15**	**22**	**45**
Peebinga 2019	Yield change from control (t/ha)	0	0.27	0.3	0.62	0.08	0.09	0.26	0.57
	Value of extra yield ($/ha)	0	78	87	180	23	26	75	165
	Marginal benefit ($/ha)	**0**	**78**	**87**	**180**	**23**	**26**	**75**	**165**
Buckleboo 2019	Yield change from control (t/ha)	0.58	0.67	1.34	0.94	0.17	1.25	0.82	1.42
	Value of extra yield ($/ha)	145	168	335	235	43	313	205	355
	Marginal benefit ($/ha)	**105**	**108**	**245**	**135**	**13**	**263**	**135**	**275**

**Estimated cost of deep ripping extrapolated from Davies et al. 2017*
Assumptions. Prices of wheat @ $250/t (2018), $290/t (2019), and barley @ $220/t (2018), $250/t (2019)
http://image.info.cargill.com/lib/fe911574736c0c7e75/m/1/Wheat_SA_Mallee_UpperSE.pdf
http://image.info.cargill.com/lib/fe911574736c0c7e75/m/1/Barley_Feed_SA.pdf

What does this mean?

Slow and restricted root growth caused by subsoil compaction can often lead to reduced crop productivity and profitability and also lead to other on- and off-farm effects such as increased wind and water erosion, dryland salinity and waterway degradation. Soil amelioration using strategic deep ripping is costly and usually slow to implement which means it can only be implemented on a small scale in a given year. Our trials have shown that ameliorating compacted sandy soils in low rainfall environments can lead to improved crop biomass and grain yield. Ripping narrow (30 cm) or wide (60 cm) gave similar outcomes in terms of grain yield, therefore wider tine spacing should be considered to use less machinery horsepower. These ongoing research activities are showing that deep ripping is not the ultimate strategy to improving crop performance but that a more holistic approach of tackling more than just one subsoil constraint can improve the longevity of benefits and overall returns on investment.

References

Crabtree W (1989). Cereal grain yield responses to deep ripping on duplex soils. Australian Journal of Experimental Agriculture 29: 691-694

Davies SL, Gazey C, Gilkes RJ, Evans DJ, Liaghati T (2006). What lies beneath? - understanding constraints to productivity below the soil surface. 2006 Regional Crop Updates, Geraldton, Department of Agriculture and Food, Western Australia

Davies S, Parker W, Blackwell P, Isbister B, Better G, Gazey C, and Scanlan C (2017). Soil amelioration in Western Australia. (Department of Agriculture and Food, Western Australia) | Date: 07 Feb 2017

Hamblin A, Tennant D and Cochrane H (1982). Tillage and the growth of a wheat crop in a loamy sand. Australian Journal of Agricultural Research 33: 887-897.

Hamblin A, Richards Q and Blake J (1988). Crop growth across a toposequence controlled by depth of sand over clay. Australian Journal of Soils Research 26: 623-635.

Isbister B, Blackwell P and Hagan J (2018). The changing options for soil compaction management. GRDC Grains Research Update. GRDC Project Number: DAW243

Jarvis RJ (2000). Deep tillage. In ‘The Wheat Book: Principles and Practice’. Eds. WK Anderson and JR Garlinge. pp. 185-187. Agriculture Western Australia, Bulletin 4443

Masters B and Davenport D (2015). Overcoming subsoil constraints to increase soil carbon on Eyre Peninsula soils. In ‘Eyre Peninsula Farming Systems 2015 Summary’. Eds. B Dzoma. Pp 205 - 208. (South Australian Research and Development Institute: Minnipa)

McBeath T, Macdonald L, Desbiolles J, Llewellyn R, Moodie M, Davoren B, Shoobridge W (2018). Options to Manage Underperforming Mallee Sands-SA Mallee Trials.

https://www.msfp.org.au/wp-content/uploads/Options-to-Manage-Underperforming-Mallee-Sands-SA-Mallee-Trials_McBeath_2018_Full.pdf

McBeath T, Macdonald L, Llewellyn R, Gupta V, Desbiolles J, Moodie M, Trengove S and Sheriff S (2019). Getting the edge on improving crop productivity on Southern sandy soils. Perth GRDC Updates.

Moodie M, Macdonald L, Correll R (2018). “Ripping” results from Mallee Sandy Soils trials.

https://www.msfp.org.au/wp-content/uploads/“Ripping”-results-from-Mallee-Sandy-Soils-trials_Moodie_2018_Full.pdf

Paterson C, Sheppard W (2008). Soil compaction trials 2006-2008. In ‘Eyre Peninsula Farming Systems 2008 Summary’. Eds. N Scholz, A Cook, A Frischke, N Wilhelm, M Bennet, C Paterson, D Brace and L Guerin. pp. 159-162. (South Australian Research and Development Institute: Minnipa)

Wilhelm N, Fisher P, Bluett C and Mitchell R (2018). Trafficking a heavy Minnipa soil does not hurt crop production but beware on deep sands. In ‘Eyre Peninsula Farming Systems 2018 Summary’. Eds. B Masters: pp 108 – 110 (South Australian Research and Development Institute: Minnipa)

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Improving crop performance on Mallee sands through subsoil injection of organic matter

Brian Dzoma[1], Nigel Wilhelm[2], Hugh Drum[2] and Kym Zeppel[1]
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Location
Loxton
Paul Rudiger
Rainfall
Av. Annual: 282 mm
Av. GSR: 190 mm
2018 Total: 136 mm
2018 GSR: 103 mm
Paddock history
2019: Barley
2018: Wheat
Soil type
Sand
Soil test
pH(water) 7.3
Plot size
15 m x 2 m x 3 rep
Trial design
RCBD with 3 replicates
Yield limiting factors
Moisture, nitrogen

Key messages

- **Deep ripping increased grain yield of wheat in 2019 on the midslope of a sand hill but not on the crest.**
- **Manures have the potential to increase crop yields, especially when applied deep into the soil profile, however there is a risk of the cereal crop haying off particularly on the crests of sandhills in very dry seasons.**

Why do the trial?

Soil amelioration is slow and costly, so it is necessary to have long-term benefits to achieve a good return on investment. Recent research has acknowledged that tackling more than one constraint is better in the long run to improve and sustain crop yields, particularly on sands in medium to low rainfall environments. The main aim of this trial is to evaluate the impact of a range of organic materials on crop performance when applied into the subsoil of a poorly performing Mallee sand. These types of sands are common across the low rainfall region of south-eastern Australia. The approach was to inject different organic materials (locally available to the Loxton district) in the form of a liquid slurry into the subsoil behind ripper tines. The hypothesis was that deep placed organic materials would promote root growth, improve subsoil fertility and result in better crop yields. A considerable amount of research over the last decade has shown the benefits of deep ripping and subsurface addition of organic material to crop production (Masters and Davenport 2015; Davies *et al*. 2017; McBeath *et al*. 2018; Moodie *et al*. 2018; McBeath *et al*. 2019) but making these approaches profitable has been difficult. In this trial, only locally available and low cost manures were tested.

How was it done?

Organic materials used were composted chicken manure, pig manure, sheep or cattle manure (from feedlots). Two identical and replicated field trials were implemented on a deep sandy soil in the northern Mallee (Loxton) in 2019. One trial was established on the crest of a sandhill and the other on the midslope of the same sandhill to investigate whether crop responses would differ depending on their position in the landscape.

The manures were injected into the subsoil (40 cm deep) on 5 April with the "Philips New Horizon" subsoil machine (Figure 1) fitted with a hopper and two ripper tines spaced 50 cm apart. To make the slurry, water was added to the manure in the hopper with a rotating mixer until it could be pumped down the ripper tines.

The manures had different nutrient compositions (Table 1) so they were applied at different rates to ensure 150 kg N/ha was added in each treatment.

Chicken and pig manure had the highest N content, and were therefore applied at half the rate of sheep and cattle manure (Table 2).

The trials were established with two controls to evaluate the manure responses against common district practice (control 2) and best management practice (control 1 but with deep ripping).

The manures were also spread on the surface for comparison at the same rates as injected into the subsoil. Surface treatments were broadcast evenly over the entire plot areas by hand on 16 April. This was after they had been deep ripped so that a direct comparison of manure placement on crop production could be assessed.

Table 1. Composition of the manures for four major nutrients per tonne of dry matter.

Manure	kg nutrient per tonne			
	N	P	K	S
Chicken	30	17	27	6
Pig	30	9	27	6
Sheep	16	6	14	3
Cattle	15	4	23	3

Table 2. Manure type, placement and application rate (t/ha).

Treatment	Manure placement	Deep rip	Application rate (t/ha)
Control 1	none	+	0
Control 2	none	-	0
Cattle manure	surface	+	10
Chicken manure	surface	+	5
Pig manure	surface	+	5
Sheep manure	subsoil	+	10
Cattle manure	subsoil	+	10
Chicken manure	subsoil	+	5
Pig manure	subsoil	+	5

+ Deep ripping to 40 cm; - no deep ripping

The trial was sown on 20 May with Spartacus CL barley at 55 kg/ha and 100 kg DAP/ha. Crop establishment was assessed on 13 June and urea was applied only to the controls at 50 kg/ha on 26 June. MCPA 750 was applied on 12 August to control broadleaf weeds, and flowering dry matter (DM) cuts were taken on 17 September. Due to the nature of the season with inconsistent and low rainfall, penetration resistance of the soil was not assessed as had been planned. Penetration resistance of all plots will be measured in 2020 when the soil is wet to depth.

What happened?

Crop responses were evident during vegetative growth with the most vigorous barley in the subsoil manure treatments. However, with only 93 mm of growing season rainfall, the crop on the crest of the sandhill did not finish as well as the midslope. Crop establishment was a little better on the sandhill (113 plants/m^2) compared to the midslope (103 plants/m^2). However, late tillering shoot DM, flowering shoot DM and grain yield were all higher on the midslope.

Crest

There were large decreases in plant density due to ripping (Table 3). Deep ripping alone caused a 37% reduction in crop establishment, compared to the district practice of 'no rip, no manure'. However, the presence of manures, regardless of where they had been placed reduced the impact of ripping on crop establishment. Rolling after deep ripping would have been a good strategy to improve trafficability and crop establishment. Placing manures on the surface or into the subsoil did not change either early vegetative or flowering biomass. Ripping alone (control 1) resulted in similar flowering DM to the unripped control (control 2) despite having nearly 40% fewer plants.

Midslope

Plant establishment was not affected by deep ripping or addition of manures.

Late tillering and flowering DM increased with injected manures, although cattle manure was the least effective. Deep ripping alone had little impact on crop growth during the season. Sheep manure placed into the subsoil resulted in a 60% increase in late tillering DM, while pig manure resulted in the highest flowering shoot DM (72% higher than district practice - control 2).

Crest

There was no yield response to deep ripping or addition of manure on the crest with all treatments averaging about 1 t/ha (Table 4). Grain yield on the crest was heavily compromised by lack of good soil moisture during the critical part of the growing season.

Figure 1. Philips New Horizon machine used to mix slurry and inject manures into the subsoil.

Table 3. Barley responses to manure and deep ripping on the crest or midslope of a sandhill at Loxton in 2019.

Site	Treatment	Manure placement	Deep rip	Plants/ m²		Late tillering DM (t/ha)		Flowering DM (t/ha)	
Crest	Control 1	none	+	86	*a*	0.57		2.08	
	Control 2	none	-	136	*d*	0.67		1.83	
	Cattle manure	surface	+	127	*cd*	0.76		2.07	
	Chicken manure	surface	+	123	*cd*	0.94		1.95	
	Pig manure	surface	+	116	*bcd*	0.58		1.95	
	Chicken manure	subsoil	+	107	*abc*	0.68		2.21	
	Cattle manure	subsoil	+	87	*ab*	0.87		2.26	
	Sheep manure	subsoil	+	115	*bcd*	0.67		2.16	
	Pig manure	subsoil	+	120	*cd*	0.76		2.36	
	F pr			*0.03*		*ns*		*ns*	
	LSD			*29*					
Midslope	Control 1	none	+	80		1.14	*abc*	4.56	*abcd*
	Control 2	none	-	113		0.83	*a*	3.53	*a*
	Cattle manure	surface	+	111		0.84	*a*	3.67	*ab*
	Chicken manure	surface	+	112		1.23	*bc*	5.44	*de*
	Pig manure	surface	+	127		0.97	*ab*	4.04	*abc*
	Chicken manure	subsoil	+	94		1.22	*bc*	4.98	*bcde*
	Cattle manure	subsoil	+	79		1.02	*abc*	5.18	*cde*
	Sheep manure	subsoil	+	116		1.33	*c*	4.88	*bcde*
	Pig manure	subsoil	+	96		1.26	*bc*	6.08	*e*
	F pr			*ns*		*0.05*		*0.01*	
	LSD					*0.35*		*1.32*	

Table 4. Grain yield of barley (t/ha) on the crest and midslope of a sandhill at Loxton in 2019 after ripping and manuring.

Site	Manure treatment	Actual grain yield (t/ha)	Ripping + manure effect (t/ha)
Crest	Pig manure – SR	0.79	-0.17
	Control 2 – not ripped	0.96	0.00
	Sheep manure - SS	0.99	0.03
	Cattle manure – SR	1.01	0.05
	Control 1 - ripped	1.02	0.06
	Chicken manure - SS	1.03	0.07
	Cattle manure - SS	1.05	0.09
	Pig manure - SS	1.10	0.14
	Chicken manure – SR	1.20	0.24
	F pr	*ns*	
Midslope	Control 2 – not ripped	1.44	0.00
	Cattle manure – SR	1.79	0.35
	Pig manure – SR	2.25	0.81
	Cattle manure - SS	2.38	0.94
	Chicken manure - SS	2.64	1.20
	Chicken manure – SR	2.68	1.24
	Sheep manure - SS	2.69	1.25
	Control 1 - ripped	2.74	1.30
	Pig manure - SS	3.32	1.88
	F pr	*0.05*	
	LSD	*1.08*	

SS = Subsoil; SR = Surface application and ripping

Midslope

The ripping benefit (calculated as the difference between control 1 (ripped) and control 2 (not ripped)) was 0.06 t/ha on the crest and 1.3t/ha on the midslope. The benefit of applying manure and deep ripping was very marginal on the crest as compared to the midslope. Barley on pig manure (subsoil) treatment had the biggest response to deep ripping and manure (1.88 t/ha) (Table 4).

There was a 90% gain in yield from deep ripping, with control 1 (ripped) achieving 2.74 t/ha and control 2 (not ripped), 1.44 t/ha. On the midslope, the physical intervention of deep ripping contributed more to final grain yield than organic manures placed either on the surface or subsoil (0.58 t/ha). Overall, ripping with the application of manure contributed a maximum response of 0.24 t/ha on the crest and 1.88 t/ha on the midslope.

Soil moisture cores were sampled post-harvest on 22 November by taking 2 soil cores (0–50 cm) per plot. These soil cores were subsampled into 0-10 cm, 10-30 cm and 30-50 cm layers, however the data presented in this paper is the total volumetric soil moisture and total shoot N (%) (Figure 2). Our data highlights that post-harvest volumetric soil moisture in the 0-10 cm, 10-30 cm and 30-50 cm zone was not affected by the physical disturbance of the soil or the addition of organic manure. The total volumetric soil moisture ranged from 22 mm (sheep manure subsoil) to 31 mm (pig manure – surface).

Plant samples collected on 17 September to determine early flowering shoot DM were also used to determine shoot nitrogen (%) as an indicator of N uptake by the plant. Past trial results from Bill Bowden from the Department Primary Industry and Regional Development (DPIRD, WA), have shown deep ripping can improve N uptake. As highlighted by our data in Figure 2, there were no significant differences in shoot N on the crest and midslope after deep ripping and addition of organic manure.

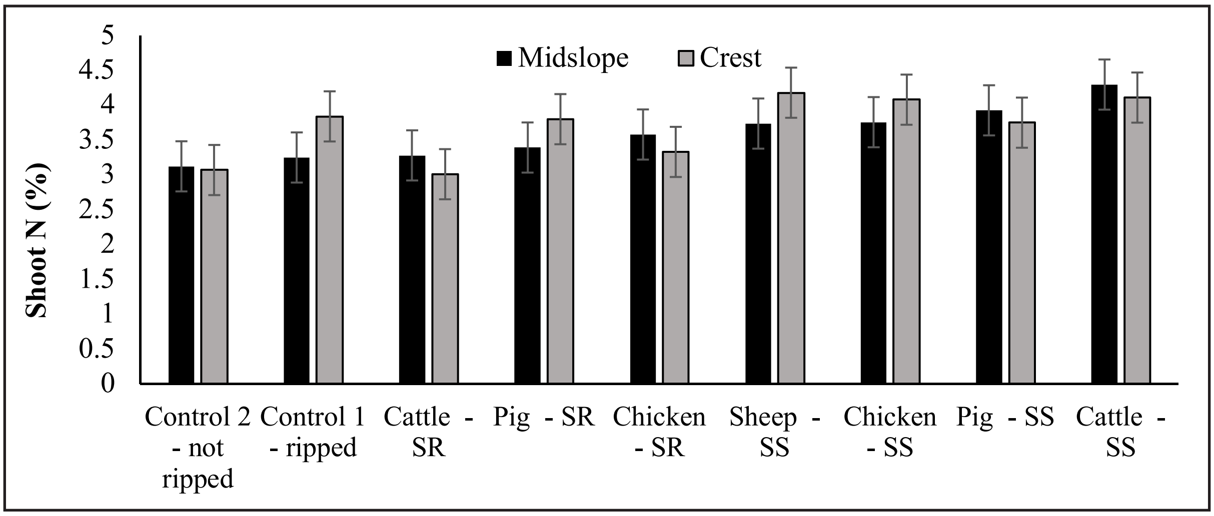

Figure 2. Shoot nitrogen (%) across manure treatments on the crest and midslope.

What does this mean?

Moisture and nitrogen use and productivity on sandy soils are commonly limited by a range of co-occurring soil constraints that limit root growth. Physical soil disturbance and use of organic ameliorants are effective interventions that can improve plant root growth, access to nutrients and water down the soil profile, however, this has to be achieved at low cost to attain the best possible profit-risk outcomes. This trial was conducted to evaluate if locally available manures can be used as a cost effective soil ameliorants by the method of injecting slurry into the subsoils of performing sandy soils. Our results have shown that on the crest there is very little gain from using the manures on the surface or subsoil in seasons where moisture is severely limiting. On the midslope the benefit of physical soil disturbance and manure addition into the subsoil is greater, however these productivity gains have to be assessed in terms of longevity, cost and returns, as all of these factors have an influence on profit and risk. The trial will continue in 2020/2021 season, monitoring responses and collecting more data that will assist in making meaningful recommendations to growers.

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References

Davies S, Parker W, Blackwell P, Isbister B, Better G, Gazey C, and Scanlan C (2017). Soil amelioration in Western Australia. (Department of Agriculture and Food, Western Australia) | Date: 07 Feb 2017

Masters B and Davenport D (2015). Overcoming subsoil constraints to increase soil carbon on Eyre Peninsula soils. In 'Eyre Peninsula Farming Systems 2015 Summary'. Eds. B Dzoma. Pp 205 - 208. (South Australian Research and Development Institute: Minnipa)

McBeath T, Macdonald L, Desbiolles J, Llewellyn R, Moodie M, Davoren B, Shoobridge W (2018). Options to Manage Underperforming Mallee Sands-SA Mallee Trials.

https://www.msfp.org.au/wp-content/uploads/Options-to-Manage-Underperforming-Mallee-Sands-SA-Mallee-Trials_McBeath_2018_Full.pdf

McBeath T, Macdonald L, Llewellyn R, Gupta V, Desbiolles J, Moodie M, Trengove S and Sheriff S (2019). Getting the edge on improving crop productivity on Southern sandy soils. Perth GRDC Updates.

Moodie M, Macdonald L, Correll R (2018). "Ripping" results from Mallee Sandy Soils trials.

https://www.msfp.org.au/wp-content/uploads/"Ripping"-results-from-Mallee-Sandy-Soils-trials_Moodie_2018_Full.pdf

Mechanics of deep ripping and inclusion plates

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Key messages (Mechanics of deep ripping)

- **At 600 mm ripping depth, the draft increased by 31% and drawbar power by 2.3-fold from 4 to 7 km/h.**
- **At 4 km/h speed, the draft and drawbar power increased by 2.7-fold from 400 to 600 mm depth.**
- **At 4 km/h, adding wings increased draft and drawbar power by 42% and 23% at 400 and 600 mm, respectively.**
- **The loosened area increased by 69% from 400 to 600 mm depth, 49% and 53%, respectively, by adding wings.**
- **Working to the shallowest depth identified and using wings maximises the energy efficiency (= loosened area per horsepower) of a ripping operation.**
- **The cost ($/ha) of deep ripping is directly influenced by drawbar power and work rate and can be optimised via tine design (wings) and operation (depth, speed).**

Key messages (Mechanics of inclusion plates)

- **At 600 mm ripping depth, a 290 mm tall inclusion plate set at 155 mm below the undisturbed surface raised tine draft by 38 and 40% at 4 and 7 km/h, respectively.**
- **In comparison, a 440 mm tall inclusion plate extending 150 mm deeper into the profile and able to maximise the depth of topsoil inclusion, created a 68 and 81% draft increase, respectively.**
- **Increasing forward speed decreased both the extent and depth of surface soil inclusion, while a 170 mm longer inclusion plate improved the extent of surface soil inclusion, even at the higher speed.**
- **The position of the plate upper edge controls the thickness of the topsoil layers that will be included. This inclusion occurs as a full layer collapse over the plate edge and not as a 'surface-first' shedding process. Setting it to match the layer of interest targeted for inclusion is critical, while very shallow settings can render inclusion over-sensitive to surface undulations.**
- **The extra cost of operating inclusion plates must be weighed against additional crop yield responses over time.**
- **DEM computer simulations help improve the understanding of the topsoil inclusion process and provide a useful basis to optimise the inclusion plate design (See: https://www.youtube.com/watch?v=A0eApjfCtoM)**

Why do the trial?

Soil compaction and hard setting layers significantly reduce root growth and prevents access to water and nutrients in deeper layers. Deep rippers should optimally be set to just below the depth of the constrained layer in order to alleviate these physical constraints. The use of a tine ripper requires high-power, drastically increasing with operating depth and forward speed. Operating the ripper too deep, such as below its critical depth, can lead to lateral soil compression at depth, characterised by a visual compacted slotting effect and significantly higher draught requirements.

Inclusion plates, pioneered in WA in early-mid 2010s, can be fitted to the rear of the ripper tines allowing the top soil layer (including surface applied amendments) to be incorporated down a deep slot. The aim of inclusion plates is to create a column of improved soil down the profile to sustain deeper root growth. While there is considerable interest in inclusion plates, little is known on how to optimise topsoil backfilling and on the changes to the draft force of a deep ripping operation.

Field experiments conducted in May 2019 at Caliph in the SA Mallee quantified the impact of ripper tine, wings and inclusion plate geometry, operating depth and forward speed on energy requirements and soil loosening/ inclusion performance. Details of trial implementation and results can be found at https://ingrain.partica.online/ingrain/vol-1-no-5-summer-20192020/flipbook/20/ .

Further work is required to develop more detailed adoption guiding messages.

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Validating research outcomes to treat production constraints on sandy soils of Eyre Peninsula

Brett Masters
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Location
Kimba, Mt Damper, Karkoo, Cummins
Graeme and Heather, Tristan and Lisa Baldock, Matt and Rhianna Foster, Reece Modra, Scott and Maryanne Mickan.
Rainfall
Av GSR/2019 GSR
Kimba: 215/150 mm
Mt Damper: 218/250 mm
Karkoo: 334/307 mm
Cummins: 361/334 mm
Soil type
Kimba: Buckleboo red sand
Mt Damper: sand over sodic clay
Karkoo: clayspread sand over clay
Cummins: shallow sand over sodic clay
Plot size
Large plot trial (30 m long x 12 - 18 m wide), 3 replicates
Yield limiting factors
Variable germination on Mt Damper site due to wind erosion on spaded plots.
Below average growing season rainfall resulting in very low stored soil moisture levels.
Hot windy days in the first week of October causing moisture stress at flowering.

Key messages

- **Production constraints on sandy soils can be overcome by mechanical intervention and the application of soil ameliorants, but the response can vary between sites and rainfall years.**
- **Despite observing large differences in crop growth between treatments at some sites, the variability within plots meant production responses were often not significant.**
- **Knowledge of the characteristics of the soil profile at depth is vital for identifying key production constraints and determining an appropriate and effective management strategy.**

Why do the trial?

There are around 5 million hectares of sandy soils under agricultural production in the low to medium rainfall areas of south-eastern Australia. These soils have multiple constraints limiting crop rooting depth and water extraction including water repellence, soil acidity, compaction and low organic carbon levels leading to poor biological cycling and nitrogen mineralisation. This can result in large differences between water limiting potential and actual crop yields.

In 2016 GRDC invested in a research program to help grain growers identify and overcome the primary constraints to poor crop water-use on sandy soils in the low-medium rainfall environment (CSP00203). The 'Sands Impacts' component of this project enables grower groups to test outcomes from the research component by applying targeted mitigation and amelioration interventions to overcome production constraints.

How was it done?

In collaboration with the Eyre Peninsula Agricultural Research Foundation and Lower Eyre Agricultural Development Association grower groups, four replicated validation trials were established at Kimba, Mt Damper, Karkoo and Cummins. Soil sampling was undertaken using a hydraulic drill rig to collect soil cores to a depth of 100 cm in March 2019 for site characterisation, pre-season nutrition and water repellence. Changes in texture and depth to carbonate were recorded and soil cores sub-sampled by profile layer, with composite samples sent for comprehensive laboratory analysis. Penetrometer resistance was also tested at each site to identify layers of high soil strength which might be affecting production.

The soil sampling identified subsurface layers of high soil strength and layers of low soil fertility at all four sites. Surface water repellence was also an issue at the Mt Damper and Cummins sites. Whilst the Karkoo site has had historical issues with surface water repellence, this was overcome when the paddock was clayspread (at around 250 t/ha) in the early 2000's. The Cummins site also had an acidic sandy A horizon with a highly bleached layer overlying a shallow sodic B horizon which causes regular waterlogging at the site.

Treatments were designed to address identified soil constraints and included a mixture of physical interventions with and without the application of soil ameliorants (Table 1). Additional nutrients treatments at Kimba and Mt Damper were calculated as the additional nitrogen, phosphorus, potassium, sulphur and trace elements needed for the difference between district average crop yield and water limited potential yield over a 3 year period (i.e. to supply potential production increases from addressing constraints).

Table 1. Summary of replicated trial sites (all sites were sown with wheat in 2019).

Co-operator / Location	Key soil constraints	In season measurements	Treatments
Baldock (TB) with Buckleboo Farm Improvement Group, Kimba	Physical, nutrients	Plant emergence, dry matter, crop yield	**Control** - untreated **Physical interventions** - deep ripping @ 35 cm, deep ripping @ 45 cm [+/- inclusion plates (IP)] **Soil ameliorants** - ripping+IP+ fluid nutrients (APP, high cost nutrition package, or low cost nutrition package)
Foster (MF) Mt Damper	Water repellence, physical, nutrients	Penetrometer resistance, plant emergence, dry matter, crop yield	**Control** - untreated **Physical interventions** - spading @ 30 cm, ripping @ 45 cm+IP, rip+IP @ 45 cm+spading @ 35 cm. **Soil ameliorants** - ripping+IP+nutrients
Modra (RM) Karkoo	Physical, nutrients. Note: Water repellence had been treated by previous clay spreading.	Penetrometer resistance, plant emergence, dry matter, crop yield	**Control** - clayspread **Physical interventions** - clay+ ripping @ 40 cm, clay+ripping @ 40 cm+ IP **Soil ameliorants** - clay+ripping @ 40 cm+IP+5 t/ha OM (lucerne pellets)
Mickan (SM), Cummins	Water repellence, Soil acidity, Physical (Shallow sodic B horizon resulting in waterlogging), Nutrients	Penetrometer resistance, plant emergence, crop yield	**Control** - limed **Physical interventions** - ripping @ 30 cm, clay+ripping @ 40 cm IP **Soil ameliorants** - clay+ripping @ 40 cm+IP+5 t/ha gypsum

Treatments were applied in March and April 2019. At all sites except Kimba, soil ameliorants were spread on the soil surface prior to implementing physical interventions. At the Kimba site a liquid tank attached to the deep ripper (BigFIG's Paxton Plough) allowed different rates of nutrients to be applied as a liquid stream behind the ripping tyne. Very dry conditions over summer and autumn, with only 14 mm of rainfall between December 2018 and the end of March, made implementation of ripping treatments difficult at all sites. The ripping tynes brought up large clods of compacted sand at the Kimba, Mt Damper and Cummins sites. Landholders at each of these sites needed to roll the site after ripping to level the site ahead of sowing. Whilst the tracked tractor and commercial deep ripper used at the Karkoo site was able to achieve better traction than those used at other sites, the ripping tynes brought up large limestone boulders on several plots. As a consequence the farmer had to remove the boulders and the Karkoo site also required rolling prior to sowing.

The trials were all sown with wheat by the landholder and managed per the rest of the paddock. In-crop measures included plant establishment and grain yield. Opportunistic sampling for spring biomass was also gathered at Kimba, Mt Damper and Karkoo. Soil penetration resistance was measured when the sites were at field capacity, except at Kimba where this was not achieved due to poor in-crop rainfall (less than 150 mm of growing season rainfall), but only crop production measurements will be reported on in this report.

What happened?

Opening rains in May and June allowed all sites to be sown by late June. There was some evidence of soil drift from spaded plots at Mt Damper at crop emergence. Good July conditions saw rapid germination and crop growth at all sites, however very dry conditions in late winter, combined with poor subsoil moisture saw the crop struggle at Kimba during spring.

Plant density

Plant density was evaluated 3 weeks post sowing. There was no difference between the control or treated plots at Kimba or Cummins. Differences in crop establishment between treatments were only observed on the Karkoo site, with the clayed control and the clay+rip treatment recording between 14 and 19% more wheat plants than where inclusion plates were used (Figure 1).

At Mt Damper, average plant numbers at crop establishment were 27 to 38% lower on treated plots than the control (which had 96 plants/m2) (apart from on the rip+IP+spading treatment). However, very high variability in emergence across this site meant that these differences were not significant (Figure 2).

Biomass

Biomass at flowering was assesed at Kimba, Mt Damper and Karkoo. There was no difference in biomass production between the control and treatments at Karkoo. At Kimba ripping with inclusion plates resulted in an increase in biomass production of at least 33% compared to the control which yielded 5.4 t/ha. However, there was not a signficant benefit compared to ripping+IP alone (7.5 t/ha) from the addition of nutrients (Figure 3).

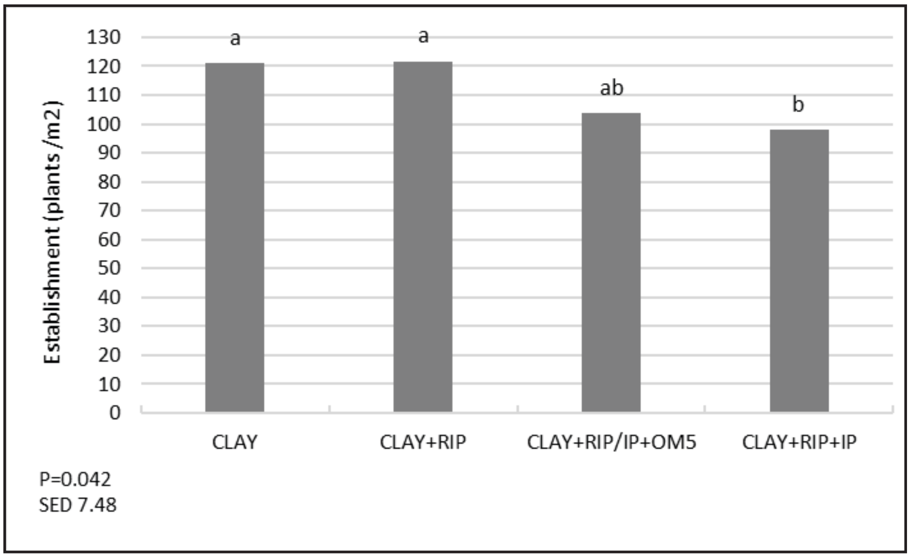

Figure 1. Plant densities at crop establishment at Karkoo. (Treatments that do not share a letter are significantly different from each other at P<0.05).

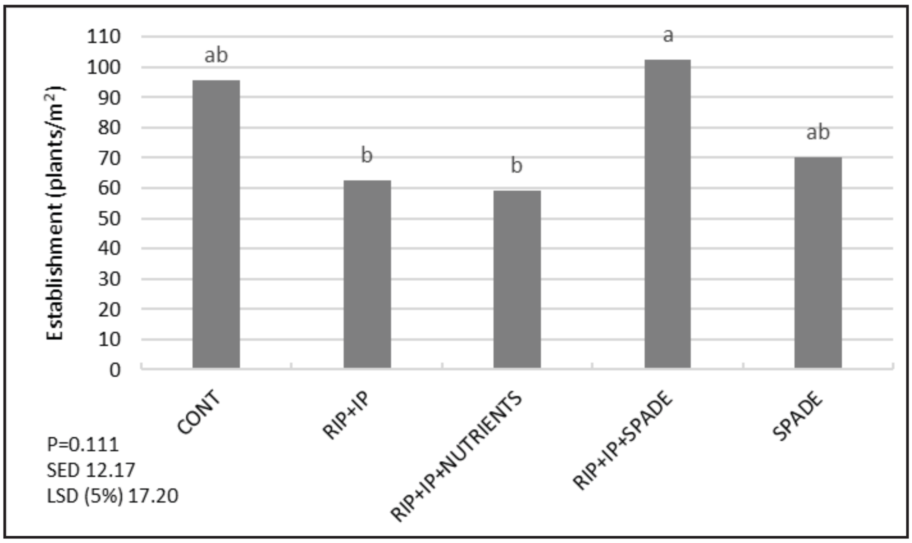

Figure 2. Plant densities at crop establishment at Mt Damper. (Treatments that do not share a letter are significantly different from each other at P<0.05).

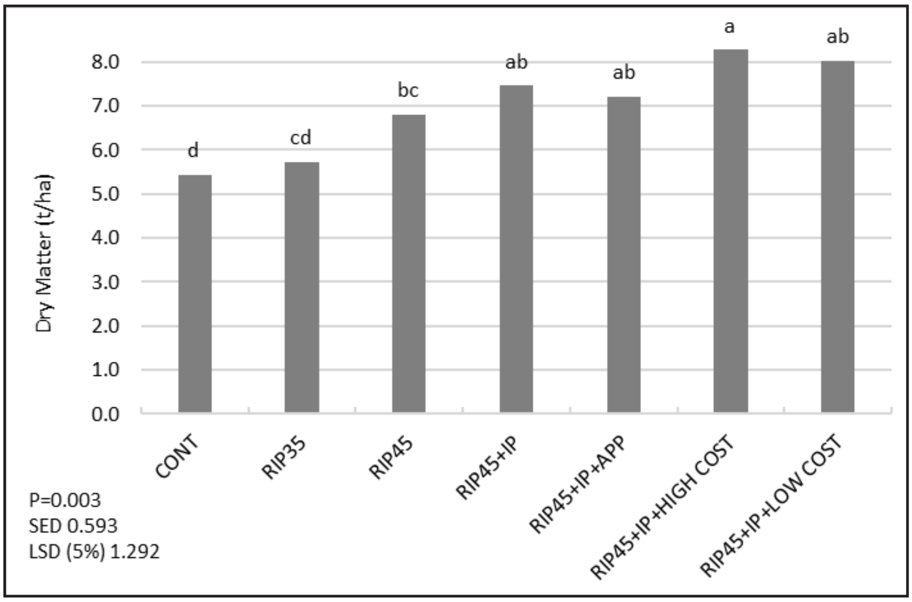

Figure 3. Spring biomass (t/ha) at Kimba. (Treatments that do not share a letter are significantly different from each other at P<0.05).

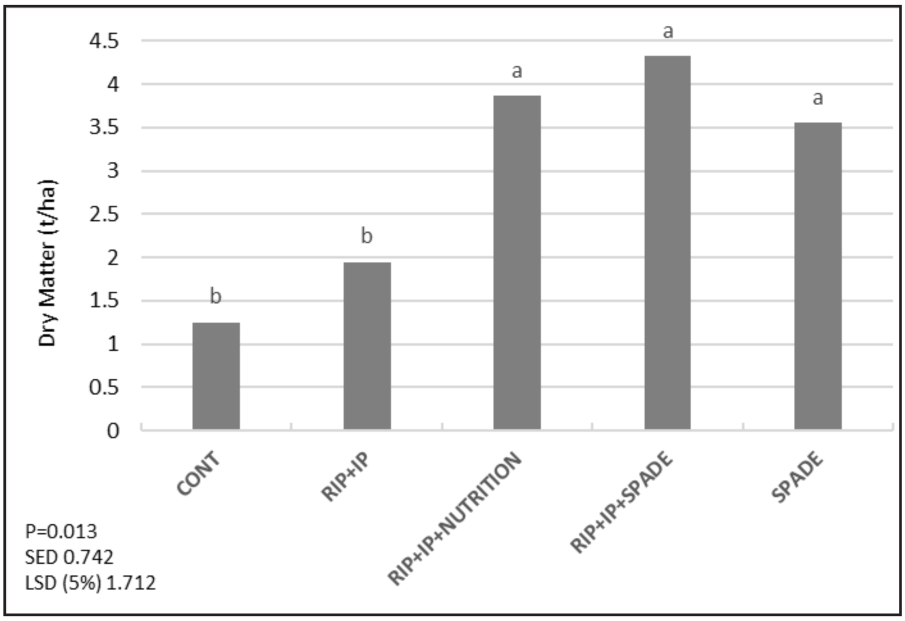

Figure 4. Spring biomass (t/ha) at Mt Damper. (Treatments that do not share a letter are significantly different from each other at P<0.05).

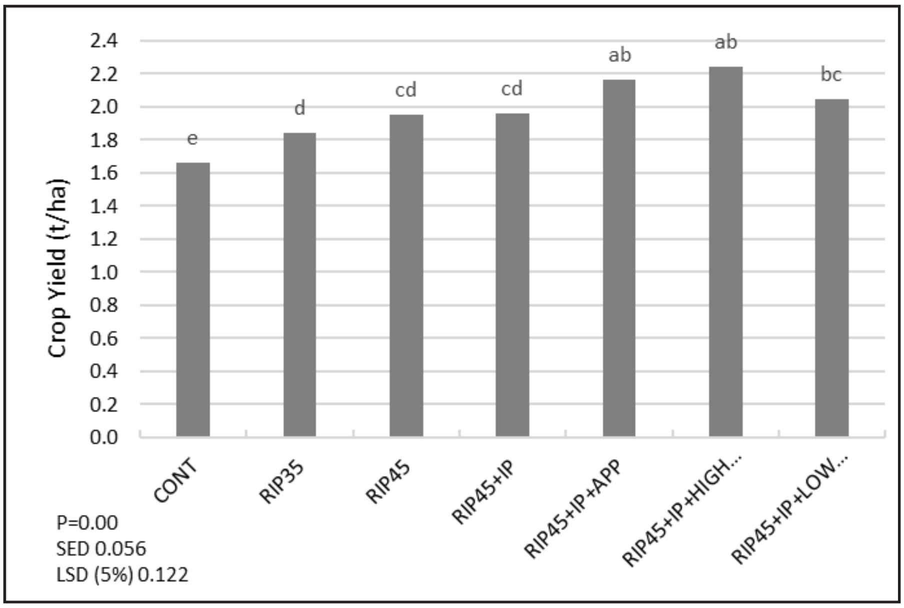

Figure 5. Wheat yield (t/ha) at Kimba. (Treatments that do not share a letter are significantly different from each other at P<0.05).

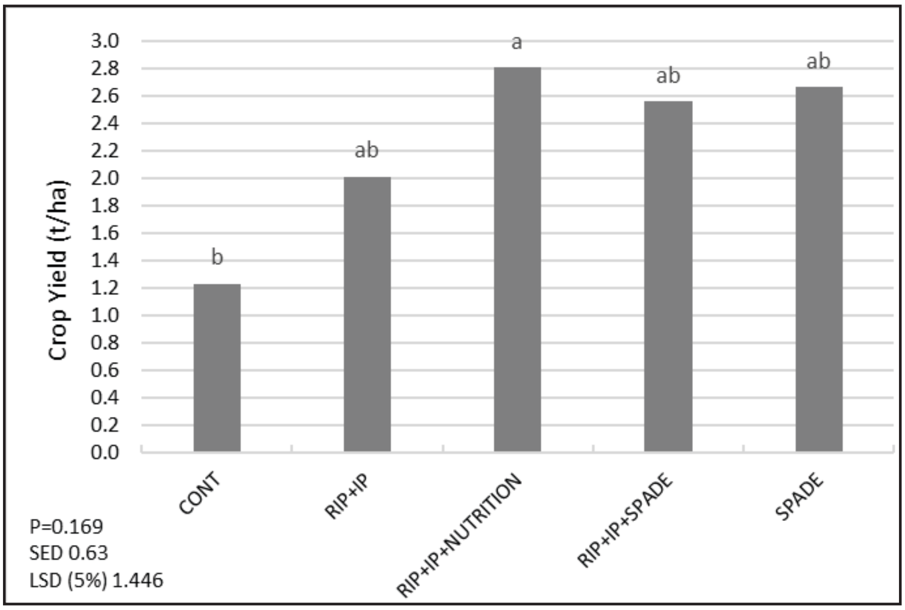

Figure 6. Wheat yield (t/ha) at Mt Damper. (Treatments that do not share a letter are significantly different from each other at P<0.05).

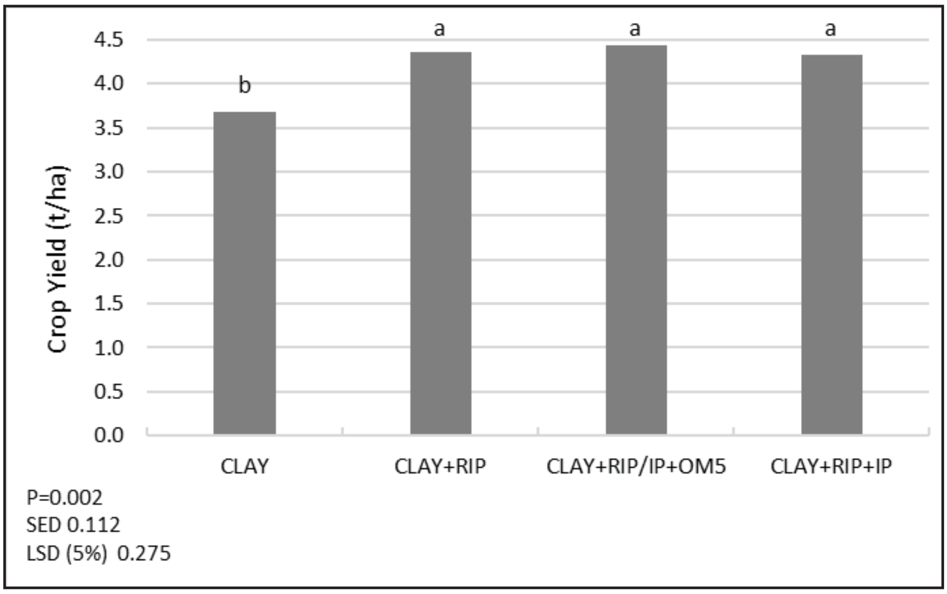

Figure 7. Wheat yield (t/ha) at Karkoo, 2019 (Treatments that do not share a letter are significantly different from each other at P<0.05).

At Mt Damper the spaded and rip+IP+nutrient treatments produced more than three times the spring biomass of the control (which yielded 1.3 t/ha) and double that of ripping+IP alone (Figure 4).

Grain yield

The trend of improved production from the ripping+IP+nutrients observed in the spring biomass at Kimba translated to grain yield increases of 25 to 30% (+0.4 to 0.6 t/ha) compared to the control (1.7 t/ha) and an additional 5 to 24% (0.1 to 0.4 t/ha) where extra nutrition was not applied (Figure 5). Whilst the high cost nutrition treatment yielded higher than the low cost treatment, it did not yield higher than where APP was applied in this season (Figure 5).

Whilst the grain yield from the spaded plots and the rip+spade at Mt Damper were more than double the control (which yielded 1.2 t/ha), only the rip+IP+nutrients was significantly different from the control (Figure 6). This is likely due to the high variability in response across the site.

At Karkoo there was an increase in grain yield by 18% from ripping compared the clayed control (which yielded 3.7 t/ha), however the use of inclusion plates and incorporation of organic matter did not result in additional grain yield responses in this season (Figure 7).

There was no yield response from any of the treatments at the Cummins site.

What does this mean?

Using mechanical interventions such as spading and ripping with inclusion plates resulted in improved grain yield of around 18% at some sites, with the addition of soil ameliorants producing an extra yield benefit. However, the results in this season were variable across the sites. This might be the result of a number of factors including:

- Highly variable seasonal conditions across the sites (i.e. very dry conditions at Kimba with more moderate seasonal rainfall at Mt Damper and on lower Eyre Peninsula) and the addition of extra nutrition at depth.
- Variability in crop emergence and growth resulting from factors such as soil drift following spading, and gross soil disturbance from ripping.
- Ripping with inclusion plates reduced crop establishment on some sites this season. Hopefully this impact will be reduced in future years as the soils settle.

A major factor in increasing yields on soils with production constraints is improving access to soil water. Good opening rains in May at Mt Damper meant that the expression of water repellence might have been less than normal. Meanwhile below average growing season rainfall on lower Eyre Peninsula meant that waterlogging, which is common at the Cummins site, was not expressed in 2019; this might explain the similarity in production from the treatments and control. At Kimba very much below average rainfall resulted in little moisture for crops to access in subsoil layers.

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

Key questions that remain unanswered include:

- How long before responses from soil applied ameliorants can be expected?
- How long the gains may last?
- What are the implications for soil carbon?
- What are the costs/benefits of these treatment options?

Production on these trial sites will continue to be monitored in 2020 and 2021.

Acknowledgements

The GRDC funded Sandy Soils project (CSP00203) is a collaboration between CSIRO, University of South Australia, Primary Industries and Regions SA, Mallee Sustainable Farming Inc, AgGrow Agronomy and Trengove Consulting. The author would also like to thank the landholders involved in this project; Graeme and Heather and Tristan and Lisa Baldock, Matt and Rhianna Foster, Reece Modra and Scott and Mary-Anne Mickan as well as the Eyre Peninsula Agricultural Research Foundation (EPARF), Lower Eyre Agricultural Development Association (LEADA) and the Buckleboo Farm Improvement Group (BigFIG) for their support of these trials.

Persistence of the herbicide clopyralid in EP soils during the 2019 season

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Location
Minnipa Ag Centre, paddock N7
Rainfall
Av. Annual: 324 mm
Av. GSR: 241 mm
2019 Total: 254 mm
2019 GSR: 234 mm
Soil type
Red loam
Soil test
Table 2
Paddock history
2019: Spartacus CL barley
2018: Chief CL wheat
2017: Stingray canola
Plot size
12 m x 2 m 3 replicates

Key messages

- **Carryover of clopyralid (~30%) and imazamox/ imazapyr (~30-50%) at low levels detected from June 2018 to March 2019.**
- **Estimatated half-life of clopyralid at Minnipa during the 2019 season was ~35 days.**
- **Ongoing analysis will determine carryover of imidazolinone and clopyralid herbicides in multiple soil types and seasons, and develop crop damage thresholds to inform soil test results.**

Why do the trial?

The overall aim of this work is to determine the persistence of imidazolinone and clopyralid herbicides over multiple seasons in different soil types and whether soilborne residues will injure subsequent crops.

Herbicides are a valuable tool for controlling weeds and reaching crop yield potential, but herbicide residues in soils can limit crop performance if not managed correctly. The recently concluded GRDC project DAN00180 (Rose *et al*. 2019) found that between 5-15% of surveyed paddocks (n=40) contained residues of sulfonylureas or trifluralin that could lower seedling vigour of some crops, but damage was avoided in most cases by growing tolerant crops (e.g. cereals or tolerant legumes in paddocks with SU residues). Growers also identified imidazolinone (group B) and clopyralid (group I) residues as potentially damaging to crops or constraining rotation options. However, the exact loss of productivity due to herbicide residues as a soil constraint has not been accurately determined due to the lack of tools to measure herbicide residues and quantify herbicide damage. It is difficult for growers and advisors to know whether herbicide residues will cause issues beyond the "label" plant-back period, because the persistence and behaviour of these residues depends on numerous site-specific factors, including soil (chemistry, organic matter, microbial activity) and climatic conditions.

As part of a national Soil CRC project (4.2.001 Developing knowledge and tools to better manage herbicide residues in soil), we undertook a field experiment at Minnipa to investigate this further.

How was it done?

Herbicide residues in soil were monitored under standard farming practice at the site. All previous in-crop, fallow and pre-emergent herbicide applications were recorded (Table 1). Spartacus CL barley was sown on 12 May 2019 at 65 kg/ha with Granulock Z® fertiliser (N:P:S:Zn 11:22:4:1) at 70 kg/ha. Soil samples were taken prior to and after application of clopyralid (Lontrel Advanced®) on 25 June 2019 at 1, 7, 21, 42 and 84 days after application. Soils (0-10 cm and 10-30 cm depths) were analysed for group I (including clopyralid) and imidazolinone herbicides using mass spectrometry methods developed at NSW DPI Wollongbar.

What happened?

Baseline topsoil samples (0-10 cm) taken on 15 March 2019, prior to sowing Spartacus barley, contained an average of 8 ng/g (nanogram/gram) of clopyralid. This is equivalent to approximately 0.025 L of Lontrel Advanced (600 g/L). The previous application of clopyralid had occurred on 24 July 2018 (0.075 L of Lontrel Advanced), suggesting approximately two-thirds of the herbicide had dissipated from the topsoil since the previous season.

Table 1. Paddock herbicide inputs during 2018-2019.

Timing of herbicide spray	Product (Active Concentration in g/L or g/kg)	Rate (L or kg/ha)
25 June 2019	Lontrel Advanced (Clopyralid 600)	0.075
12 May 2018	Ester 680 LVE (2,4-D ester 680) TriflurX (Trifluralin 480) Roundup DST (470) Goal Tender (Oxyfluorfen 480)	0.035 1.6 1.2 0.04
24 July 2018	Lontrel Advanced (Clopyralid 600) Intervix (Imazamox 33; Imazapyr 15) Polo 570 LVE (MCPA Ester 570)	0.075 0.50 0.45

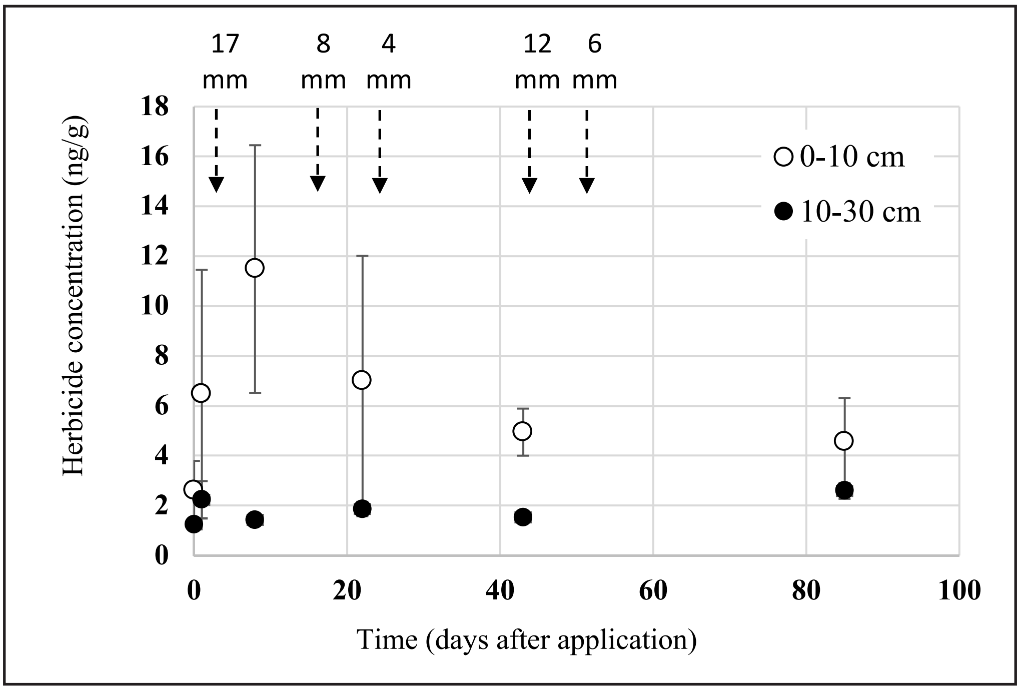

Figure 1. Concentration of clopyralid in 0-10 cm and 10-30 cm soil profile prior to (Time=0 d) and after (Time=1-84 d) application of 75 ml Lontrel Advanced on 25 June 2019. Rainfall timing and amount (mm) are indicated at the top of the figure by dashed arrows.

By the time of the 2019 in-crop application of clopyralid (0.075 L of Lontrel Advanced), topsoil residue concentrations had fallen to~3 ng/g (Figure 1). After a fresh application of clopyralid on 25 June 2019, and subsequent rain on 29-30 June, the concentration of clopyralid in topsoil increased from 3 to ~12 ng/g (Figure 1). Dissipation of the clopyralid from the top 0-10 cm occurred between 7-42 d after application, but slowed after this time. A minimal amount of clopyralid appeared to move into the subsoil, with only a slight increase in clopyralid concentration in the 10-30 cm layer over the monitoring period (Figure 1). The half-life of clopyralid at this site during the monitoring period (to date) was estimated to be approximately 35 d, which is similar to the commonly reported clopyralid half-life values of 5-65 d (Lewis *et al*. 2016; Congreve and Cameron 2018) and less than the longer half-lives (57-161 d) we observed in Birchip, Victoria, 2019. As with many herbicides this would be a function of moisture and in particular microbial activity leading to biodegradation of the herbicide. However, of interest is that the dissipation appears to slow down over time and a small amount of residual clopyralid that could be resistant to degradation – in this case, about 2-3 ng/g. A similar occurrence was observed in a paddock soil from Birchip, analysed as part of the larger current Soil CRC project (4.2.001). This residual amount could be strongly bound to soil minerals or organic matter, and may not be available to plants under normal circumstances. Ongoing analysis until sowing in 2020 will identify the total carryover to the following season.

What does this mean?

One of the most interesting results to date from this work was the concentration of herbicides in soil prior to the 2019 clopyralid spray. Clopyralid (8 ng/g), 2,4-D (33 ng/g), imazamox (5 ng/g) and imazapyr (5 ng/g) were detected in baseline topsoil samples taken in March 2019 before sowing. Those herbicide concentrations demonstrate some carryover from 2018 (clopyralid, imazamox/imazapyr in July 2018) – representing about 50% carryover of imazapyr and 30% carryover of clopyralid and imazamox.

To date there are very few crop thresholds values available to indicate the soil concentrations of herbicides at which crop damage may occur. Although we have previously found a 20% shoot biomass reduction in lupins exposed to 50 ng/g clopyralid in a sandy soil (Rose et al. 2019), the growth of cereals (as occurred this season) would not have been impacted. However, other legumes such as lentil, field pea and faba bean may be more sensitive than lupins and the presence of an additional herbicide of the same mode of action (2,4-D) may have additive effects if legumes were sown. The detected imidazolinone residues would also not have affected the Imi-tolerant Spartacus barley grown in the 2019 season. Although these residues levels may have affected non-tolerant crops, sowing occurred within the 10-month plant-back window specified on the label for sensitive crops, which means such crops should not have been sown.

Ongoing monitoring until sowing in 2020 will determine how much carryover of all herbicides has occurred through the entire year. Other ongoing work in this project will generate representative damage thresholds for different crops in different soil types, to provide growers with guidance as to potential effects of a known residue concentration if a soil herbicide analysis is undertaken. This will help to increase confidence in crop selection, timing of sowing and herbicide management to ensure soil and crop performance are not limited by herbicide residues. Importantly, this project aims to prevent major crop damage due to herbicide residues and give farmers greater flexibility in crop rotations to further build soil health.

References

Congreve, M. and Cameron, J. (eds) (2018). Soil behaviour of pre-emergent herbicides in Australian farming systems – a national reference manual for advisers. 2nd Edition. GRDC publication, Australia. https://grdc.com.au/__data/assets/pdf_file/0033/366873/Pre-emergent-manual-Web_HR.pdf

Lewis, K.A., Tzilivakis, J., Warner, D. and Green, A. (2016). An international database for pesticide risk assessments and management. Human and Ecological Risk Assessment: An International Journal, 22(4): 1050-1064. DOI: 10.1080/10807039.2015.1133242. https://sitem.herts.ac.uk/aeru/ppdb/en/index.htm

Rose M., Van Zwieten L., Zhang P., McGrath G., Seymour N., Scanlan C., Rose T. (2019) Herbicide residues in soil - what is the scale and significane? GRDC Grains Research Update, Wagga Wagga, Feburary 19th 2019. https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2019/02/herbicide-residues-in-soil-what-is-the-scale-and-significance

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Impact of herbicide residues on crop and pasture productivity in alkaline sandy soils

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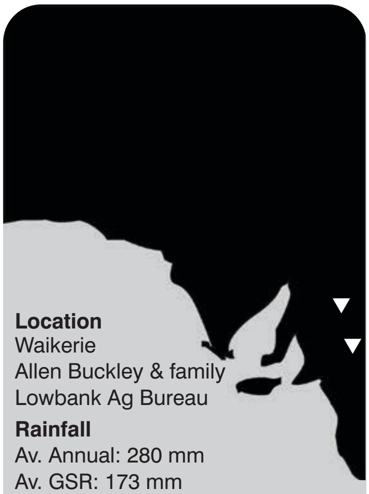
[1]SARDI, Loxton Research Centre; [2]SARDI, Waite



Location
Waikerie
Allen Buckley & family
Lowbank Ag Bureau
Rainfall
Av. Annual: 280 mm
Av. GSR: 173 mm
2019 Total: 120 mm
2019 GSR: 108 mm
Paddock history
2018: Scope barley
2017: Cereal Rye
2016: Fallow
Soil type
Sand
Soil test
pH(water) 6.86
Plot size
15 m x 2 m x 3 rep
Trial design
RCBD with 3 replicates and two treatment factors
Yield limiting factors
Moisture

Location
Peebinga
George Gum and family
Rainfall
Av. Annual: 319 mm
Av. GSR: 210 mm
2019 Total: 191 mm
2019 GSR: 152 mm
Paddock history
2018: Scope barley
2017: Fallow
2016: Fallow
Soil type
Sand
Soil test
pH(water) 7.27
Plot size
15 m x 2 m x 3 reps
Trial design
RCBD with 3 replicates and two treatment factors
Yield limiting factors
Moisture

Key messages

- **Traces of Lontrel residues can severely damage shoot dry matter of field peas and vetch.**
- **Intervix residues above 10 ml/ha can reduce grain yield of Gladius wheat and Nipper lentils by 44% and 36% respectively.**
- **Around 50% of applied Lontrel and Intervix can carry over into the next season, when rainfall from spraying to sowing is below 150 mm.**

Why do the trial?

Herbicide residues pose a new challenge to growers, particularly in low to medium rainfall farming systems, as they can reduce flexibility in terms of rotation options. Although there are economic and productivity benefits from carryover herbicides providing longer term weed control, there are issues with some herbicides that are remaining active in the soil longer than intended and in sufficient quantities that may damage sensitive crop or pasture species sown in subsequent years. This issue can be compounded by environmental stresses such as drought or waterlogging. Without taking action, herbicide residues could result in subclinical losses in crop yield and could also influence crop rotations in the future, as much as weed, pest and disease considerations do now.

To investigate this issue, shadehouse experiments were conducted to evaluate the lower limits of tolerance of wheat, lentils, field peas and vetch to Lontrel (Clopyralid), Intervix (Imazamox/Imazapyr) and Logran (Triasulfuron) residues. Two replicated field trials were also conducted on different sandy soils in the northern (Waikerie) and southern (Peebinga) Mallee.

How was it done?

Pot experiment

A pot experiment was set up on 9 May 2019 using the protocol reported in previous article (EPFS Summary 2018 The impact of herbicide residues on selected tolerant and susceptible crop and pasture species, p135). Herbicide residue concentrations were lower than the ones used in the pot experiment in 2018 (Table 1). This time, the goal was to refine the lower level critical limits for Intervix on conventional wheat and susceptible lentil varieties, and Lontrel on field peas and vetch. Emerged plants were counted 10 days after sowing (DAS) to determine germination percentage. At 20 DAS (29 May) all pots were thinned down to four plants per pot. All pots were terminated at 80 DAS (29 July), and the effects of herbicides on shoot biomass recorded. A representative soil sample was also collected from each pot to determine the amount of remaining herbicide.

Field trial

Herbicide treatments (Table 2) were imposed on 26 July 2018 by spraying different herbicide concentrations on plots sown to Scope barley at 3 bar pressure, 4.5 km/hr speed and 200 L/ha water rate.

Table 1. Herbicide treatments and simulated residues (product/ha) for the Loxton pot experiment.

Herbicide rate (relative to RFR, x)	Intervix (ml/ha)	Logran (g/ha)	Herbicide rate (relative to RFR)	Lontrel (ml/ha)
0x	0	0	0x	0
0.02x	10	0.5	0.002x	0.6
0.04x	20	1.0	0.004x	1.2
0.06x	30	1.5	0.006x	1.8
0.08x	40	2.0	0.008x	2.4
0.1x	50	2.5	0.01x	3
	wheat, lentils		field peas, vetch	

RFR = recommended field rate

This approach allowed 10 months for treatments to settle and move into the soil profile to simulate herbicide carryover. Prior to sowing in 2019, 0–10 cm soil cores were sampled from each plot to determine the level of herbicides still present. Samples were prepared and analysed with liquid chromatography and mass spectrometry at the CSIRO lab (Waite). Trials were then sown on 21 May 2019 to wheat, lentils, field peas or vetch. On 12 August, Clethodim was applied @ 500 ml/ha plus oil @ 1L/ha to control grasses in legumes, and MCPA 750 @ 1.2 L/ha to control broadleaf weeds in wheat. Nodule sampling was done on 10 plants per plot on 21 August at Peebinga and 3 September at Waikerie. Flowering dry matter (DM, 1 square metre) cuts were done on 17 September and the trials were harvested on 18 November (Waikerie) and 19 November (Peebinga).

What happened?

Pot experiment

The conventional wheat variety Gladius was affected by Intervix residues at or above 4% recommended field rate (RFR, 0.04x) and Nipper lentils by residues at or above 2% RFR (0.02x). Gunyah field peas shoot DM was reduced by Lontrel residues as low as 0.8% of RFR (0.008x), and Volga vetch by residues above 0.4% of RFR (0.004x). These very low herbicide residue limits are suggesting that damage can occur to sensitive crops from herbicide levels which may be hard to detect.

Field trial

Plantback periods for southern Australian winter dominant rainfall areas stipulate that a minimum of 25 mm rain event in the post-harvest summer to autumn period, with a subsequent extended period of at least 1 week where the top 10 cm of the soil stays moist is required for substantial breakdown of soil residues. Fastest residue breakdown will occur under good soil moisture and warm conditions, which promote microbial activity. Dry hot conditions in summer and autumn in the Mallee do not promote degradation of these herbicides. From the Intervix applied at RFR (500 ml/ha), 42% and 55% of imazamox residues were detected prior to sowing; and 50% and 60% of imazapyr residues were detected at Peebinga and Waikerie respectively (Table 4). Logran residues were very low at both sites, indicating that more than 90% of the triasulfuron had broken down during the summer and autumn months. Waikerie received 25 mm and Peebinga 45 mm of rainfall over a 2 day period in December 2018. The low level of Logran residues might be attributed to the summer rainfall received, because sulfonylurea (su) herbicide's primary mode of breakdown begins with chemical hydrolysis which is moisture dependent.

Table 2. Field trial herbicide treatments.

Herbicide rate (relative to RFR, x)	Intervix (ml/ha)	Logran (g/ha)	Lontrel (ml/ha)
0x (control)	0	0	0
0.5x	250	12.5	150
1x (RFR)	500	25	300
2x	1000	50	600
Crops	wheat, lentils	lentils	peas, vetch

RFR = recommended field rate

At both sites, Intervix residues did not affect crop establishment, early and late shoot DM or grain yield of Kord CL Plus wheat (Table 5). Kord CL Plus is derived from a cross between Gladius and an imi tolerance donor. Kord CL Plus carries two genes for Clearfield resistance, providing improved levels of tolerance to imidazolinone (imi) herbicides, and therefore offers more options for in-crop weed management and crop rotation.

Crop establishment of Gladius was not affected by the residues present at either site. However, there was a reduction in flowering shoot DM at 2x RFR residues, and grain yield at residues above 0.5x RFR at both sites (Table 5).

Table 3. Mean shoot dry matter (g/plant) for wheat, lentils, field peas and vetch.

Residue rate	Intervix				Residue rate	Lontrel			
	Gladius (wheat)		Nipper (lentil)			Gunyah (peas)		Volga (vetch)	
0x	1.59	b	0.96	d	0x	1.76	b	3.17	b
0.02x	1.29	b	0.26	c	0.002x	1.32	b	2.21	ab
0.04x	0.05	a	0.20	bc	0.004x	1.13	b	1.64	a
0.06x	0.16	a	0.10	ab	0.006x	1.25	b	1.64	a
0.08x	0.00	a	0.03	a	0.008x	0.11	a	0.65	a
0.1x	0.10	a	0.08	ab	0.01x	0.97	b	1.16	a
F.Pr	$p<0.001$		$p<0.001$			$p<0.001$		$p<0.001$	

Table 4. Applied and remaining imazamox, imazapyr, triasulfuron and clopyralid herbicides in autumn of 2019 after application in 2018 at two Mallee field sites.

Site	Rate	Detected Imazamox residues*	Remaining residues (%)	Detected Imazapyr residues*	Remaining residues (%)	Detected triasulfuron residues*	Remaining residues (%)	Detected clopyralid residues*	Remaining residues (%)
Peebinga	0x	0.0	0	0.00	0	0.00	0.0	0.0	0
	0.5x	1.5	55	0.80	64	0.06	1.9	5.0	34
	1x	2.3	42	1.30	52	0.12	1.9	12.7	42
	2x	5.4	49	3.20	64	0.22	1.8	20.1	33
Waikerie	0x	0.0	0	0.00	0	0.00	0.0	0.0	0
	0.5x	1.2	44	0.60	48	0.03	1.1	7.7	52
	1x	3.0	55	1.50	60	0.05	0.8	17.3	58
	2x	5.2	47	2.60	52	0.08	0.7	31.7	53

**% detected residues 10 months after application (ug/kg soil)*

These results imply that a yield penalty of 17% (Peebinga) and 40% (Waikerie) can occur to conventional non Clearfield wheat varieties when 50% of Intervix is carried over into the next growing season. For a 1 t/ha wheat crop @ $250/ton, these losses could translate to approximately $42.50/ha at Peebinga and $100/ha at Waikerie. This scenario of high residues is breaking the plantback guidelines and illustrates the importance of heeding them.

At both sites, Intervix residues did not affect crop establishment, early and late shoot DM, nodulation and grain yield of PBA Hurricane lentils (Table 6). PBA Hurricane XT lentils are high yielding small red lentil variety with improved tolerance to residual levels of SU and imi herbicides. In the case of Nipper (small red lentil sensitive to SU and imi herbicides), crop establishment and nodulation was not affected by Intervix residues. However, at Peebinga, there was a reduction in flowering shoot DM at 0.5x of RFR. No grain yield was recorded at Peebinga as the crop ran out of moisture post flowering. At Waikerie flowering shoot DM of lentils was not affected by Intervix residues, however grain yield was reduced by 36% at 1x residues relative to the control (Table 6).

Triasulfuron residues did not affect noduation of PBA Hurricane lentils (Table 7) at both sites. At Peebinga, triasulfuron residues at 0.22 ug/kg reduced flowering shoot DM of both PBA Hurricane and Nipper lentils. At Waikerie triasulfuron residues had small but inconsistent effects on plant population. Flowering shoot DM was reduced by 38% at 0.05 ug/kg and grain yield by 40% at 0.03 ug/kg residue level, all relative to the untreated control. No lentil grain yield was recorded at Peebinga.

Clopyralid residues did not affect field peas establishment at both sites (Table 8), however as the growing season progressed, some of the emerged plants eventually died, particularly in the 2x RFR treatments. Flowering shoot DM was reduced at Peebinga by 42% at 5 ug/kg, and by 78% at 32 ug/kg clopyralid residue level at Waikerie relative to the control. Nodule numbers per root were not affected by clopyralid residues at Waikerie but at Peebinga there was a reduction at 13 ug/kg level. At Waikerie, grain yield was reduced by 49% at 8 ug/kg clopyralid residue level. No grain yield was recorded at Peebinga.

Plant population and flowering shoot DM of Volga vetch was reduced by Lontrel herbicide residues at both sites. Relative to the control, flowering shoot DM at Peebinga was reduced by 50% at 17 ug/kg and at Waikerie by 68% at 8 ug/kg clopyralid residue level. No grain yield was recorded at both sites for vetch.

Table 5. Effect of Intervix on wheat plant density, GS31 and flowering shoot DM and grain yield.

Crop	Herbicide rate	Peebinga				Waikerie			
		Plants/ m^2	GS31 Shoot DM (t/ha)	Flowering shoot DM (t/ha)	Grain yield (t/ha)	Plants/ m^2	GS31 Shoot DM (t/ha)	Flowering shoot DM (t/ha)	Grain yield (t/ha)
Kord CL wheat	0x	150	1.63	3.53	0.88	147	0.91	1.5	0.42
	0.5x	146	1.97	3.89	0.61	146	1.14	1.52	0.4
	1x	150	2.05	3.99	0.67	148	0.98	1.31	0.33
	2x	171	1.85	4.38	0.74	162	1.00	1.26	0.27
	F.Pr	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*
Gladius wheat	0x	166	1.98	3.91	0.81	154	1.06	1.47	0.5
	0.5x	162	1.78	3.91	0.67*	150	1.11	1.49	0.3*
	1x	143	1.65	3.65	0.60*	148	0.74*	1.12	0.28*
	2x	171	1.06	2.86*	0.49*	139	0.21*	0.55*	0.24*
	F.Pr	*ns*	*ns*	$p<0.03$	$p<0.004$	*ns*	$p<0.001$	$p<0.02$	$p<0.003$

**Significantly different to nil*

Table 6. Effect of Intervix on lentil plant density, nodulation, shoot DM and grain yield.

Crop	Residue rate	Peebinga				Waikerie			
		Plants/ m^2	Flowering shoot DM (t/ha)	Nodules per root	Grain yield (t/ha)	Plants/ m^2	Flowering shoot DM (t/ha)	Nodules per root	Grain yield (t/ha)
PBA Hurricane lentils	0x	156	1.45	23	*	161	0.70	6	0.79
	0.5x	150	1.35	9	*	158	0.69	7	0.74
	1x	138	1.37	13	*	155	0.70	6	0.77
	2x	154	1.57	12	*	146	0.79	6	0.80
	F.Pr	*ns*	*ns*	*ns*	*	*ns*	*ns*	*ns*	*ns*
Nipper lentils	0x	164	1.19	12	*	15	0.49	7	0.69
	0.5x	151	0.99*	12	*	165	0.61	4	0.79
	1x	160	1.04	9	*	160	0.41	3	0.44*
	2x	140	0.94*	8	*	155	0.31	5	0.43*
	F.Pr	*ns*	$p<0.05$	*ns*	*	*ns*	*ns*	*ns*	$p<0.05$

**Crop failed due to drought.*

Table 7. Effect of Logran on lentil plant density, nodulation, shoot DM and grain yield.

Crop	Residue rate	Peebinga				Waikerie			
		Plants/ m^2	Flowering shoot DM (t/ha)	Nodules per root	Grain yield (t/ha)	Plants/ m^2	Flowering shoot DM (t/ha)	Nodules per root	Grain yield (t/ha)
PBA Hurricane lentils	0x	148	1.29	21	*	169	0.78	15	0.99
	0.5x	152	1.04	21	*	145	0.69	16	0.88
	1x	140	1	33	*	122*	0.64	18	0.9
	2x	112	0.8*	23	*	152	0.69	14	0.93
	F.Pr	*ns*	$p<0.01$	*ns*	*	$p<0.001$	*ns*	*ns*	*ns*
Nipper lentils	0x	130	0.83	18	*	144	0.56	11	0.86
	0.5x	128	0.7	20	*	159	0.44	10	0.52*
	1x	145	0.66	29	*	138*	0.35*	9	0.35*
	2x	105	0.45*	19	*	148	0.38*	11	0.39*
	F.Pr	*ns*	$p<0.01$	*ns*	*	$p<0.001$	$p<0.04$	*ns*	$p<0.01$

Table 8. Effect of Lontrel on field peas plant density, nodulation, shoot DM and grain yield.

Crop	**Residue rate**	**Peebinga**				**Waikerie**			
		Plants/ m^2	**Flowering shoot DM (t/ha)**	**Nodules per root**	**Grain yield (t/ha)**	**Plants/ m^2**	**Flowering shoot DM (t/ha)**	**Nodules per root**	**Grain yield (t/ha)**
Gunyah field peas	0x	46	2.4	35	*	46	1.37	56	0.63
	0.5x	30	1.39*	37	*	56	1.12	52	0.32*
	1x	40	0.86*	26*	*	52	0.96	60	0.17*
	2x	28	0.19*	23*	*	34	0.3*	44	0.09*
	F.Pr	*ns*	$p<0.002$	$p<0.01$	*	*ns*	$p<0.004$	*ns*	$p<0.01$

Table 9. Effect of Lontrel on vetch plant density, nodulation and flowering shoot DM.

Crop	**Residue rate**	**Peebinga**				**Waikerie**			
		Plants/ m^2	**Flowering shoot DM (t/ha)**	**Nodules per root**	**Grain yield (t/ha)**	**Plants/ m^2**	**Flowering shoot DM (t/ha)**	**Nodules per root**	**Grain yield (t/ha)**
Volga vetch	0x	40	1.35	54	*	53	1	20	*
	0.5x	40	1.13	35	*	30	0.32*	18	*
	1x	33	0.68*	40	*	22	0.09*	15	*
	2x	29*	0.49*	33	*	18*	0.04*	20	*
	F.Pr	$p<0.05$	$p<0.01$	*ns*	*	$P<0.05$	$p<0.001$	*ns*	*

Table 10. Herbicide residue tolerance for wheat, lentils field peas and vetch in 2018 and 2019 pot experiment.

Crop	**Herbicide residues tolerance (lower limit)***			
	Intervix		**Lontrel**	
	2018	**2019**	**2018**	**2019**
Wheat (Gladius)	50	10		
Lentil (Nipper)	50	10		
Field peas (Gunyah)			0	2.4
Vetch (Volga)			0	1.2

**Limit in ml/ha soil residues*

What does this mean?

Herbicide residues are often too small to be detected by chemical analysis, and the real problem for growers is detecting the level of residues in the field before they cause a problem. Quantifying yield penalties from low residue levels on susceptible crops is a much bigger issue which has the potential to further increase risk in marginal environments. Our results from the pot experiment have demonstrated that crop damage can occur to susceptible lentils and non-Clearfield wheat varieties when Intervix residues remaining in soil are above 10 ml/ha (Table 10). For legumes like field peas and vetch, the residue tolerance limit for Lontrel is under 3 ml/ha, which is hard to detect, but can however cause reduction in shoot dry matter.

The field experiment has also demonstrated that yield losses can occur to susceptible crop species when Intervix, Logran and Lontrel herbicide residues are present in the soil. However, it should be noted that some of the crop responses to residues may have been affected by the tough season with only 108 mm growing season rainfall at Waikerie and 152 mm at Peebinga. It is also important to note that some of the damage recorded is outside plantback guidelines, and only done for experimental purposes. Such damage can be avoided if growers stick to the recommended re-cropping intervals. The trial will continue in 2020/21 to investigate the impact of the remaining residues on conventional vs Clearfield canola varieties.

Acknowledgements

Thanks to the Gum and Buckley family for their enthusiasm in providing suitable trial sites at their properties, and GRDC for funding this trial through the SARDI/GRDC Mallee Bilateral project - Improving sustainable productivity and profitability of Mallee farming systems with a focus on soil improvements (DAS00169-BA).

Comparative effects of pesticides on South Australian soil microbial functions

Jowenna Xiao Feng Sim[1], Casey Doolette[1], Barbara Drigo[1], Erica Donner[1], Allan Mayfield[2] and Enzo Lombi[1]

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Key messages

- **This study will deliver South Australian farmers with information to aid decision making on the use of pesticides by investigating the effect of 20 pesticides, including insecticides, herbicides and fungicides on soil microbial function in three South Australian (SA) soils.**
- **The information on cumulative effects and persistence of negative effects on selected soil-pesticide combinations could be instrumental in safeguarding the long-term productivity and profitability of SA grain growers.**
- **Understanding the correlation between a pesticide's mode of action and its effects on soil function may aid in the development of new active ingredients and/or the reformulation of current pesticides.**
- **The insights into lab-field transferability will provide greater understanding of how the complexities of environmental factors affect pesticide impacts on soil functions.**

Why do the trial?

This project will deliver essential information to South Australian farmers for identifying the best soil-pesticide combinations for maintaining healthy, well-functioning soil microbial communities in their soils.

Crop protection products, such as pesticides, have contributed to the profitability of the agriculture sector, contributing $20.6 billion to the annual harvested crop in Australia. However, pesticides can affect soil microbial community structure and function and hence vital, microbially-driven ecosystem services such as nutrient cycling, soil structural stability and plant pathogen control.

There are several factors that influence the effect that a pesticide will have on soil microorganisms and soil fertility. Such factors include the chemical structure, concentration and toxicity of the pesticide and soil properties. Different pesticides will therefore affect soil microbial communities differently depending on soil type, but these interactions are not well understood. Most past studies have only investigated the effect of a single pesticide on a single nutrient cycle (mostly the nitrogen cycle), using a limited number of soil types. For example, 15 previous studies have investigated the effect of pesticides on nitrate production in soil, and most of these studies only tested one pesticide in one soil. More importantly, of these 15 studies, only one used an Australian soil; a Queensland sugarcane cropping soil. Therefore, there is a scarcity of information regarding the potential effects of pesticides on the soil microbial communities of southern Australian agricultural soils.

One of the aims of this study is to investigate the comparative effect of 20 commercial agricultural pesticides on soil functions driven by microbial and enzymatic activities in three different SA soil types. The cumulative effects and persistence of negative impacts of selected soil-pesticide combinations will also be further studied to ensure ongoing pesticide performance and benefit. Overall, this project will aid farmers in the selection of future pesticide strategies that maximise farm outputs while retaining, or even improving, SA soil fertility.

How was it done?

During the first 12 months of this three-year project, we have carried out laboratory experiments testing 20 commercialised pesticides, with different modes of action (Table 1), on three SA soil types. The pesticides include four insecticides, eight herbicides, and four fungicides, all supplied by six agrochemical companies; Bayer, BASF, Syngenta, FMC, Nufarm and ADAMA. The three SA soil types are 1) a grey calcareous sandy soil from Piednippie, Eyre Peninsula 2) a clay-loam soil from the Hart Field site in the Clare Valley where a field trial will also be conducted in 2020, and 3) a sodic soil from Pine Hill, South East SA.

Table 1. Pesticides selected for targeted investigation.

Pesticide	Class	Mode of action	Product name	Supplier	Concentration of active ingredient
Chlorpyrifos	Insecticide	AChE inhibitor	Chlorpyrifos 500EC	Nufarm	500g/L
Fipronil	Insecticide	Chloride channel blocker	Legion	Nufarm	500 g/L
Alphacypermethrin	Insecticide	Sodium channel blocker	Astound Duo	Nufarm	100 g/L
Imidacloprid	Insecticide	nAChR modulator	Gaucho®	Bayer	600 g/L
Chlorsulfuron	Herbicide	ALS inhibitor	TACKLE®	ADAMA	750 g/kg
Imazamox	Herbicide	ALS inhibitor	Raptor	BASF	700 g/kg
Atrazine	Herbicide	PS II inhibitor	Atragranz	Nufarm	900 g/kg
Trifluralin	Herbicide	Microtubule inhibitor	Triflur X	Nufarm	480 g/L
Propyzamide	Herbicide	Microtubule inhibitor	Rustler® 900WG	FMC	900 g/L
Prosulfocarb	Herbicide	Lipid synthesis inhibitor	Countdown®	Adama	800 g/L
Metolachlor	Herbicide	VLCFA inhibitor	Bouncer® 960S	Nurfam	960 g/L
Pyroxasulfone	Herbicide	VLCFA inhibitor	Sakura 850WG	Bayer	850 g/kg
Isoxaflutole	Herbicide	HPPD inhibitor	Balance® 750WG	Bayer	750 g/kg
Clopyralid	Herbicide	Synthetic auxin	Archer 750	Nufarm	750 g/L
Paraquat	Herbicide	PS I inhibitor	Shirquat 250	Nufarm	250 g/L
Glyphosate	Herbicide	EPSP inhibitor	Weedmaster® DST	Nufarm	470 g/L
Flutriafol	Fungicide	Sterol biosynthesis inhibitor	Intake® HiLoad Gold	Nufarm	500 g/L
Metalaxyl-M	Fungicide	RNA polymerase I	ApronXL	Syngenta	350 g/L
Penflufen	Fungicide	SDH inhibitor	EverGol Prime	Bayer	240 g/L
Azoxystrobin	Fungicide	Ubiquinol oxidase inhibitor	Supernova 250 SC	Nufarm	250 g/L

The 20 pesticides were tested on the three soil types at two different doses (equivalent to one and five times the recommended dose) and incubated for four weeks under controlled conditions (i.e. constant temperature, and humidity) to give 120 treatments prepared in triplicate. At the end of each incubation period, a suite of high-throughput molecular tools was used to monitor the structure, diversity and function of soil microbial communities involved in three nutrient cycles: carbon cycle, nitrogen cycle and phosphorus cycle. We further investigated effects on the nitrogen cycle by measuring potential nitrification (a test that indicates the potential for ammonium to be converted to nitrite; one of the most important steps in the nitrogen cycle), and, the expression of functional genes involved in this process (i.e. *amoA* genes).

All statistical analyses are being carried out using GraphPad Prism 8.2.0. In the middle of the second year, this study will assess lab-field transferability of the experimental data by establishing a field trial that will be conducted over two years at the Hart Field Site. The field trial will test three to five selected soil-pesticide combinations of special interest to growers. The cumulative effects and persistence of the selected pesticides will also be investigated in laboratory experiments that will run in parallel to the field trial. Repeat applications will be applied every six months and samples will be collected two weeks after pesticide application, just before the next application. The fate of the pesticides will also be tested in parallel throughout the experiment using ^{14}C-labelled compounds. For the correlation of a pesticides' mode of action to any negative impacts on non-target organisms, multiple pesticides of interest with similar modes of action will be further investigated to determine the presence of any possible relationship.

What happened?

Data have been collected from the laboratory experiments in the first year of the project (2019) and are currently being analysed. More laboratory work will be continued in the second year of the project and more results will be collected from the Hart field trial, which will start in May 2020.

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University of South Australia

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Section 3

Section Editor:
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Natural Resources Eyre Peninsula

Break Crops

Eyre Peninsula 2019 NVT canola trial yields in t/ha and expressed as percentage of site mean.

Nearest Town	**Lock**			**Minnipa**		
Variety	**t/ha**	**%**	**Oil (6% moisture)**	**t/ha**	**%**	**Oil (6% moisture)**
Hyola 575CL	1.49	116	40.7	1.02	95	41.6
Pioneer 43Y92 (CL)	1.22	95	40.4	1.11	103	37.7
Pioneer 44Y90 (CL)	1.58	123	40.0	1.15	106	38.8
Saintly CL	1.07	83	37.2	1.08	100	38.6
VICTORY V7002CL	0.90	70	39.8	1.05	97	40.7
Site mean (t/ha)	**1.29**			**1.08**		
CV (%)	5.67			6.27		
Probability	<0.001			0.19		
LSD (t/ha)	*0.12*			*0.11*		
Sowing Date	07/05/2019			02/05/2019		
Trial comments				Trial has a high P value (0.19) indicating low significance of variety effect. Interpret results with caution		
Variety						
ATR Bonito	1.19	100	41.8	1.08	95	41.9
ATR Stingray	0.78	65	38.4	0.97	86	38.5
Hyola 350TT	1.11	93	37.6	1.18	104	38.1
Hyola 550TT	1.13	95	38.6	1.14	100	38.5
HyTTec Trident	1.23	104	37.6	-	-	38.4
HyTTec Trophy	1.24	105	39.1	1.14	101	37.4
InVigor T 3510	1.32	111	37.2	1.02	90	37.3
InVigor T 4510	1.37	115	37.7	1.17	103	37.7
Monola 416TT	-	-	-	-	-	-
Pioneer 44T02 TT	1.06	89	38.8	1.06	94	40.2
SF Spark TT	1.20	100	39.5	1.12	99	39.5
Site mean (t/ha)	**1.19**			**1.13**		
CV (%)	6.06			6.12		
Probability	<0.001			<0.001		
LSD (t/ha)	*0.12*			*0.11*		
Sowing Date	07/05/2019			02/05/2019		
Variety						
AV Garnet	1.21	108	38.8			
Nuseed Diamond	1.06	95	39.1			
Nuseed Quartz	1.16	104	38.3			
Site mean (t/ha)	**1.12**					
CV (%)	6.53					
Probability	<0.001					
LSD (t/ha)	*0.12*					
Sowing Date	07/05/2019					

Break crop selection for Eyre Peninsula low rainfall farming systems

Sarah Day[1], Helena Oakey[2], Richard Saunders[3] and Penny Roberts[1]
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Location
Minnipa Agricultural Centre,
paddock S10
Rainfall
Av. Annual: 324 mm
Av. GSR: 241 mm
2019 Total: 254 mm
2019 GSR: 234 mm
Soil type
Clay loam
Plot size
2 m x 10 m x 3 reps
Trial design
Experimental: Split plot

Key messages

- **Field pea had higher biomass and grain yield production than other break crop species at Minnipa, although @RISK analysis suggests field pea is only profitable as a grain crop in 41% of years.**
- **@RISK analysis model outcomes indicate chickpea, vetch hay and lentil are lower risk break crop species, and are profitable in more than 50% of years.**
- **Field pea and vetch have multiple alternative end-use options in dry seasonal conditions that can be utilised to recover crop input costs and salvage a financial return.**

Why do the trial?

Farming systems in the low rainfall zone of southern Australia are dominated by cereal production. There is increasing concern about grass weed and soil-borne disease pressure, diminishing soil fertility (particularly nitrogen), and water use efficiency, as a result of continuously cropping cereals. Break crops have a key role to play in addressing these issues, as well as diversifying crop production and economic risk, and maintaining long-term sustainability of the system. However, there remains a lack of information available to growers about choosing the break crop best suited to their situation, as break crop development to date has largely occurred in medium and high rainfall zones. The aim of this research is to identify the best break crop options for different climate, soil type and biotic stress situations within major cropping regions of the southern low rainfall zone.

How was it done?

A break crop species-by-variety trial was conducted at Minnipa Agricultural Centre in 2017, 2018 and 2019 to compare varieties of six break crop species. This trial was part of a wider program, with similar trials undertaken at four key locations across the southern low rainfall zone. The trials include three to six varieties (to represent major potential options for the low rainfall zone) of canola, lupin, field pea, vetch, lentil, chickpea and faba bean. Lupin was not included at Minnipa after consultation with local advisors, as it is not suited to the environment. Varietal options included herbicide-tolerant varieties and those with potential for different end-uses. Measurements taken include site soil characteristics, soil moisture, grain yield, biomass yield and gross margin. Plot arrangement was in a split plot randomised design with three replicates, with random assignment of break crop species to the whole plot and variety to the sub plot. The use of this design ensures each break crop species receives appropriate management.

The trial was sown at Minnipa using an experimental plot seeder with 27 cm row spacing. Biomass measurements were taken at late flowering to early podding growth stage to identify potential use as a hay, forage or manure crop. Gross margin was calculated using the PIRSA Rural Solutions 'Farm Gross Margin and Enterprise Planning Guide' and a five-year average grain price for each season. A multi-environment trial analysis using a factor analytic model (Smith, Cullis, & Thompson, 2001), with adjustment for design factors and spatial variation, was conducted for biomass and grain yields. Models were fitted in ASReml-R (Butler, Cullis, Gilmour, & Gogel, 2009), in the statistical software platform R.

A model developed by Rural Directions Pty Ltd using @RISK, an add-on to Microsoft Excel, was used to assess risk and net profit associated with including different break crop options in a three-year break-wheat-wheat rotation. Percentile 10, 50 and 90 yields and prices were used in the model (Table 2), together with low-input variable costs for each crop, and the model was used to analyse 5000 seasonal outcomes. Estimated yield benefits and penalties associated with the following crop, and estimated fixed costs (depreciation, finance cost and overhead costs) were included in the model.

Table 1. Break crop species by variety trial fertiliser rate, sowing dates and harvest dates at Minnipa, 2017-2019.

	2017	2018	2019
Sowing date	Canola: 31 May Vetch, field pea: 2 June Chickpea, faba bean, lentil: 30 June	21 June	Pulses: 15 May Canola: 24 May
Fertiliser	Pulses: 75 kg/ha MAP Canola: 75 kg/ha DAP	Pulses: 100 kg/ha MAP Canola: 100 kg/ha DAP	Pulses: 100 kg/ha MAP Canola: 100 kg/ha DAP
Harvest date	21 November	16 November	Field pea: 1 November Canola: 7 November Lentil: 13 November Faba bean, vetch, chickpea: 25 November

Table 2. Grain price and yield percentiles used in the @RISK model analysis.

	Price ($/t) percentiles			Yield (t/ha) percentiles		
	P10	P50	P90	P10	P50	P90
Wheat	180	230	280	0.4	1.3	2.8
Canola	450	490	530	0.2	0.5	1.2
Lentil	415	660	1000	0.2	0.6	1.3
Chickpea	620	1000	1400	0.2	0.6	1.3
Field pea	200	320	485	0.2	0.8	1.7
Faba bean	240	323	461	0.2	0.6	1.3
Lupin	180	320	500	0.2	0.7	1.6
Vetch hay	180	240	300	0.7	2.4	5.3

What happened?

Seasonal conditions

In 2017, well above average rainfall was recorded for January and February, providing some stored subsoil moisture prior to sowing. However, dry conditions in March and April dried out the top soil, and continued dry conditions into May and June resulted in poor canola establishment. Rainfall totalling above 80 mm throughout July and August, along with increasing temperatures in August, aided rapid crop growth. Scattered showers in October were generally too late to be beneficial to crop yields, with warmer temperatures and low soil moisture leading to rapid crop senescence.

Close to average rainfall conditions were experienced in 2018 (Figure 1). However, dry conditions from January to June led to soil profiles containing little to no stored soil moisture. Well-above average rainfall was recorded in August, and warmer sunny days led to rapid crop growth. Heavy frost events were experienced in September, with the worst affected crops in the district being cut for hay. Showers during early October were not enough to benefit crop yields.

Below average annual rainfall was recorded in 2019 (Figure 1). Soil profiles were dry prior to sowing, with less than 20 mm of rain leading up to May. Adequate rainfall during May and June fell in time for sowing to be completed. Growing season rainfall was just above average, with heavy rainfall in late winter and early spring aiding crop growth.

Biomass production

Field pea and vetch are both versatile break crop species that can be grown for grain, hay, silage, grazing, or green or brown manure. The versatility of field pea and vetch allows a financial return to be salvaged if crops are drought or frost affected. Biomass production of field pea (1.2-3.2 t/ha) and vetch (1.05-2.06 t/ha) was higher than other break crop species at Minnipa (Figure 2). Field pea variety performance was inconsistent, with no one variety out-performing all other varieties in all three seasons. Conventional type field pea are often preferred when grown for alternative end-uses to grain, due to their higher biomass potential. However, conventional type field pea have not offered consistent improved biomass production over semi-leafless types. Additionally, conventional type field pea have poor lodging resistance, therefore semi-leafless varieties may be a more suitable option, regardless of intended end-use.

Vetch biomass production was similar across varieties at Minnipa, while across all low rainfall environments in the project, Volga had higher biomass production than Rasina and Timok. Early maturing canola variety Nuseed Diamond had consistent high biomass production compared to other canola varieties. Desi chickpea PBA Striker had higher biomass yield than Genesis090 and PBA Monarch at Minnipa in all three seasons (Figure 2).

PBA Striker also showed improved early vigour and ground cover over kabuli PBA Monarch, visually and statistically from normalised difference vegetation index measurements.

Faba bean biomass production was similar across varieties in 2017 and 2018. In 2019, PBA Samira and PBA Marne produced 21% and 22% more biomass than PBA Bendoc, respectively (Figure 2). Lentil biomass production was similar across varieties at Minnipa. Of the herbicide tolerant lentil varieties, PBA Hallmark XT consistently had higher biomass production than PBA Hurricane XT. For conventional varieties, biomass production was similar, with a slight increase in biomass from PBA Jumbo2 at Minnipa (Figure 2).

Grain yield

Grain yield of field pea (0.18-1.40 t/ha) was higher than all other break crop species at Minnipa in 2017-2019 (Figure 3), showing they have consistent and reliable production in this region. As with biomass production, field pea variety performance was inconsistent and no single variety out-yielded other field pea varieties across all three seasons. Vetch variety grain yield performance was also variable at Minnipa. Early maturing Volga was often the highest yielding vetch variety across low rainfall environments in the wider program. PBA Hallmark XT was the highest yielding lentil variety in 2018, while PBA Jumbo2 was the highest yielding in 2019 (Figure 3). Faba bean grain yield was similar across varieties, with a 0.2 t/ha drop in grain yield of PBA Samira in 2019, compared to PBA Marne and PBA Bendoc (Figure 3). PBA Striker desi chickpea and Genesis090 kabuli chickpea varieties were higher yielding than the large seeded kabuli PBA Monarch. Hybrid Nuseed Diamond canola was at least 12% higher yielding than other canola varieties across all seasons at Minnipa.

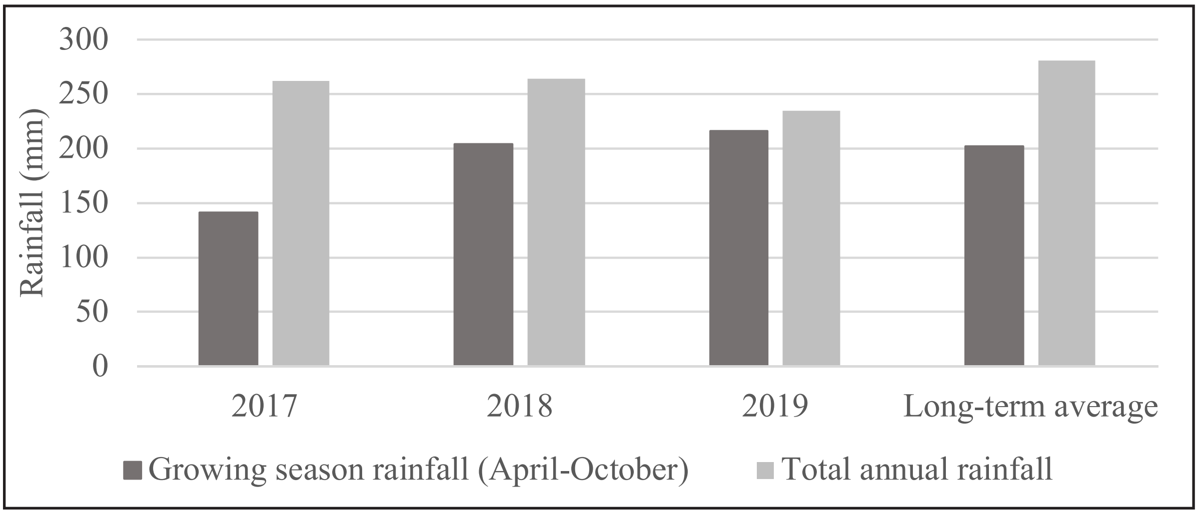

Figure 1. Growing season rainfall and total annual rainfall (mm) for 2017-2019, compared to the long-term average rainfall, recorded at Minnipa Agricultural Centre.

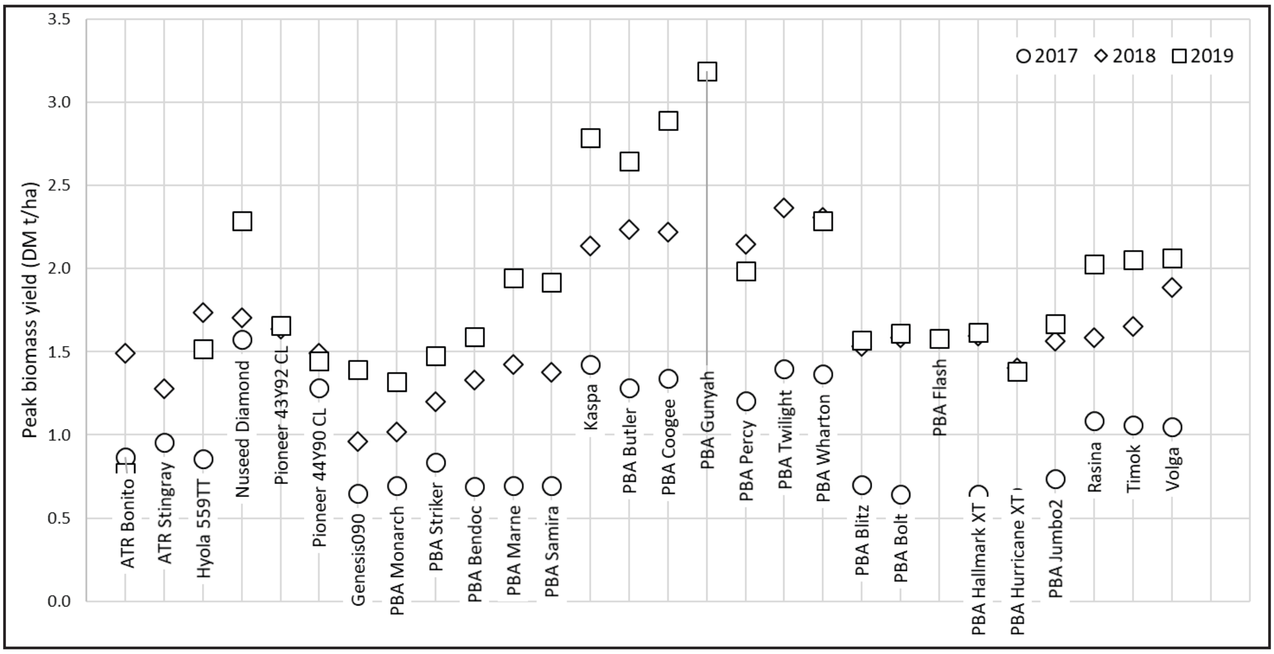

Figure 2. Peak biomass yield performance (DM t/ha) of break crop varieties at Minnipa over three seasons (2017-2019). Varieties of the same crop species are grouped together along the x-axis. Standard error is 0.17-0.23.

Gross margin and @RISK analysis

The @RISK analysis of 5000 seasonal outcomes provided a percentage of years that each break crop would be profitable, and the net profit for each rotation sequence (Table 3). Average net profit per hectare per year over a three year rotation for chickpea and lentil was $181.86 and $72.71, respectively, compared to $4.40 for field pea. Rotation sequences including field pea were profitable in 40.7% of years, and including lentil were profitable in 51.6% of years. Sequences that included chickpea were profitable in 55.5% of years. However, it is important to keep in mind that this analysis was based on a low input system with the application of only one fungicide spray, and chickpea would not be as profitable in a season with high disease risk or infection of ascochyta blight. The analysis indicated that canola and faba bean were the least profitable and higher risk break crop options, profitable in 34.3% and 38.7% of years, respectively.

What does this mean?

The decision to grow a break crop is generally done with a whole systems approach, as break crops can be utilised to address the issues and constraints that arise from continuously cropping cereals. The choice of break crop is made depending on the reason for growing a break crop, crop end-use, financial risk, paddock selection and soil type. Field pea production is more stable than other break crop species across the low rainfall environment. However, field pea is least suited to frost prone areas, and is a risk for grain production where spring frost events occur frequently. Field pea has multiple alternative end-uses to grain, and with high biomass potential can be utilised as a hay, forage, silage or manure crop when frost or drought affected, to salvage a financial return.

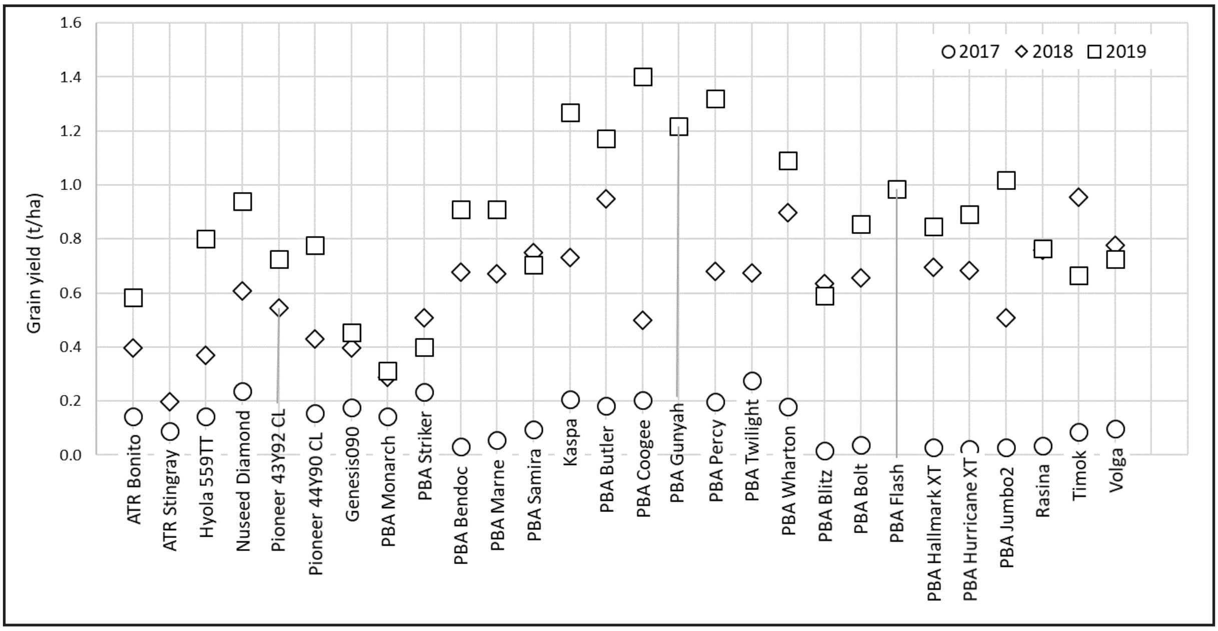

Figure 3. Grain yield (t/ha) of break crop varieties at Minnipa over three seasons (2017-2019). Varieties of the same crop species are grouped together along the x-axis. Standard error is 0.03-0.11.

Table 3. @RISK analysis of break crop options in a 3-year rotation with wheat, with rotation sequence ranked from lowest risk and most profitable, to highest risk and least profitable. Lupin were not grown at Minnipa, but were included in break crop trials as part of the wider program.

Rotation sequence	Average gross margin $/ha	Average net profit $/ha	% of years break crop is profitable	Rank
Chickpea-wheat-wheat	281.86	181.86	55.5	1
Vetch hay-wheat-wheat	178.03	78.03	56.6	2
Lentil-wheat-wheat	172.71	72.71	51.6	3
Lupin-wheat-wheat	124.28	24.28	44.3	4
Field pea-wheat-wheat	104.40	4.40	40.7	5
Faba bean-wheat-wheat	89.68	-10.32	38.7	6
Canola-wheat-wheat	55.81	-44.19	34.3	7

Vetch is also a versatile crop, having multiple potential end-uses, and is a good fit in a mixed farming system. Vetch hay can be profitable in 56.6% of years. Canola, lentil and faba bean can provide herbicide tolerant crop options where in-crop weeds or herbicide residues are an issue. Canola also has a good fit where cereal root diseases are limiting production (Kirkegaard, Christen, Krupinsky, & Layzell, 2008). However, canola requires adequate soil moisture at sowing for successful germination, in particular on heavier soil types, and may be an opportunistic crop in some environments.

Lentil can be profitable in 51.6% of years. However, lentil is more sensitive to soil constraints than other break crop species and plant height is often low, leading to poor harvestability. Faba bean would be suitable where a break crop is needed in a frost prone area, as faba bean tolerates reproductive frost events better than other pulse crop species. Chickpea can be profitable across the southern low rainfall zone in 55.5% of years. Although chickpea grain yields were low at Minnipa (0.14-0.51 t/ha), chickpea has shown better adaptability and stability in the upper Victorian Mallee.

Each break crop species has its own unique fit in the farming system, and all available agronomic, local, and paddock information needs to be taken into consideration when selecting a break crop to fit into each individual farming system. Each break crop species has a number of varieties with a range of agronomic characteristics to select from that are suitable for production in the low rainfall environment. Although top performing varieties have been identified for some break crop species, the final selection will depend on the individual farming system, in particular where soil type, herbicide residues and/or broadleaf weeds are a constraint to production.

Acknowledgements

The research undertaken as part of this project is made possible by the significant contributions of growers through both trial cooperation and the support of the GRDC (DAS00162A), and the authors would like to thank them for their continued support. The continued assistance in trial management from SARDI Agronomy groups at Clare and Minnipa, as well as Frontier Farming Systems, is gratefully acknowledged and appreciated.

Useful Resources

Day S, Oakey H, Roberts P. (2019). A systems approach to break crop selection in low rainfall environments. Proceedings of the 2019 Agronomy Australia Conference, 25-29 August 2019, Wagga Wagga, Australia.

Day S, Oakey H, Saunders R, Roberts P. (2020). Break crop selection in low rainfall environments – one size does not fit all. GRDC Grains Research Updates, 11-12 February 2020, Adelaide, Australia.

References

Butler, D., Cullis, B., Gilmour, A., & Gogel, B. (2009). ASReml-R Reference Manual. Retrieved from Toowoomba, Australia:

Kirkegaard, J., Christen, O., Krupinsky, J., & Layzell, D. (2008). Break crop benefits in temperate wheat production. Field Crops Research, 107(3), 185-195. doi:10.1016/j.fcr.2008.02.010

Smith, A., Cullis, B., & Thompson, R. (2001). Analyzing Variety by Environment Data Using Multiplicative Mixed Models and Adjustments for Spatial Field Trend. Biometrics, 57(4), 1138-1147. Retrieved from www.jstor.org/stable/3068246

Group B herbicide tolerance in lentil and faba bean on the Eyre Peninsula

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[1]SARDI, Clare; [2]SARDI, Port Lincoln

Location
Yeelanna
Rainfall
Av. Annual: 411 mm
Av. GSR: 330 mm
2019 Total: 360 mm
2019 GSR: 334 mm
Soil type
Clay loam over red clay
Soil test
pH at 10 to 30 cm: 7.8
Plot size
1.75 m x 10 m x 3 reps
Trial design
Experimental: Split Plot

Location
Tooligie
Rainfall
Av. Annual: 311 mm
Av. GSR: 249 mm
2019 Total: 235 mm
2019 GSR: 222 mm
Soil type
Loamy sand
Soil test
pH at 10 to 30 cm: 7.9
Plot size
1.75 m x 10 m x 3 reps
Trial design
Experimental: Split Plot

Location
North Block (Coulta)
Rainfall
Av. Annual: 519 mm
Av. GSR: 435 mm
2019 Total: 479 mm
2019 GSR: 402 mm
Soil type
Loamy sand over loamy clay
Soil test
pH at 10 to 30 cm: 5.4
Plot size
1.75 m x 10 m x 3 reps
Trial design
Experimental: Split Plot

Key messages

- **High levels of crop safety were observed in imidazolinone tolerant lentil varieties, with no grain yield loss from any simulated residue treatments of sulfonylurea herbicides, or post-emergent applications of imidazolinone herbicides, at North Block in 2018, or Tooligie in 2019.**
- **High levels of crop safety were observed in the imidazolinone tolerant faba bean variety, with no grain yield loss from any simulated residue treatments of sulfonylurea herbicides, or post-emergent applications of imidazolinone herbicides, at Yeelanna in 2019.**
- **Access to herbicide tolerance traits will provide growers with an increased opportunity to diversify their cropping rotations and increase in-crop control options, specifically for broadleaf weed control in areas with high weed burdens.**

Why do the trial?

To make full use of in-crop rainfall, stored soil moisture and nutrients, and prevent weed seed contamination, the control of weeds in a pulse break crop phase is essential. Currently, herbicides are the primary method of weed control in broadacre cropping systems. However, there are limited options for broadleaf weed control in pulse crops, as there are few effective broadleaf post emergent herbicides available for use in faba bean and lentil. Along with limited control options, the presence of possible herbicide residues, such as sulfonylureas (SU), from previous crops are major deterrents for including pulses in a cropping rotation where there is an increased risk of herbicide damage. In recent years, Group B herbicide tolerant (HT) lentil and faba bean varieties have been released to Australian growers and have proven very popular for giving more flexible weed control options, particularly for late emerging broadleaf weeds. The Group B herbicide tolerance traits not only provide growers with in-crop options for broadleaf weed control, but also allow these pulse crops to be grown on Group B (including SU) herbicide residues, which can persist from previous crop applications for up to 24 months or longer, depending on rainfall (minimum of 700 mm) and soil pH (as per DuPont™ Glean® and Tackle® WG product labels).

The aim of these trials was to evaluate the levels of tolerance to simulated residues and post-emergent applications of Group B herbicides in lentil XT varieties, and a faba bean mutant derived line with Group B herbicide tolerance traits.

How was it done?

The performance of the HT lentil varieties PBA Hurricane XT and PBA Hallmark XT, as well as the HT faba bean variety PBA Bendoc were compared across a range of Group B herbicide treatments (Table 1). Treatments of metsulfuron-methyl, chlorsulfuron and triasulfuron were applied prior to sowing and incorporated by sowing (IBS), to demonstrate “simulated” SU residues

Table 1. Herbicide treatments compared in the 2018 and 2019 trials. IBS = Incorporated by sowing.

Chemical	Chemical family	Application rate	Application timing
Metsulfuron-methyl 600 g/kg	SU	7 g/ha	IBS
Chlorsulfuron 750 g/kg	SU	12 g/ha	IBS
Triasulfuron 750 g/kg	SU	10 g/ha	IBS
Imazamox 33 g/L + Imazapyr 15 g/L	IMI	750 g/L	Post-emergent
Imazethapyr 700 g/kg	IMI	100 g/ha	Post-emergent

**Note that some herbicides are currently unregistered for use in lentil and faba bean and these treatments were included for experimental purposes only. The results within this document do not constitute a recommendation by the author or author's organisation for that particular use. Permits for the use of Intercept® are now available for the lentil XT and faba bean IMI HT lines. A reminder that any off-label herbicide use can result in crop damage; and product label rates, permits, plant-back periods and directions for use must be adhered to.*

Table 2. Faba bean and lentil varieties included in the herbicide response trials, along with site location and year the trials were conducted.

Year	Site	Crop type	Variety
2018	North Block	Faba bean	Nura
2018	North Block	Faba bean	PBA Bendoc
2018	North Block	Lentil	PBA Hallmark XT
2019	Yeelanna	Faba bean	Nura
2019	Yeelanna	Faba bean	PBA Bendoc
2019	Yeelanna	Faba bean	Samira
2019	Yeelanna & Tooligie	Lentil	PBA Hallmark XT
2019	Yeelanna & Tooligie	Lentil	PBA Hurricane XT
2019	Yeelanna & Tooligie	Lentil	PBA Jumbo 2

Two post-emergent imidazolinone (IMI) treatments of imazamox + imazapyr and imazethapyr were applied at the 5 node growth stage. Each trial was arranged as a split-plot design with herbicide assigned to the whole plot and variety assigned to the sub-plot, with three replications of each treatment.

In 2018 and 2019, combined lentil and faba bean herbicide trials were established at North Block and Yeelanna, while the Tooligie site in 2019 looked at lentil herbicide evaluation alone (Table 2). Throughout the duration of the trials, a number of measurements were taken including the normalised difference vegetation index (NDVI), plant height, biomass yield, herbicide damage score and grain yield. The data was analysed using Genstat 20th edition.

What happened?

Below average rainfall was received in both 2018 and 2019 seasons at all sites which may impact results.

At the 2018 North Block site, both simulated residue as well as post-emergent treatments had no effect on grain yield, NDVI or grain quality for PBA Hallmark XT (data not shown). The average yield was 1.5 t/ha at this site. Similarly, PBA Bendoc's grain yield was not affected by simulated residue or post-emergent herbicide treatments (Figure 1). Nura was unaffected by both post-emergent IMI treatments, however, it suffered a 52% and 74% reduction in grain yield from chlorsulfuron and metsulfuron-methyl, respectively, compared to the nil.

From the results of the lentil herbicide trials conducted in 2019 at Yeelanna, it was found there was no effect of any of the herbicide treatments on the grain yield of PBA Hallmark XT. PBA Hurricane XT also had no grain yield reduction from any post-emergent herbicide treatments, but was affected by the metsulfuron-methyl IBS herbicide treatment with a 31% reduction in grain yield (Figure 2). PBA Jumbo 2, a commercial line without HT traits, suffered severe reductions in grain yield from all IBS and post-emergent Group B herbicide treatments, with no grain obtained from trial plots treated with metsulfuron-methyl, and imazamox + imazapyr.

Results from the replicated lentil herbicide trial in 2019 at Tooligie indicated very similar findings to what was found at Yeelanna (Figure 3). No grain yield reduction was found in both Group B tolerant lentil varieties, PBA Hallmark XT and PBA Hurricane XT, from any herbicide treatments. However, PBA Jumbo 2 recorded significant yield reductions from all herbicide treatments, with between 94% and 88% yield loss from all IBS treatments, and 93% and 58% yield loss from the imazamox + imazapyr, and imazethapyr, post-emergent herbicide treatments respectively.

The IMI tolerant faba bean variety PBA Bendoc recorded no reduction in grain yield from all herbicide treatments, with an average yield of 3.6 t/ha at Tooligie in 2019 (Figure 4).

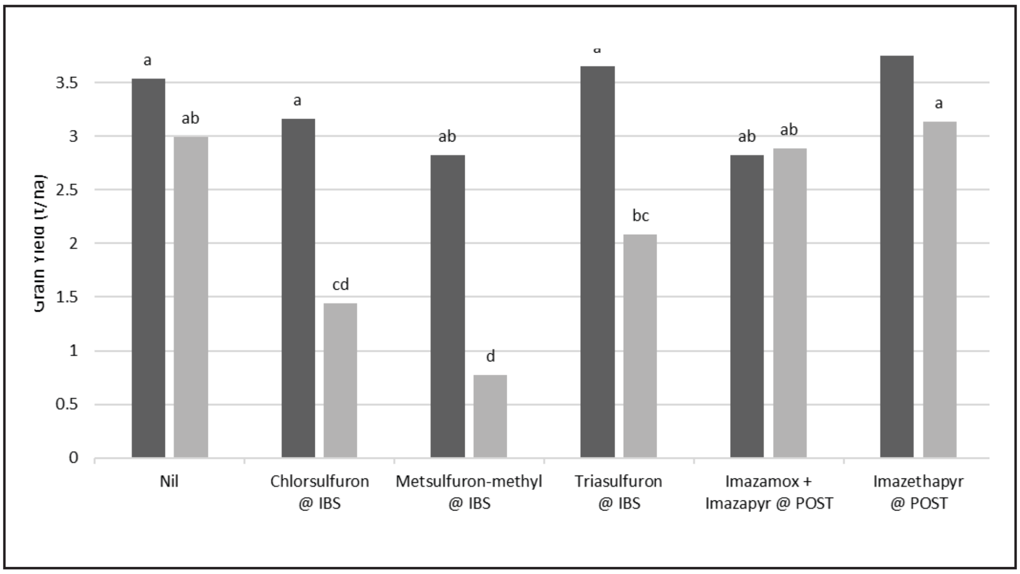

Figure 1. Grain yield response of faba bean varieties to Group B herbicides at North Block, 2018. Bars labelled with the same letter are not significantly different (P≤0.05).

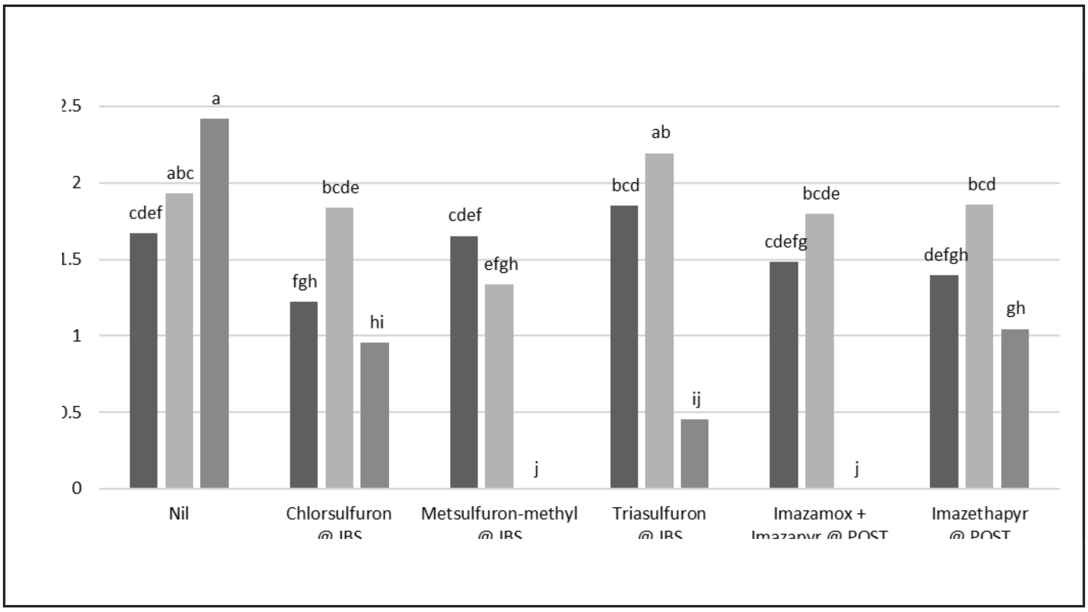

Figure 2. Grain yield response of lentil varieties to Group B herbicides at Yeelanna, 2019. Bars labelled with the same letter are not significantly different (P≤0.05).

However, both Nura and PBA Samira, commercial varieties without the herbicide tolerance traits, recorded losses in grain yield from all IBS herbicide treatments (ranging from 36% to 100%, and 24% to 80%, respectively), and the imazamox + imazapyr post-emergent herbicide treatment (35% and 33%, respectively). No loss in grain yield was recorded for the imazethapyr post-emergent herbicide treatment.

What does this mean?

High levels of tolerance were observed in both the commercially available XT lentils and HT faba bean (PBA Bendoc), for both simulated SU residues and IMI post-emergent herbicide application. Tolerance to these herbicide chemistries within pulse species, such as lentil and faba bean, provides growers with the option of using an in-crop herbicide application for the suppression of broadleaf weeds, that would previously not be available. This is particularly important when considering weed seed burdens and weed control options if dry sowing is implemented to maximise yield potential, while optimising operations for growers. Intercept® (imazamox + imazapyr) is now permitted for use as a post-emergent herbicide application in IMI tolerant lentils, applied at the 3 to 6 node growth stage, and IMI tolerant faba beans, applied at the 4 to 5 leaves unfolded growth stage.

In conditions such as dry sowing, a delayed break in the season or receiving minimal summer/autumn rainfall, herbicide residual effects can become far more pressing on crop rotation choices. The decision as to which pulse to grow, and where, should be based on a matter of risk and rotation need. The presence of SU herbicide residues in the soil profile from previous crop rotations has been recognised for having a significant negative impact on pulse crop performance.

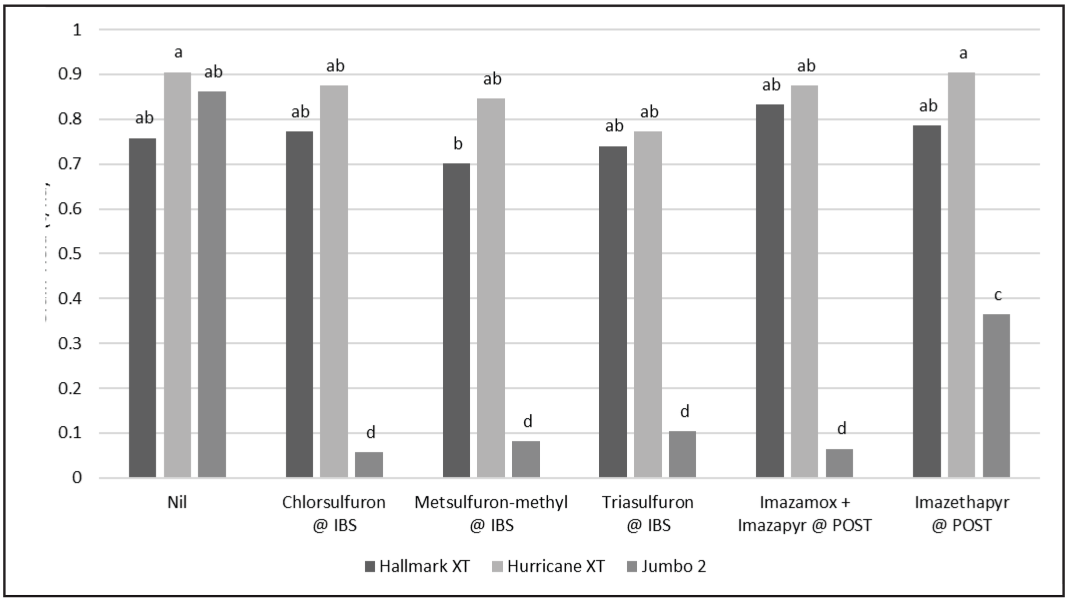

Figure 3. Grain yield response of lentil varieties to Group B herbicides at Tooligie, 2019. Bars labelled with the same letter are not significantly different (P≤0.05).

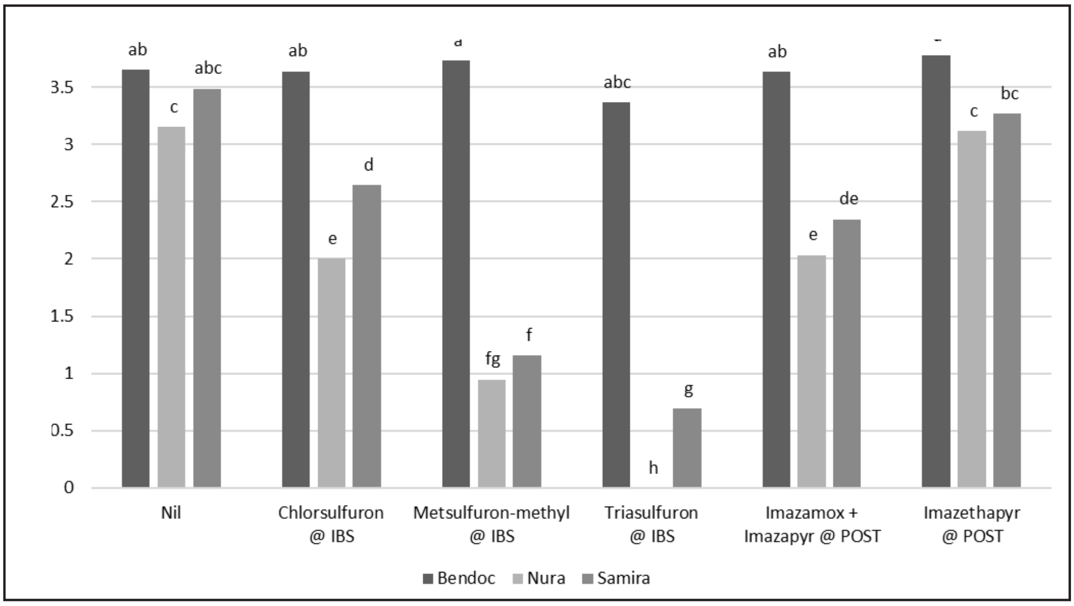

Figure 4. Grain yield response of faba bean varieties to Group B herbicides at Tooligie, 2019. Bars labelled with the same letter are not significantly different (P≤0.05).

An intolerance to these herbicide chemistries, many of which have a long plant back period, can have a profound negative impact on plant developmental structures contributing to overall grain yield components.

In terms of pulse crop sensitivities, lentil and chickpea are the most severely affected by Group B SU herbicide residues (e.g. chlorsulfuron and triasulfuron), with faba bean and field pea the least affected. Chickpea, faba bean and field pea are least sensitive to group B IMI herbicides (e.g. imazamox and imazethapyr), with lentil being extremely sensitive. A lentil rotation using a conventional variety should not immediately follow after faba bean or field pea if some group B herbicides have been used (e.g. flumetsulam, imazamox and imazethapyr), and minimum cropping intervals should be adhered to.

Access to HT traits will provide growers with an increased opportunity to diversify their cropping rotations, and increase in-crop control options, specifically for broadleaf weed control in areas with high weed burdens. With the increased interest and adoption of HT varieties, preventing the evolution of herbicide resistant weeds through integrated weed management strategies will be essential in the present and future. Therefore, it is crucial that permits, product label rates, plant back periods and all label directions for herbicide use are adhered to.

Acknowledgements

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Improving vetch growth and nodulation on Mallee sands

Brian Dzoma[1]**, Nigel Wilhelm**[2]**, Hugh Drum**[2] **and Kym Zeppel**[1]

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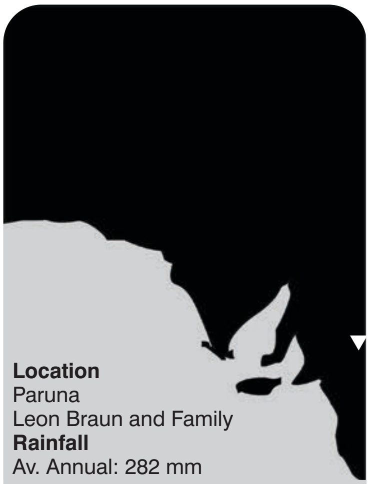

Location
Paruna
Leon Braun and Family
Rainfall
Av. Annual: 282 mm
Av. GSR: 190 mm
2019 Total: 136 mm
2019 GSR: 105 mm
Paddock history
2019: Vetch
2018: Wheat
Soil type
Sand
Soil test
pH (Water): 7.45
Plot size
15 m x 2 m x 3 reps
Trial design
Factorial RCBC with 3 replicates
Yield limiting factors
Moisture, compaction

Key messages

- **Placing P with the seed or banded to a depth of 8 cm below the seed does not affect vetch nodulation, leaf tissue P concentration and late flowering shoot dry matter.**
- **Leaf tissue P concentration and late flowering shoot dry matter increase with increasing rates of P.**

Why do the trial?

Phosphorous (P) is an essential macronutrient which influences plant shoot and root growth. It is generally the least available nutrient, particularly in sandy soils due to chemical bonding with Fe, Al, Ca and Mn in most production regions of Australia. Inadequate P restricts root and shoot growth and other functions which reduce N fixation by legumes. Vetch (*Vicia sativa*), a versatile pasture legume that can be used for grain, pasture, hay/silage or green manure, is being grown on naturally infertile Mallee soils which are often quite deficient in P. Vetch struggles to achieve optimum productivity on low P soils resulting in less fixed nitrogen returned to the system. This article reports on the responses of vetch to different rates of P placed at different depths below the seed at seeding. By achieving the optimum rate and right depth to place the P at sowing, productivity gains in the form of improved dry matter production, grain yield, nodulation and N fixation can result in multiple benefits, particularly in low rainfall mixed farming systems.

How was it done?

A replicated field trial was established in 2019 at Paruna (northern SA Mallee) on a red loamy sand (Colwell P, 16 mg/kg). The trial was sown to Volga vetch @ 35 kg/ha on 23 May. Five rates of P were applied as triple superphosphate (TSP) (0:46:0), at 3 different depths below the seed (Table 1). Plot length was 15 m and all treatments were replicated three times.

Emerged plants were counted on 19 June 2019 to determine plant population, and on 15 August, Clethodim @ 500 ml/ha + 1 L/ha wetter was applied to control grassy weeds. Samples for nodulation and leaf tissue P were taken on 8 August. Late flowering/early podding biomass was sampled on 5 September.

What happened?

With total growing season rainfall of only 105 mm, crop growth and productivity was severely limited. However, visual responses to the different rates of P applied at different depths were evident during the early part of the growing season, before flowering.

Response to P rates

Mean plant population for the site was 70 plants/m^2 and was not consistently affected by increasing rates of P (Figure 1a), regardless of its position. This shows there are situations where P applied at sowing up to 32 kg P/ha will not have a negative impact on crop establishment (but this will not always be the case). Overall nodulation for the site was good, as the mean total number of nodules per root was 48. For vetch on light soils, 20 nodules per plant at 8 weeks post sowing is considered satisfactory (GRDC, 2014). The mean nodules per root were not consistently affected by the different rates of P (Figure 1c).

Plant tissue analysis is an important tool because it shows the nutrient status of plants at the time of sampling. This, in turn, is a guide as to whether soil nutrient supplies are adequate. Plant tissue analysis can also detect unseen deficiencies and may confirm visual symptoms of deficiencies. The most sensitive tissue for detecting P deficiency is the youngest mature leaf. The critical level for vetch during vegetative growth is 0.3% (GRDC, 2018). Leaf tissue P at the site ranged from 0.15–0.24%, which is lower than the critical level. Leaf tissue P in vetch increased with increasing P applied at sowing (Figure 1b).

Table 1. Treatment details, Paruna 2019.

Crop	Volga vetch
Main plot factor (P placement)	With seed
	Shallow (4 cm below seed)
	Deep banded (8 cm below seed)
Sub-plot factor (kg P/ha)	0, 4, 8, 16, 32
Experimental design	Factorial RCBD x 3 replicates

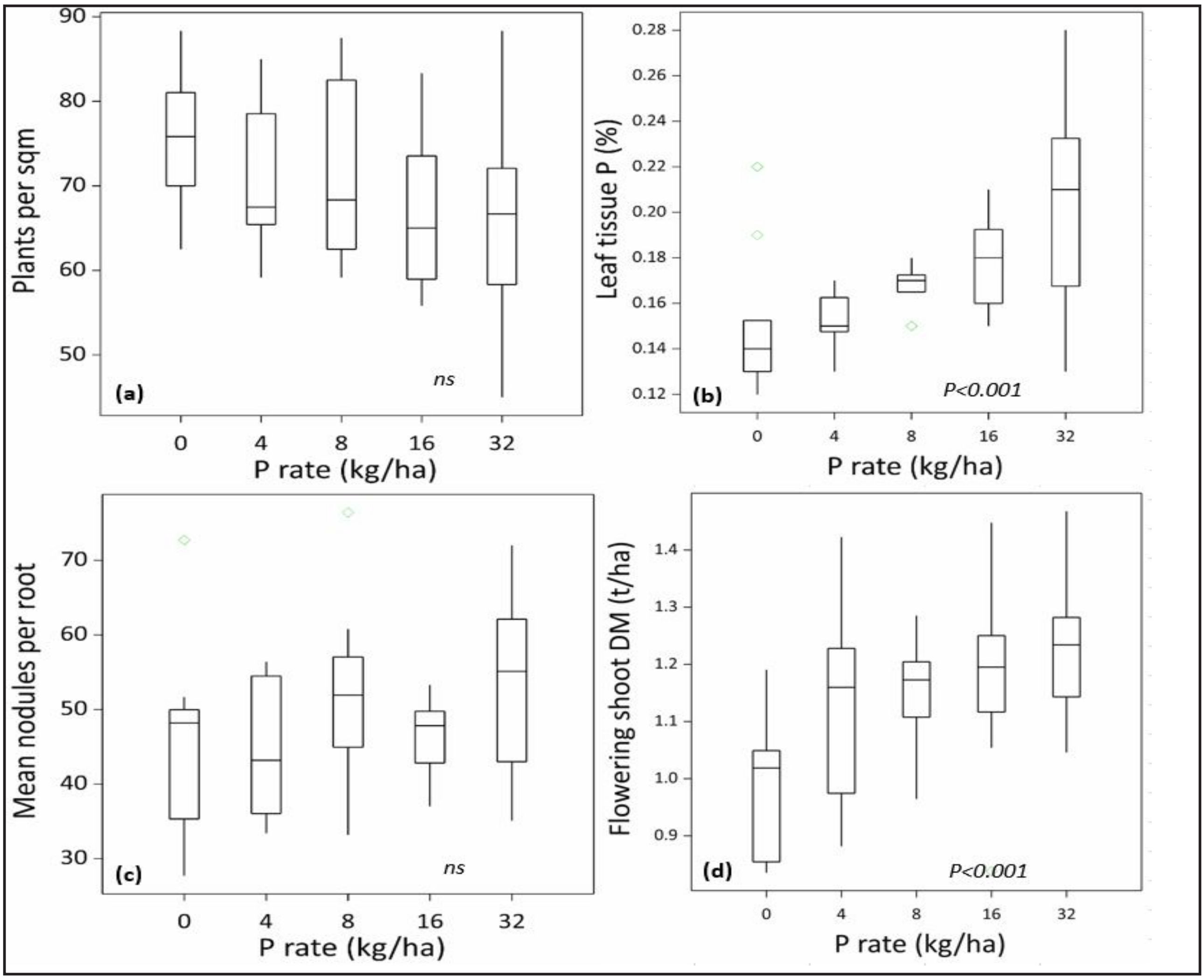

Figure 1. (a) Effect of different P rates on crop establishment leaf tissue, (b) P concentration, (c) nodules per root and (d) late flowering shoot dry matter.

Box and whisker plots show the shape of the distribution, the central value, and the variability. The lines extending from the boxes indicating variability outside the upper and lower quartiles, and the median is shown as a line in the centre of the box

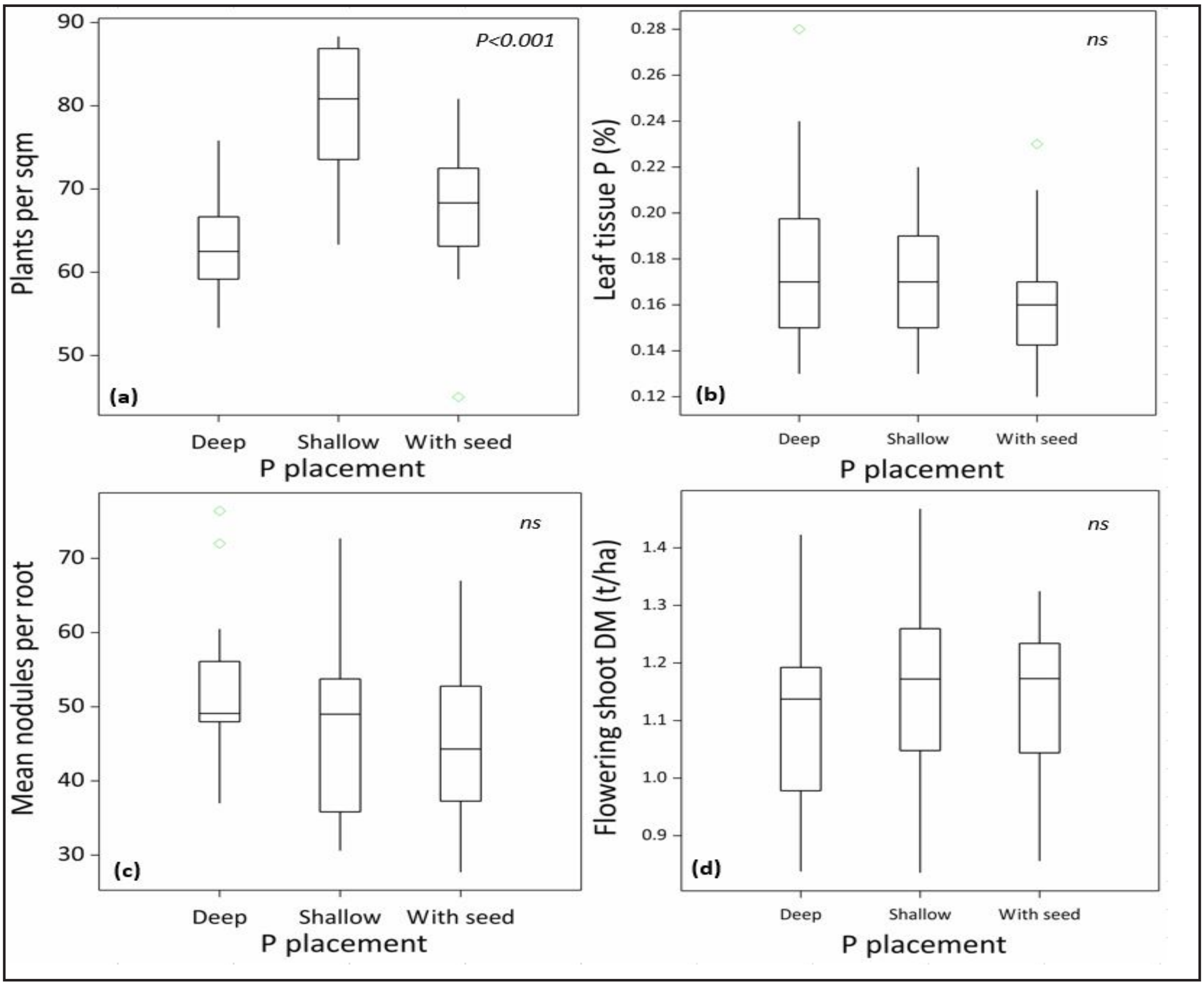

Figure 2. (a) Effect of P placement on crop establishment, (b) leaf tissue P concentration, (c) nodules per root and (d) late flowering shoot dry matter.

Crop biomass production was low because of a hot dry finish to the season. Flowering shoot DM for the site ranged from 0.95–1.30 t/ha, and the vetch crop responded positively to higher rates of P (Figure 1d). Matic *et al*., (2006) reported that average DM yield for Rasina vetch grown in 2006 at a trial site in Kingsford was 4.8 t/ha and 2.5 t/ha in Lameroo and Nagel *et al*., (2011) have reported that average grain yield for 2009, 2010 and 2011 was 2.2 t/ha from 4 sites in SA. Our trial site mean of 1.3 t DM/ha for late flowering DM reflects the impact of a below average season for the SA northern Mallee.

Responses to P placement

Establishment was significantly affected by the depth of placement of P at sowing. Plants/m^2 ranged from 63 (deep), 67 (with seed) and 79 (shallow). The shallow banding of P at sowing had significantly more plants/m^2 than deep banding or placing the P in the seed zone at sowing (see Figure 2a). Establishment with P in the seed row was possibly depressed by fertiliser toxicity, by P deficiency with deep P and better with shallow P because it avoided fertiliser toxicity and also supplied P to the crop (i.e. avoided P deficiency). Several authors (Singh *et al*., 2005; Bell *et al*., 2018 and McBeath *et al*., 2007) have reported that applying P at depth (15 to 30 cm deep on 50 cm bands) can improve yields over a number of cropping seasons (if other nutrients are not limiting). With our deepest treatment (8 cm below the seed), P was placed in the top 10 cm soil layer which is often dry. This explains the lack of response because of the immobile nature of P, limited rainfall and crop root architecture. There was no response in leaf tissue P, number of nodules per root and flowering shoot DM, to P placement as shown in Figures 2b-d.

What does this mean?

Vetch is now a significant legume rotation in cereal cropping systems in Australia's low and medium rainfall zones. There is limited recognition of the impact of phosphorus on vetch productivity in low rainfall Mallee environments. Estimates of the impact of soil P levels on nodulation and N fixation in alkaline coarse textured soils are also poorly understood.

We imposed four different rates of P as TSP at three different placement depths to investigate productivity responses that can be achieved by vetch on soils with low P reserves. Our results have shown that P fertiliser placed up to 8 cm below the seed will not result in more nodules on roots and will not improve DM production above P placed closer to the surface which is consistent with the results from a similar trial at Peebinga, 2018 (Dzoma *et al*., 2018).

However, it should be noted that if targeting higher plant densities, shallow banding P fertiliser can improve plant numbers and crop establishment. To improve vetch productivity on soils with low P reserves, the results show that dry matter production can be significantly improved by increasing the rate of P fertiliser at sowing. Matic *et al*., 2008 have also noted the importance of adding P when sowing Woolly pod vetch, as it generally provides a good start and growth. P applications, however, need to be matched against expected productivity gains for different soil types and rainfall regions to make sure fertiliser applications are economically justifiable.

References

Bell M, Lester D, Sands D, Graham R, and Schwenke G (2018). The P Story So Far – An Update On Deep P Research Findings. https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2018/03/the-p-story-so-far-an-update-on-deep-p-research-findings

Dzoma, B., Wilhelm, N., & Zeppel, K. (2018). Effect of rate and placement of phosphorus on vetch performance. Eyre Peninsula Farming Systems 2018 Summary Section 8: Nutrition, p 193 -196.

GRDC (2014). Inoculating legumes. The back pocket guide. Grains Research and Development Corporation.

GRDC (2018). GrowNotes (Northern). Vetch: Section 5: Nutrition and Fertiliser. Retrieved from: https://grdc.com.au/__data/assets/pdf_file/0017/370700/GrowNote-Vetch-North-05-Nutrition.pdf.

Nagel, S., Matic, R. & Kirby, G. (2011).Vetch in Australian farming systems. Eyre Peninsula Farming Systems 2011 Summary, Section: Breakcrops, p 71-72.

Matic, R., Nagel, S., Kirby, G. & Smith K. (2006). Vetch breeding and vetch use in Australia. Proceedings on 8th International Symposium of Forage Crops. Forage Crops Institute Novi Sad, Serbia.

McBeath, T.M., McLaughlin, M.J., Armstrong, R.D., Bell, M., Bolland, M.D.A., Conyers, M.K., Holloway, R.E. & Mason, S.D. (2007). Predicting the response of wheat (Triticum aestivum L.) to liquid and granular phosphorus fertilisers in Australian soils. Australian Journal of Soil Research 45, 448-458.

Matic, R., Nagel, S. & Kirby, G. (2008). Woolly pod Vetch. Pastures Australia. http://keys.lucidcentral.org/keys/v3/pastures/Html/Woolly_pod_vetch.htm

Singh, D. K., Sale, P. W. G., Routley, R. R. (2005). Increasing phosphorus supply in subsurface soil in northern Australia: rationale for deep placement and the effects with various crops. Plant and Soil, (269), 35–44. doi: 10.1007/s11104-004-2475-6.

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Herbicide tolerance and weed control in lentil on sandy soils

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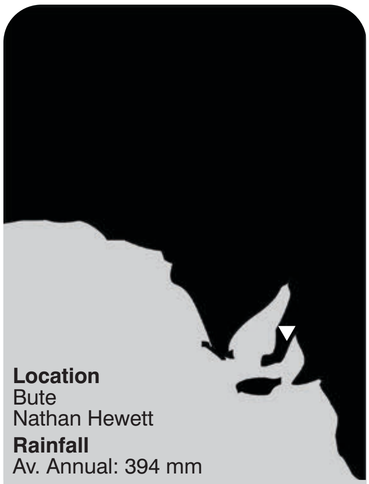

Location
Bute
Nathan Hewett
Rainfall
Av. Annual: 394 mm
Av. GSR: 295 mm
2019 Total: 216 mm
2019 GSR: 213 mm
Yield
Actual: 1.3t in control treatments, highest yielding treatmants were up to 1.4t/ha
Paddock history
2018: Wheat
2017: Lentil
Soil type
Neutral to alkaline sand hill, with deep sand (>1m) in a dune swale environment
Soil test
0-10 cm: PBI 41, DGT P 84, N 42, SOC 0.69%, pH$_{(H20)}$ 7.7
10-30 cm: PBI 58, DGT P >5, N 22, SOC 0.24%, pH$_{(H20)}$ 8.6
Plot size
1.5 m x 10 m on 2 m centres x 3 reps
Trial design
Randomised complete block design
Yield limiting factors
Low rainfall and terminal drought, moderate effects, low levels of pod drop prior to harvest

Key messages

- **Sandy soils can have narrow safety margins for commonly used broadleaf herbicides used in lentils. Herbicide damage from some Group C and B herbicides reduced lentil growth and grain yield on a sandy soil at Bute.**
- **Herbicide efficacy on four weed species was variable between products. Herbicide combinations were required to provide high levels of control of all four weed species.**
- **Optimising the herbicide strategy in lentils on sandy soils requires a balance between minimising crop effect, but achieving acceptable weed control. This requires knowledge of the target weeds and their resistance status to determine which herbicides to use and in what combination. The benefit of high level weed control then needs to be weighed against the risk of herbicide damage to the crop.**

Why do the trial?

Herbicide damage in lentils can occur readily on sandy soils from both pre and post emergent applications. Low clay content, low organic carbon and low cation exchange capacity of sand hills predispose these areas to increased risk from herbicide damage. It is possible that even without visible plant injury symptoms, there is an underlying level of herbicide damage restricting biomass production and yield of lentils on these soil types. Previous work conducted on a similar soil type in 2015, 2017 and 2018 showed that in some cases when more than one herbicide is applied the level of damage can be greater than the sum of the damage of the single herbicides on their own. The results from trials such as these can be influenced greatly by soil type and weather events and therefore need to be repeated to explore the range of responses that can occur.

In previous trials, the weeds that are present in the plots have been removed so that the effect of the herbicide is the only factor that is influencing crop performance. It is possible that higher weed density as a result of either no or low efficacy herbicide treatments being applied, will lead to reduced grain yield compared to more damaging, higher efficacy treatments.

This trial aimed to test the safety level of several commonly used herbicide options and combinations on PBA Hurricane XT lentils in both plots with natural weed populations present and plots with weeds removed by hand to limit competition with the crop.

How was it done?

The trial was a randomised complete block design with 17 herbicide treatments and two weed population treatments. In the plots with weeds removed, all weeds were removed by hand during the counting process and this was done at a time to limit the competition with the crop. The trial had three replicates.

The plots were 10 m x 1.5 m and were sown with PBA Hurricane XT using knife points and press wheels on 250 mm spacing with 60 kg MAP on 17 May 2019.

Pre-emergent herbicides were applied on 16 May 2019 prior to sowing using a hand boom, post emergent treatments with diflufenican and Intercept were applied using a shielded sprayer to prevent herbicide movement between plots on 27 June and 9 July respectively. Herbicide treatments are displayed in Table 1.

Measurements throughout the season included vigour and herbicide damage scores, GreenSeeker NDVI, weed density, weed biomass scores, pod drop prior to harvest and grain yield. Crop lower limit soil samples were taken post-harvest to a depth of 120 cm, these were segmented to 10-20, 20-40, 40-60, 60-90, and 90-120. Results were analysed with the statistical package R.

What happened and what does this mean?

Crop performance

Weed competition

The hand weeding treatment, plus and minus weeds, only affected NDVI recorded on the 19 August and 24 September. As a result of removing the weeds from the plots by hand, the total plot biomass was reduced and therefore the NDVI readings were reduced by 4% and 5% respectively. Unexpectedly, hand weeding the plots to remove the weeds did not increase the grain yield of lentils, indicating that the weed competition did not cause significant yield loss even in the nil herbicide treatments.

Group C herbicides (simazine, diuron, metribuzin, Terbyne, simazine/diuron mixture)

The Group C herbicides simazine, diuron and Terbyne reduced GreenSeeker NDVI by an average of 23% on 22 July (Table 2). This level of damage from these three herbicides continued until 19 August (24% reduction). By 24 September the damage from the simazine and diuron treatments was no longer significant whereas the Terbyne treatment NDVI was still 16% lower than the control. The metribuzin treatments caused less damage than the other Group C herbicides with an 11% and 9% reduction in NDVI for the 22 July and 19 August respectively. Grain yield was not significantly reduced by metribuzin, diuron or the simazine/diuron combination applied alone. The other Group C herbicide treatments of simazine and Terbyne reduced grain yield by 17 and 26%, respectively.

Group F herbicide (diflufenican)

Diflufenican applied alone had no significant negative impact on any crop performance attribute measured. However, there is a trend for the NDVI to be lower where simazine/diuron was applied in combination with diflufenican compared to simazine/diuron applied alone.

Group B herbicides (chlorsulfuron and Intercept)

Chlorsulfuron applied alone (IBS) reduced crop NDVI 22 July by 14% compared to the control. However, at later timings NDVI was unaffected when chlorsulfuron was applied alone. Despite little effect on crop NDVI at later timings, grain yield (0.93 t/ha) was still reduced by 27% with no other herbicides present. This suggests there was significant effect on the crop below the soil surface that was not obvious in above ground canopy growth.

Table 1. Herbicide treatments for the lentil herbicide tolerance weed control trial at Bute 2019.

Herbicide treatment	Treatment code	Group C	Group C Rate (g/ha)	Diflufenican (mL/ha)	Chlorsulfuron (g/ha)	Intercept (mL/ha)
1	Nil	0	0	0	0	0
2	Sim	Simazine900	400	0	0	0
3	Diu	Diuron900	800	0	0	0
4	Ter	Terbyne750	750	0	0	0
5	Met	Metribuzin750	180	0	0	0
6	Si/Di	Sim/Diu	200/400	0	0	0
7	Chl	0	0	0	5	0
8	Int	0	0	0	0	500
9	Si/Di+Chl	Sim/Diu	200/400	0	5	0
10	Si/Di+Int	Sim/Diu	200/400	0	0	500
11	Chl+Int	0	0	0	5	500
12	Si/Di+Ch+Int	Sim/Diu	200/400	0	5	500
13	Dff	0	0	150	0	0
14	Si/Di+Dff	Sim/Diu	200/400	150	0	0
15	Si/Di+Ch+Dff	Sim/Diu	200/400	150	5	0
16	Si/Di+Dff+Int	Sim/Diu	200/400	150	0	500
17	Complete	Sim/Diu	200/400	150	5	500

Note: Not all rates and herbicides used in this trial are registered for use in lentil and the results and findings reported in this article do not constitute a recommendation of their use by the authors.

Table 2. Crop performance, including vigour score 22 July (0=poor vigour 9=high vigour), GreenSeeker NDVI for 22 July, 19 August and 24 September and grain yield (t/ha) for the lentil herbicide tolerance trial at Bute 2019. NDVI values are predicted from a REML spatial analysis conducted using the statistical package R, letters denote statistical differences.

Treatment code	Group C	Group C Rate (g/ha)	Diflufe-nican (mL/ha)	Chlorsul-furon (g/ha)	Intercept (mL/ha)	Pred. Vigour score 22 July	Pred. NDVI 22 July	Pred. NDVI 19 Aug	Pred. NDVI 24 Sept	Grain yield (t/ha)
Nil	0	0	0	0	0	7.1 d	0.304 h	0.563 f	0.670 ef	1.27 ab
Sim	Simazine	400	0	0	0	5.2 abcd	0.230 abcdf	0.410 abc	0.592 cde	1.06 cdef
Diu	Diuron	800	0	0	0	4.4 abc	0.228 abcd	0.433 bcd	0.609 cdef	1.15 bcd
Ter	Terbyne	750	0	0	0	5.2 abcd	0.240 bcde	0.415 bc	0.565 c	0.95 def
Met	Metribuzin	180	0	0	0	5.3 abcd	0.264 efg	0.514 def	0.674 ef	1.26 ab
Si/Di	Sim/Diu	200/400	0	0	0	5.5 bcd	0.241 abcdeg	0.451 cde	0.619 cdef	1.13 bcde
Chl	0	0	0	5	0	6.0 cd	0.262 eg	0.506 def	0.597 cde	0.93 ef
Int	0	0	0	0	500	7.1 d	0.299 h	0.534 f	0.662 def	1.44 a
Si/Di+Chl	Sim/Diu	200/400	0	5	0	5.0 abc	0.235 abcde	0.443 bcde	0.567 c	1.00 cdef
Si/Di+Int	Sim/Diu	200/400	0	0	500	5.1 abc	0.247 cdeg	0.427 bc	0.583 cd	1.28 ab
Chl+Int	0	0	0	5	500	5.5 bcd	0.258 deg	0.438 bcde	0.554 bc	0.65 g
Si/Di+Ch+Int	Sim/Diu	200/400	0	5	500	4.5 abc	0.225 abc	0.363 ab	0.475 ab	0.55 g
Dff	0	0	150	0	0	6.2 cd	0.275 gh	0.524 ef	0.688 f	1.39 a
Si/Di+Dff	Sim/Diu	200/400	150	0	0	4.0 ab	0.217 abc	0.399 abc	0.576 cd	1.16 bc
Si/Di+Ch+Dff	Sim/Diu	200/400	150	5	0	3.6 ab	0.211 ab	0.383 abc	0.562 c	0.92 f
Si/Di+Dff+Int	Sim/Diu	200/400	150	0	500	3.2 a	0.217 abc	0.368 ab	0.543 bc	1.14 bcd
Complete	Sim/Diu	200/400	150	5	500	3.7 ab	0.209 a	0.337 a	0.454 a	0.61 g
LSD (P=0.05)						*REML*	*REML*	*REML*	*REML*	*0.2*
CV										*16.9*
Fpr						*<0.001*	*<0.001*	*<0.001*	*<0.001*	*<0.001*

Intercept applied alone on 9 July did not have any impact on NDVI or grain yield. However, when applied in combination with chlorsulfuron, which did not affect NDVI at these timings either, NDVI was reduced by 23% and 19% on 19 August and 24 September, respectively. Although Intercept applied alone (1.44 t/ha) did not reduce grain yield and chlorsulfuron reduced grain yield by 27%, when these two Group B products were applied in combination, grain yield (0.65 t/ha) was reduced by 49% compared to the control. When the Group B herbicides and simazine/diuron were applied in combination, the grain yield (0.55 t/ha) was not significantly lower than the two Group B products applied together. This is in contrast to previous trials, where damage from Group B and C herbicides combined has increased the crop effect.

NDVI and grain yield relationship

Data from previous trials has shown that there is a strong relationship between crop biomass, measured as NDVI, and grain yield on these sandy soil types. The data from this trial supports this, in that the herbicide treatments that caused significant reductions in NDVI also reduced grain yield. Where this trial differs to previous trials is that the slope of the curve is much steeper than has been observed in most previous trials. This means that the reduction in crop biomass has had a more severe impact on grain yield than in previous trials.

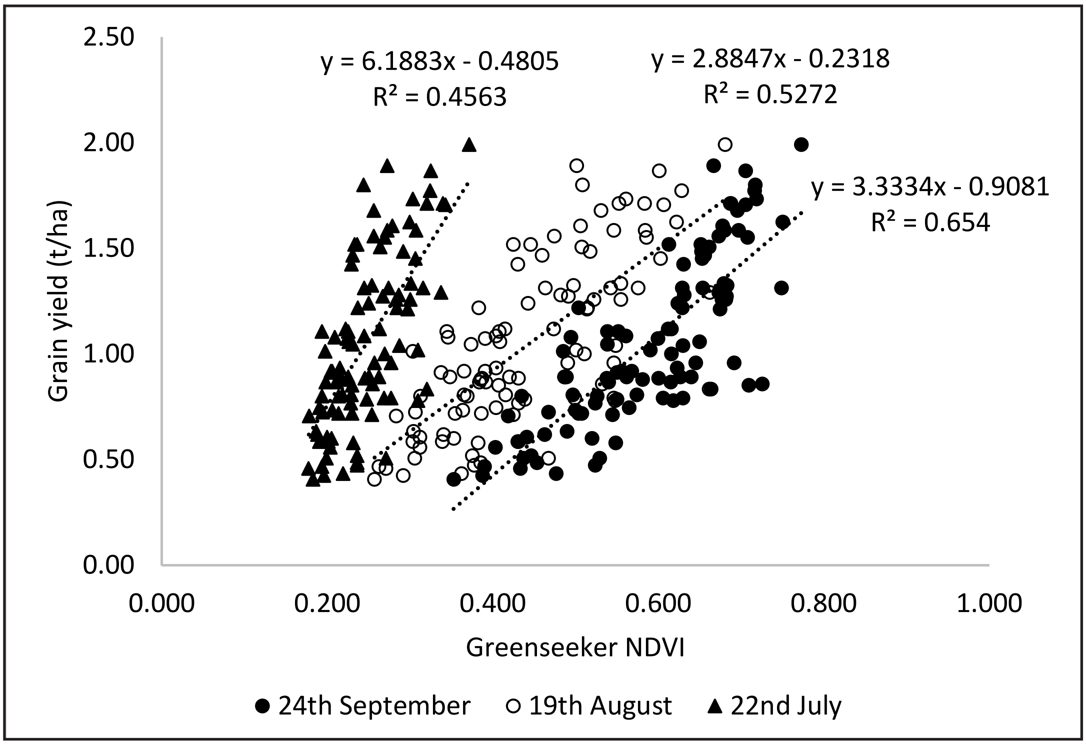

Figure 1. The relationship between plot GreenSeeker NDVI and lentil grain yield (t/ha) for the lentil herbicide tolerance and weed control trial at Bute 2019.

Table 3. Weed efficacy statistics for the lentil herbicide tolerance trial at Bute 2019 including medic populations (5 August), medic score (5 August) (0=no medic remaining, 100=no impact on medic biomass), sow thistle/m^2 (5 August), sow thistle/plot (30 September), mustard/m2 (5 August), mustard/plot (30 September) and wild turnip/plot (30 September).

Treatment code	Medic /m^2	log (1+ Medic /m^2)	Medic Score	Log (1+ Medic Score)	Thistle /m^2	Thistles /plot	Log (1 + Thistles /plot)	Mustard /m^2	Mustard / plot	Log (1 + Mustard /plot)	Turnip /plot	Log (1 + Turnip /plot)
Nil	232.1	5.0	100.0	4.6	4.1	18.0	2.9	2.1	23.0	2.9	1.3	0.7
Sim	86.0	4.1	60.0	4.0	0.4	5.3	1.7	0.5	5.7	1.9	0.3	0.2
Diu	68.9	3.9	41.7	3.6	1.1	6.3	1.8	1.1	5.7	1.7	2.3	1.2
Ter	42.1	2.9	45.0	3.8	1.2	7.0	2.0	0.7	4.0	1.4	0.3	0.2
Met	56.1	3.3	66.7	4.2	1.9	20.3	3.0	0.7	7.3	2.0	2.3	1.0
Si/Di	89.5	4.0	34.0	3.3	1.3	5.0	1.7	0.5	3.7	1.4	0.7	0.4
Chl	44.9	3.3	2.5	1.1	4.7	30.7	3.4	9.9	31.7	3.5	1.0	0.5
Int	82.7	4.2	13.3	2.6	1.5	4.7	1.7	3.5	38.3	3.2	0.3	0.2
Si/Di+Chl	21.5	2.8	2.7	1.0	0.4	6.3	1.9	0.5	6.3	1.7	0.0	0.0
Si/Di+Int	35.2	3.0	2.3	1.0	0.3	3.0	1.1	0.9	8.7	2.3	0.0	0.0
Chl+Int	27.2	3.1	1.2	0.7	2.0	8.0	2.2	4.8	27.7	3.4	0.0	0.0
Si/Di+Ch+Int	30.3	2.5	0.8	0.6	0.3	2.0	1.0	0.5	6.0	1.8	0.0	0.0
Dff	51.2	3.4	65.0	4.1	0.5	0.7	0.5	0.7	0.0	0.0	0.0	0.0
Si/Di+Dff	23.3	2.8	10.5	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Si/Di+Ch+Dff	15.9	2.1	1.3	0.6	0.7	0.0	0.0	0.3	0.0	0.0	0.0	0.0
Si/Di+Dff+Int	18.3	2.3	1.7	1.0	0.5	0.0	0.0	0.1	0.3	0.2	0.0	0.0
Complete	19.7	2.8	1.0	0.6	1.3	0.0	0.0	0.4	0.0	0.0	0.0	0.0
LSD (0.05)		*1.1*	*15.9*	*0.6*	*1.8*	*7.1*	*0.7*	*2.5*	*20.1*	*1.0*	*1.5*	*0.7*
CV		*28.6*	*52.3*	*24.04*	*118.8*	*61.90*	*27.18*	*136.9*	*121.80*	*37.70*	*170.40*	*161.20*
Fpr		*<0.001*	*<0.001*	*<0.001*	*<0.001*	*<0.001*	*<0.001*	*<0.001*	*0.003*	*<0.001*	*0.014*	*0.017*

Weed efficacy

Medic *(Medicago spp.)*

Medic control was evaluated through plant population and a score of biomass. In some treatments medic population did not truly represent the efficacy of the herbicide, as although there may have been high plant numbers, the biomass of the medic had been reduced by over 90%, so the second score was conducted.

Of the Group C herbicides, Terbyne and metribuzin reduced the medic population by 82% and 76% respectively (Table 3) where simazine and diuron, or the mixture, did not significantly reduce the population at this time. Chlorsulfuron applied alone reduced the medic population by 81% and, despite being applied post emergent, the diflufenican was able to produce 78% control. Combining the three herbicide treatments, Si/Di, Dff and Chl produced the greatest level of control at this time.

The medic score better represents the efficacy of the herbicides on medic populations at this site. The Group C herbicide metribuzin and simazine were not effective at reducing medic biomass significantly, but diuron, Terbyne and the simazine and diuron mix reduced the biomass score by 55%, 58% and 66%, respectively. A general observation was that any medic surviving Group C application did not suffer ongoing suppression, where the surviving plants were more or less unaffected by Group C herbicide application in the spring. This is in contrast to the Group B herbicide effects on medic which were long lasting. When the simazine/diuron mixture was applied with diflufenican a 90% reduction in biomass score was achieved where diflufenican alone did not have any significant effect. The Group B herbicide, chlorsulfuron, had the biggest impact on the medic biomass with a 96% reduction. Intercept, applied post emergent did not perform as well as chlorsulfuron when applied individually, but produced a similar level of control to chlorsulfuron when applied in combination with other herbicides such as the simazine and diuron mix.

Common sow thistle *(Sonchus oleraceus)*

Early population counts of sow thistle (5 August) show a population in the untreated plots of 4.3 plants/m^2. All Group C herbicide treatments were able to provide significant early suppression with an average 75% reduction in numbers. Diflufenican produced a greater level of control with 94% control. Of the Group B herbicides, chlorsulfuron did not have any impact on sow thistle population but the application of Intercept on 9 July reduced the population by 61%.

Once the sow thistles commenced stem elongation and were above the crop canopy, a second count (30 September) was conducted where all sow thistles in the plot were counted. From this data, the efficacy of the Group C herbicides simazine, diuron and Terbyne was maintained, with control of the sow thistle population averaging a 65% reduction in population. However, by this time metribuzin was no longer providing any control. The Group F herbicide diflufenican maintained control of sow thistle with a 96% reduction in population, and in combination with simazine and diuron provided 100% control. As in the early assessment, chlorsulfuron applied alone did not provide any control. There was actually a significant increase in sow thistle density in response to chlorsulfuron application; this may have been due to the reduction in lentil biomass and crop competition increasing weed seedling recruitment and making it easier for the sow thistle to grow beyond the lentil canopy. Intercept maintained control with a 74% reduction in thistle sow population.

Indian hedge mustard *(Sisymbrium orientale)*

At the time of the first assessment of mustard (5 August) there was only a low population with the untreated control plots having only 2 plants/m^2 and no significant reduction in population was identified. At the timing of the second assessment (30 September) the Group C herbicides simazine, diuron and Terbyne provided an average of 78% control reducing the population to only 0.3 plants/m^2. Metribuzin appeared to have an impact on the population, but likely due to the low population and variation across the site, this was not found to be significant. Neither of the Group B herbicides provided any control, indicating that the Indian Hedge Mustard population at this site is likely resistant to these Group B herbicides. In contrast, the diflufenican treatments provided 100% control.

Wild Turnip (*Brassica tournefortii*)

Wild turnip had the lowest population of all species. The untreated control only had an average of 1.3 plants/plot. Despite the low population, some treatment differences were still evident. Diflufenican provided virtually 100% control, with only a single wild turnip plant being found in all 15 plots treated with it. Also, any combination of two herbicides was able to provide virtually complete control.

Acknowledgements

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Managing frost and heat in lentil and faba bean

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Location
Minnipa Agricultural Centre, Paddock N9
Rainfall
Av. Annual: 324 mm
Av. GSR: 241 mm
2018 Total: 239 mm
2018 GSR: 176 mm
Yield
Potential: Pulses - 2 t/ha
Actual: 1 to 1.2 t/ha
Paddock history
2017: Wheat
2016: Pasture
2015: Wheat
Soil type
Clay Loam
Soil test
Nitrate 16, ammonium 2, sulphur 9.3 (mg/kg)
Plot size
1 m x 1 m x 3 reps
Trial design
The trial was a factorial split plot design with sowing date allocated to main plots and variety to subplots
Yield limiting factors
Limited rainfall throughout the growing season

Location
Roseworthy
Rainfall
Av. Annual: 400 mm
Av. GSR: 315 mm
2018 Total: 275 mm
2018 GSR: 201 mm
Yield
Potential: Pulses - 5 t/ha
Actual: 1.5 to 2 t/ha
Paddock history
2017: Barley
2016: Canola
2015: Faba bean
Soil type
Sandy clay loam
Soil test
Ammonium 15, nitrate 10 (mg/kg)
Plot size
1 m x 1 m x 3 reps

Key messages

- **Pulses are more vulnerable to yield loss from heat and frost stress in a critical period centred around early podding.**
- **Sowing time and variety choice are crucial to reduce risk of stress at this stage.**
- **We define the safer window for the critical period as less than 10% chance of frost (0°C in the Stevenson screen) and less than 30% chance of heat (>34°C in the Stevenson screen).**
- **In environments of upper Eyre Peninsula, such as Minnipa, there is limited frost risk, hence early sowing will minimise heat risk and maximise potential yield.**
- **However, at sites such as Laura (Mid North), there is a safer window after frost and before heat.**
- **Results should be considered in conjunction with grower specific conditions and the trade-off between early sowing, weed and disease management and rainfall.**

Why do the trial?

Pulses are growing in popularity as a result of good prices and rotational benefits such as decreased N input and enhanced grass weed control options. However frost and combinations of water and heat stress at critical growth stages can compromise crop yield. Previous work in pulses has established that the most important time to maintain growth and limit stress is the period around pod set. Sowing date and variety choice are the two main tools to manipulate time of flowering and pod-set, and thus manage the risk of extreme temperatures, water stress and the trade-off between frost and heat risk.

This research aims to identify the safer temperature windows for the critical period for yield for faba bean and lentil in cropping regions of southern Australia. This work follows on from EPFS Summary 2016 p62, EPFS Summary 2017, p146 and EPFS Summary 2018, p62.

How was it done?

Field trials have been conducted at Minnipa Agricultural Centre (2016-18), Hart (2016), Roseworthy (2017-18), Bool Lagoon (2016-17) and Conmurra (2018) to test the effect of sowing date on phenology and yield of lentil and faba bean varieties. We combined six sowing dates ranging from 20 April to 11 July with ten varieties of each crop chosen in consultation with breeders and industry experts. Faba bean varieties included Icarus, AF03001-1, PBA Rana, PBA Samira, Farah, PBA Zahra, Aquadulce, 91-69, Fiord, and Nura. Lentil varieties were PBA Blitz, Northfield, CIPAL901, CIPAL1301, PBA HurricaneXT, PBA Hallmark XT, PBA Giant, PBA Jumbo2, Nugget, and Matilda.

For each species at each location, three replications were sown for each variety and sowing date. Crops were sown by hand in a split-plot design with sowing dates allocated to the main plot and

Trial design
As above
Yield limiting factors
Limited rainfall throughout the growing season

Location
Conmurra
Rainfall
Av. Annual: 650 mm
Av. GSR: 490 mm
2018 Total: 709 mm
2018 GSR: 570 mm
Yield
Potential: Pulses - 5 t/ha
Actual: 3 t/ha
Paddock history
2017: Faba bean
2016: Cereal
2015: Cereal
Soil type
Black clay loam
Soil test
Ammonium 5, nitrate 35, sulphur 9 (mg/kg)
Plot size
1 m x 1 m x 3 reps
Trial design
As above
Yield limiting factors
Some accidental herbicide damage limited yield

varieties randomized within each subplot. Plot size was 1 m^2 and consisted of 3 rows, 0.27 m apart. Density was 60 plants/m^2 (faba bean) and 120 plants/m^2 (lentil). Prior to sowing, P was supplied by applying 80 kg/ha of MAP (10:22:0:0). During the growing season, we measured phenology twice weekly within the central rows of the plots. We recorded emergence and the date when 50% of plants within the central row show the first appearance of: flowers, pods, end of flowering and maturity.

Phenology data was then used to calibrate and validate APSIM (Figure 1). The model was used with historical weather data to simulate flowering date for early, mid and later flowering varieties across 61 years and nine sowing dates ranging from 1 April to 1 August. We use 200°Cd (degree days) after flowering as the critical period.

What happened?

Lentil data is still being analysed so only the faba bean data is presented. The observed data was matched to the simulated data explaining more than 87% of the variability (Figure 1) providing a reliable tool to predict flowering across varieties, sowing dates, years and environments. In agreement with observations, modelling showed that delayed sowing reduced the length of phenological phases and reduced the spread of the critical period (Figure 2 bottom panels).

The safer window for the critical period ranged from before 9 October in Minnipa, and between 1 September and 27 October in Laura (Figure 2).

Due to the low frost risk at Minnipa, sowing any variety before 15 July hits the safer window. However, at sites such as Laura where spring frosts are a risk, but the onset of heat occurs later in spring, sowing needs to be later than 1 May (or with PBA Samira on 1 May) and can be as late as 30 July.

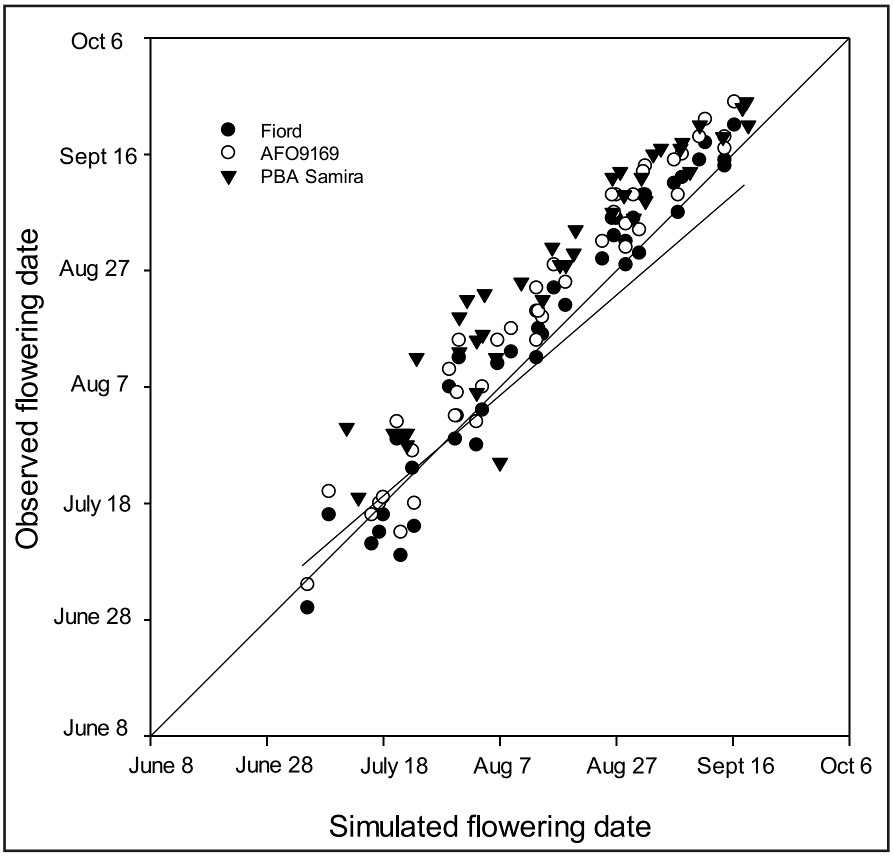

Figure 1. Comparison of observed and simulated flowering date for three faba bean varieties. The solid line is the 1:1 line representing perfect agreement, while the shorter line is a reduced major axis (RMA) regression done with IRENE. R^2 for the individual regressions are: Fiord 0.91, PBA Samira 0.87 and AFO9169 0.95.

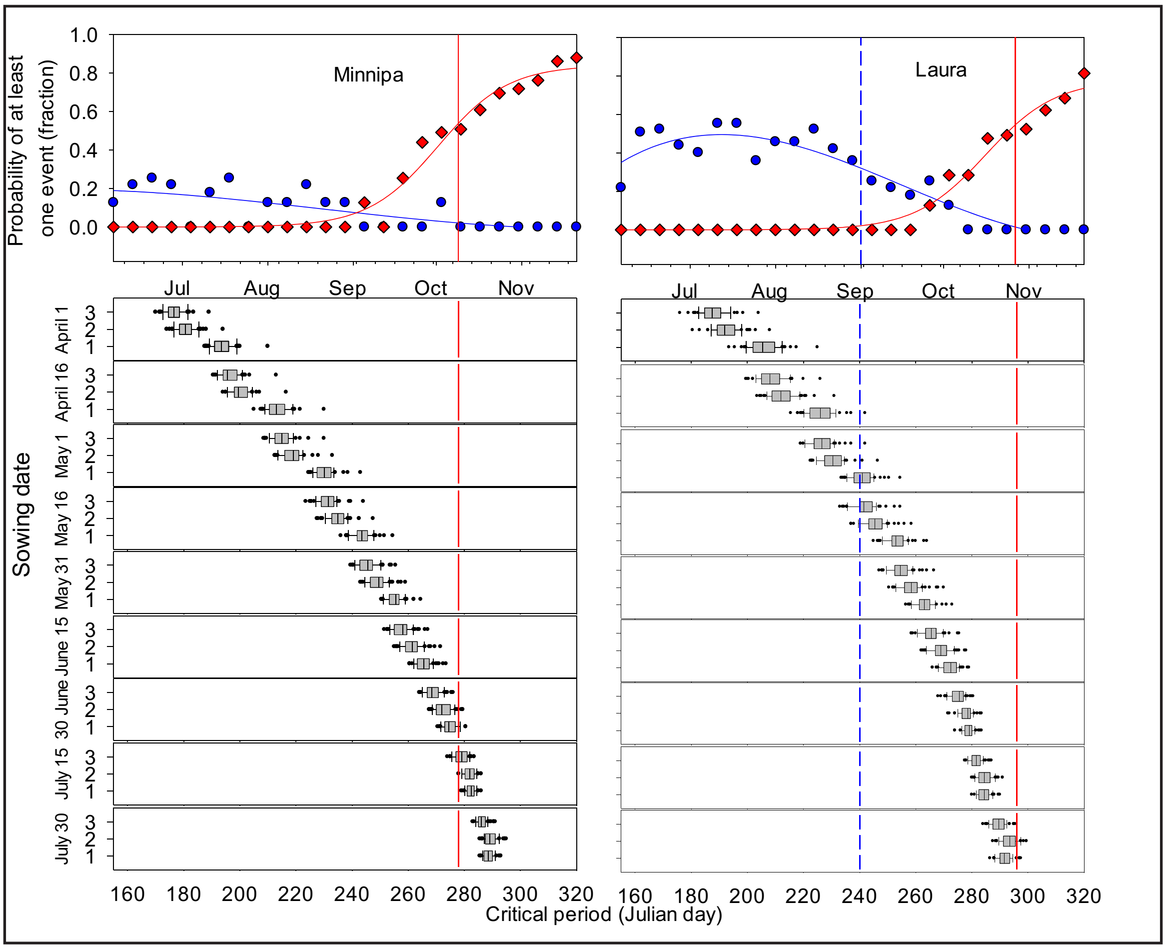

Figure 2. Weekly probability of experiencing at least one frost (circles) or heat event (diamonds) (top panels), and the critical period for three faba bean varieties (bottom panels) with sowing dates ranging from 1 April to 30 July. Varieties are Fiord, PBA Samira and AFO9169. Probabilities have been square root transformed (e.g. take the square root of the probability) in order for the models to best describe the data. For Minnipa the safer window is before the 30% heat risk (solid line), while for Laura the safer window is between the dashed line (10% frost risk) and the solid line (30% heat risk). Note Minnipa does not reach 10% frost risk, hence no dashed line.

What does this mean?

The genetic variability in phenology of both lentil and faba bean coupled with sowing date, can be strategically used by growers to target a specific safer window that reduces likelihood of both frost and heat stress. In the absence of severe frost, sowing before the middle of May will be more likely to provide the maximum yield for drier locations of upper Eyre Peninsula such as Minnipa, whilst allowing some flexibility in the system for other factors such as soil moisture, weed and disease control. In cooler environments delayed sowing is necessary to avoid damage from frost in the critical period. Results for lentil and a wider range of environments for faba bean will be made available later in 2020.

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Narrowing the gap between seeding rate and emergence of canola and lentils

Claire Browne[1] and Glenn McDonald[2]

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Location
Birchip (Barber's)
Rainfall
Av. Annual: 333 mm
Av. GSR: 234 mm
2019 Total: 231 mm
2019 GSR: 197 mm
Yield
Actual: Canola 2.2 t/ha, Lentils 3.2 t/ha
Paddock history
2018: Birchip West: fallow, East Barley
2017: Birchip West: lentils, East lentils
2016: Birchip West: barley, East oats

Key messages

- **The conventional disc seeder yielded the highest in the seeder demonstration.**
- **The precision planter had a higher establishment percentage, but this did not translate into extra grain yield in the seeder demonstration.**
- **Across a variety of seeders, it was found that seeder set up had a greater impact on establishment than seeder age or type, highlighting that seeder set up is crucial to get everything right.**
- **Establishing greater than 45 plants/m^2 in canola or 100 in lentils did not increase yield (small plot trials).**

Why do the trial?

The aim of the first trial was to compare performance of commercially available seeding systems on a large scale at two sowing rates of canola, assessing establishment and subsequent grain yield. The second trial aimed to determine the effect of sowing density, row spacing and seeder type on plant establishment and grain yield in canola and lentils.

A survey of 35 grower paddocks was conducted across the Wimmera and Mallee to assess plant establishment of canola and lentils in 2018. Results found average canola establishment of 61 per cent of target density and 78 per cent in lentils, however individual growers achieved much higher establishment rates. Tough seasonal conditions in autumn 2018 may have contributed to these results, but it highlights the potential of improved plant establishment as an area of focus for growers to reduce unnecessary seed waste. If every seed sown was established, significant seed savings could be made.

Research undertaken in 2018 showed lentils were better at reaching target densities than canola. This suggests it might be more critical to get plant establishment right in canola than lentils. The 2018 trials found canola yields were more responsive to plant densities than lentil yields. There was no consistent impact from seeder type (conventional or precision) on establishment and yield.

There is increasing interest in precision planters for winter crops. They are designed to place single seeds at a consistent spacing along the row at a precise and uniform depth. This results in every seed having an equal area to establish and makes it less likely to compete with its neighbour (Gutsche 2015). When sowing high value seed crops it is important to get high, uniform establishment to minimise seed losses. Given the increased interest in precision planters, it is important to understand which farming systems and sowing conditions they perform well in, as well as their limitations.

Two trials were conducted in 2019 to compare establishment and yield at different plant densities in conventional seeders and precision planters. One trial compared six commercial seeders using canola as the test crop. The second set of trials examined responses to a range of plant densities in canola and lentil in small plots.

How was it done?

Trial 1 Seeder demonstration

The first trial consisted of a comparison of six commercial seeders at Birchip. The six seeders included four conventional air seeders and two precision planters (Table 1). Three of the seeders were tyned and three were disc systems.

The trial was sown into a dry seedbed on 12 April 2019 at two target densities – 109 and 55 plants/m^2, equivalent to 3.5 kg/ha and 1.75 kg/ha – using grower-retained Stingray canola. The Stingray had a germination of 98% and seed size was 318,470 seeds/kg, which is on the smaller side for canola seed.

As a demonstration, one precision planter also sowed canola at 35 plants/m^2 (1.1 kg/ha). Each seeder sowed two runs of 50 m in a randomised complete block design with three replicates. Fertiliser at sowing was MAP (10:22:0:0) at a rate of 40kg/ha. The same seed and fertiliser was used across all seeders (one precision planter used liquid fertiliser with matched nutrition). The depth specified by BCG was 2 cm. Apart from the sowing rates and fertiliser rates no other specifications were given for how to sow the trial. Decisions on seeder set up and speed of sowing were made by each operator. Ideally, each seeder was operated under 'optimal' conditions with decisions about seeder set-up and seeder operation made by each grower. No herbicides were applied before sowing to minimise the risk of any interaction with seeders. The trial was managed during the season along with the surrounding crop.

Assessments included establishment counts five days apart after the first sign of emergence, final establishment counts and interplant spacings. Interplant spacings were measured once the canola had fully established and grain yield was collected with a plot header.

Trial 2 Small plot trials

The second trial involved two replicated field trials sown using a split plot design, with the canola in the fallow paddock and the lentils on adjacent barley stubble (Table 2). Fertiliser was applied IBS due to limitations of the plot seeder. Sowing occurred on 16 May after the site received 38 mm of rain during the first half of the month. Sowing densities were adjusted to account for the canola seed germination of 93% and lentils of 98%.

Assessments included emergence counts five days apart from the first sign of emergence until full establishment was reached. Interplant distances were measured once the canola and lentils had fully established and grain yield was measured using a plot header on 1 November.

Table 1. Seeder information for the six seeders used in the trial.

Seeder	Type	Row spacing (cm)	Fertiliser placement	Seeder age (years)
Flexicoil 820	Tyne	30.5	With seed	22
Horsch 18NT sprinter	Tyne with coulters	25.0	With seed	1
Horwood Bagshaw scaribar	Tyne with coulters	37.5	Below seed	15
Morris RAZR disc	Disc	25.0	Below seed	1
Precision Planter (Spot on Ag)	Disc precision planter	33.3	Liquid only	1
Horsch Maestro	Disc precision planter	25.0	Demo machine (fert was broadcast prior to sowing)	1

Table 2. Sowing rates (target density) for lentils (Hurricane) and canola (Hyola 559 TT), seeder type and row spacings used.

Canola sowing rates target density (plants/m^2)	Lentils sowing rates target density (plants/m^2)	Seeder	Row spacings
15	40	Precision (singulation) disc seeder	22.9 cm (9 inch)
25	60		
35	80		
45	100	Disc seeder, press wheels	30.5 cm (12 inch)
55	120		
65	140		

What happened?

Trial 1 Seeder demonstration

There was an average of 63% canola establishment, with establishment ranging from 41 to 93%. There were significantly different establishments between seeders. The precision planter sowing at 35 plants/m^2 achieved 100 % establishment. This highlights that precision seeders can achieve very high establishment at low plant density.

The precision seeders had a smaller interplant distance (average 6.8 cm) than the conventional seeders (average 8.2 cm). The CV% of the interplant distance indicates the uniformity of the plant stand. Using precision planters resulted in more uniform stands than sowing with conventional air seeders: average CV% for the precision planters was 83% and the CV% for the conventional seeder was 91% (P=0.038).

The measured sowing depth ranged from 1.1 cm to 1.8 cm and did not differ significantly between the precision planters and conventional seeders. Differences in sowing depth were observed between individual seeders e.g. the seeding depth for the Horsch tyne machine was deeper due to it being set up for cereals at the time of sowing.

The conventional disc at low sowing density had the highest yield (Table 3), which was 0.4 t/ha higher than the next seeder, a precision planter. The average yield of the conventional seeders was 0.1 t/ha higher than the precision planters. The disc seeders in the trial yielded 0.2 t/ha more than the tyne seeders (P<0.006).

Yields varied from 2.3 t/ha to 3.0 t/ha. The conventional disc (at both densities) yielded the highest (Table 3). The dry sowing conditions at sowing favoured disc systems, which is why they worked well in these trials. In a commercial setting and wet conditions, sowing logistics may become more challenging with a disc.

Sowing density did not affect grain yield (P=0.818) of 2.50 t/ha at 55 plants/m^2 compared to 2.48 at 109 plants/m^2. This highlights an opportunity to reduce sowing rates without sacrificing yield. The canola sown with the precision planter at 35 plants/m^2 had an establishment of 103% and yielded 2.3 t/ha. Precision planters generally operate better with larger size seed, due to their seed singulation capabilities. Hybrid seeds are often larger than the seed used in this trial and generally are more costly and vigorous. Similar yields can be achieved at lower sowing rates using larger seed.

Table 3. Canola plant establishment (%) and interplant distance (IPD) (cm) and grain yield (t/ha) for the six seeders. Different letters indicate significant difference.

Seeder	Target (plants/m^2)	Plant establishment (plants/m^2)	Establishment (%)	Interplant distance (cm)	Grain yield (t/ha)
Conventional tyne 1	55	40^{bcd}	74	8.8	2.4cd
	109	63^{bc}	58	5.4	2.3d
Conventional disc 1	55	41^{bcd}	75	10.3	3.0a
	109	47^{bcd}	43	5.6	2.9ab
Conventional tyne 2	55	31^{cd}	56	10.2	2.4cd
	109	101^{a}	93	3.6	2.3d
Conventional tyne 3	55	26^{c}	47	14.7	2.4cd
	109	46^{bcd}	42	7.0	2.5cd
Precision planter 1	55	25^{d}	45	10.2	2.5cd
	109	56^{bcd}	51	4.9	2.6bc
Precision planter 2	35	36^{bcd}	103	7.7	2.3d
	55	37^{bcd}	68	8.3	2.3d
	109	67^{b}	61	4.3	2.3d
Seeder (P=0.05) *LSD* *CV*		*<0.001* *15* *18.1*	<0.001 26.3	<0.001 1.3 19.1	<0.001 0.3 6.9%
Conventional		50	60	8.2	2.5
Precision		46	58	6.8	2.4
Seeder type (P=0.05) *LSD* *CV %*		 *ns* *36.6*	 *ns* *36.7*	*0.038* *1.2* *42.5*	*<0.001*

Investing time in seeder set-up for particular crops can optimise establishment. The trial results indicated good establishment can be achieved using conventional equipment. There appears to be no strong relationship between plant establishment and final grain yield. This suggests establishment percentage is not the only factor influencing grain yield - other aspects of the seeders that were not assessed might contribute to yield. The paddock survey carried out in 2018 showed there is room for improvement in establishment.

Trial 2 Small plot trials

Lentils

Average plant establishment in the lentils was higher from the conventional seeder with 120 plants/m^2 compared to the precision seeder's 76 plants/m^2 (Table 4). Wide row spacing had higher plant establishment of 108 plants/m^2 compared to narrow row spacing with 88 plants/m^2 ($P<0.001$). Emergence was quicker with the conventional seeder. At 11 days after sowing, the precision sown had reached 40% of the targeted 120 plants/m^2 and the conventional sown had reached 74% of targeted establishment (Figure 1).

All target sowing densities were achieved in lentils with the conventional seeder. The precision seeder did not quite reach any of the targeted densities (Table 4).

Table 4. Lentil establishment (plants/m^2) (number in brackets is % establishment) and interplant distance (cm) for lentils at six sowing densities with two seeders (conventional, precision) and two row spacings (cm).

Lentil sowing rates (target density)	Establishment (plants/m^2) (number in brackets is % establishment)		Interplant distance (cm)	
	Conventional	**Precision**	**Conventional**	**Precision**
40 plants/m^2	65 (162)	39 (97)	7.5	10.5
60 plants/m^2	76 (126)	55 (91)	5.2	7.6
80 plants/m^2	105 (131)	74 (92)	3.8	6.1
100 plants/m^2	124 (124)	87 (87)	3.3	4.8
120 plants/m^2	174 (145)	118 (98)	3.0	4.5
140 plants/m^2	174 (124)	85 (60)	3.1	5.1
Average	120 (133)	76 (84)	4.3	6.4
Sig. diff. Density	*<0.001*		*<0.001*	
Seeder	*<0.001*		*<0.001*	
Seeder x density	*0.003*		*ns*	
LSD (P=0.05) Density	*18*		*0.6*	
Seeder	*10*		*0.3*	
Seeder x density	*25*		*0.9*	
CV%	*10.4*		*1.27*	

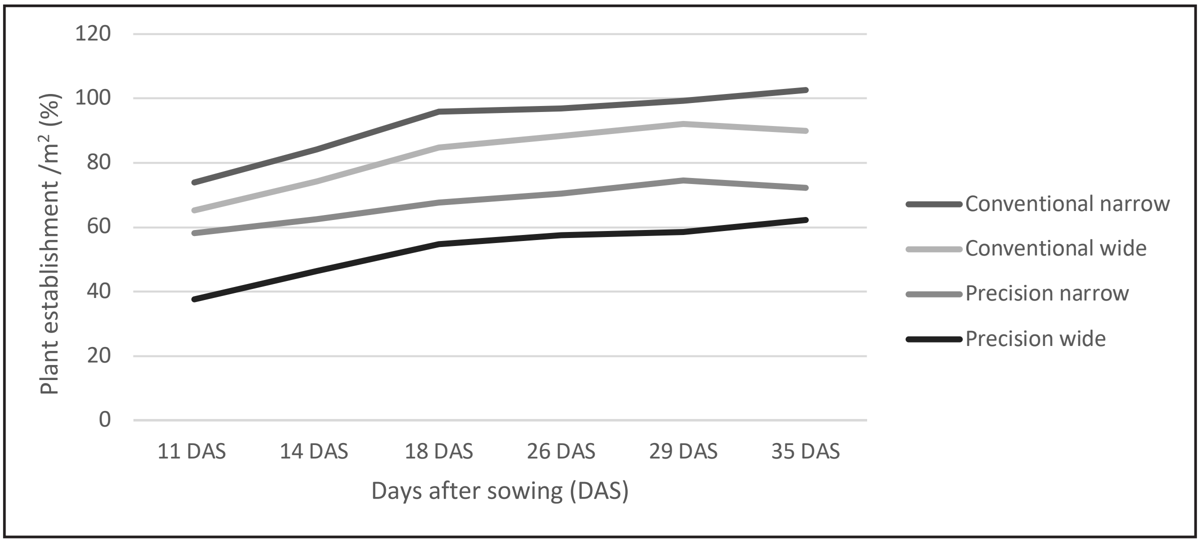

Figure 1. Lentil establishment (%) at days after sowing (DAS) for the 120 plants/m^2 treatment.

Lentil yield was affected by establishment density: the target densities of 100, 120 and 140 plants/m^2 all had the same grain yield, which was higher than the 40, 60 and 80 plants/m^2 (Figure 2). The response to plant density was the same in the precision and conventional seeders. This shows no yield advantage to sowing lentils higher than the targeted 100 plants/m^2. The conventional seeder yielded 3.4 t/ha, which was 0.2 t/ha higher than the precision seeder.

Canola

Establishment numbers varied depending on canola sowing rate. The sowing densities of 55 and 65 plants/m^2 both recorded the same establishment numbers (Table 5). A greater number of plants was established under the wider row spacing (40 plants/m^2) than the narrow row spacing (32 plants/m^2).

Canola had greater establishment under the conventional seeder (39 plants/m^2) than the precision seeder (33 plants/m^2). The canola sowing rates were based on a germination of 93% and assumed field establishment of 100%. The sample size means canola in some cases had a germination percentage of greater than 100. Likewise, sowing into a moist seedbed may have contributed to higher establishment which is consistent with results from the 2018 paddock survey.

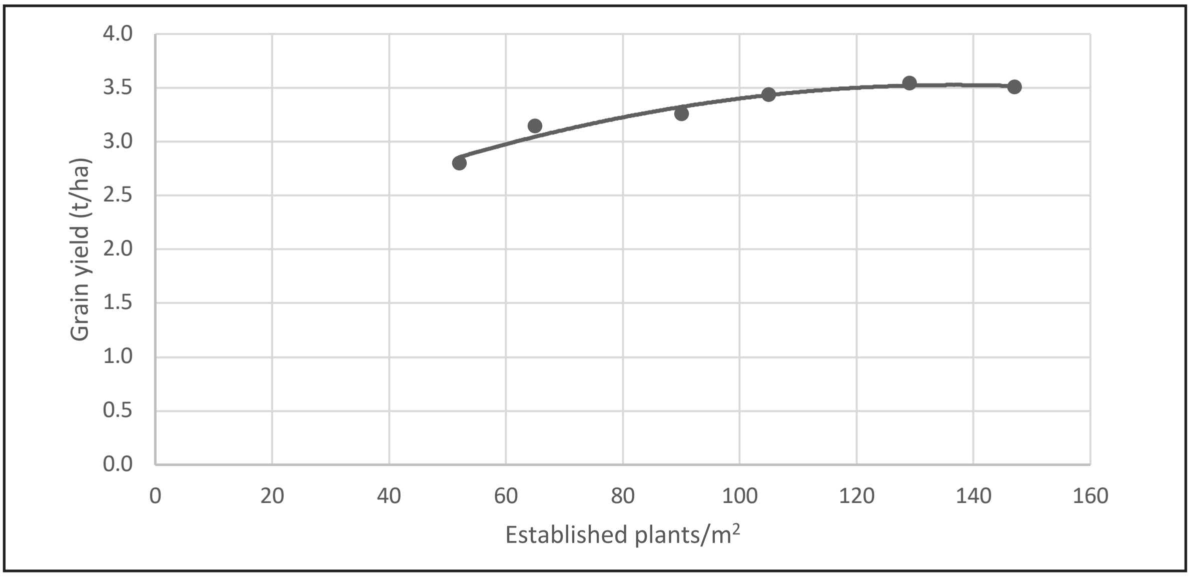

Figure 2. Grain yield response (t/ha) to number of plants established (plants/m^2) averaged over both seeders and row spacings in lentils. Density (P<0.01, LSD=0.2 t/ha).

Table 5. Canola establishment (plants/m^2) at six sowing densities and two seeder types and two row spacings (cm), letters indicate significant difference.

Canola sowing rates (target density)	**Conventional (plants/m^2)**		**Avg Establishment (%)**	**Precision (plants/m^2) (%)**		**Avg Establishment (%)**
	Narrow	**Wide**		**Narrow**	**Wide**	
15 plants/m^2	21^{hijk}	20^{hijk}	136	1^{0k}	14^{jk}	79
25 plants/m^2	30^{fgh}	26^{ghi}	112	16^{ijk}	25^{ghij}	84
35 plants/m^2	30^{fgh}	42^{cde}	103	24^{ghij}	34^{defg}	83
45 plants/m^2	41^{cdef}	50^{bc}	101	33^{efg}	45^{bcd}	87
55 plants/m^2	*39^{cdef}*	*66^{a}*	*95*	*44^{cde}*	*43^{cde}*	*79*
65 plants/m^2	*48^{bc}*	*56^{ab}*	*80*	*42^{cde}*	*62^{a}*	*80*
Sig. diff. Density	*<0.001*					
Row spacing	*<0.001*					
Seeder	*0.002*					
Seeder x density x row spacing	*0.017*					
LSD (P=0.05) Density	*6.0*					
Row spacing	*3.4*					
Seeder	*3.4*					
Seeder x density x row spacing	*11.7*					
CV%	*23.7*					

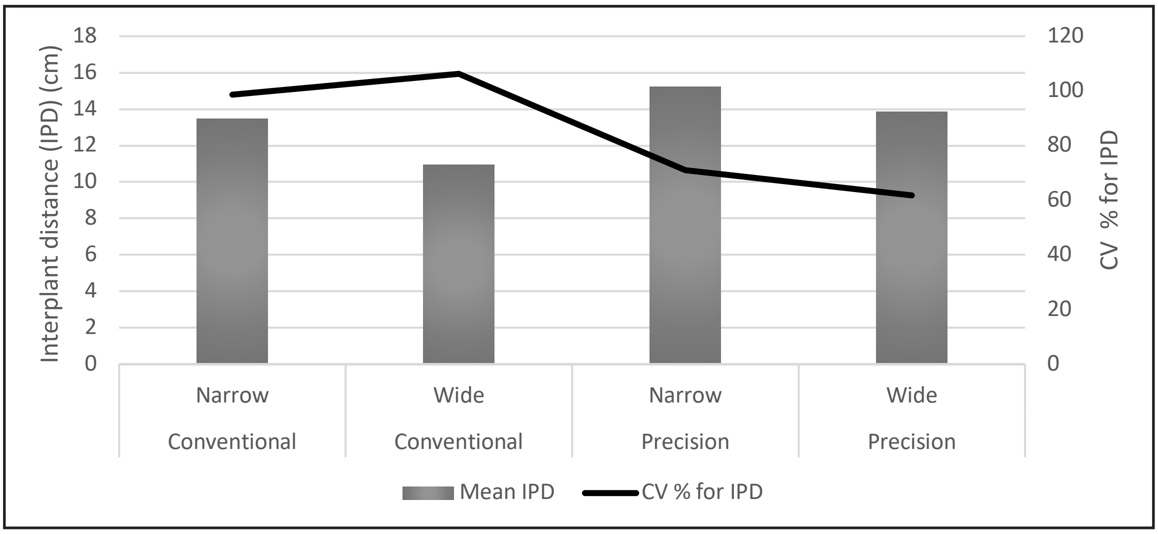

Figure 3. Mean interplant distance (cm) and CV (variation) % for the interplant distance.

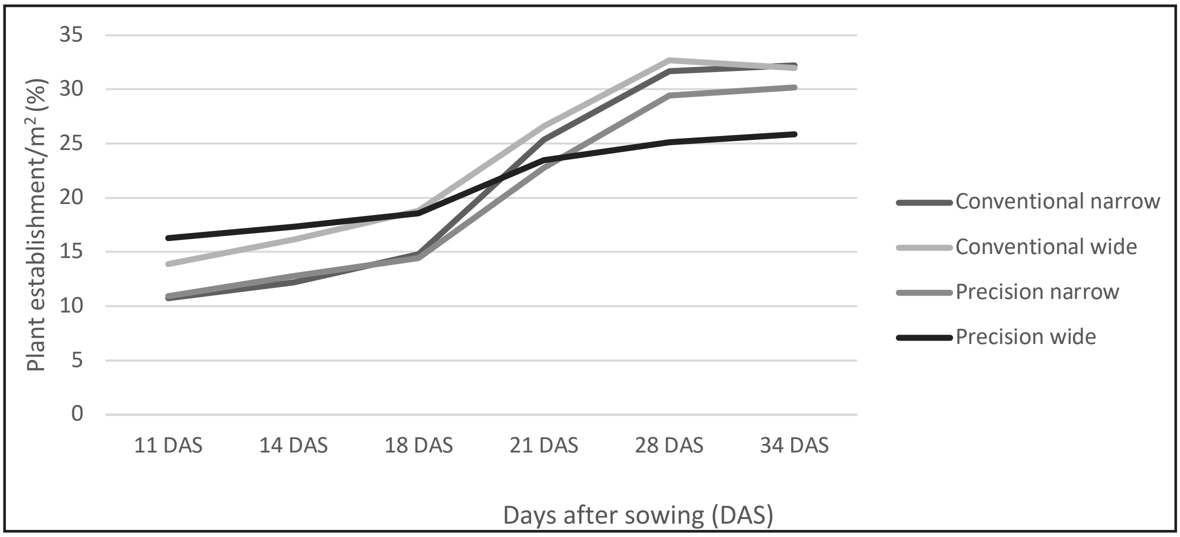

Figure 4. Canola establishment (%) at days after sowing (DAS) for the 35 plants/m² treatment.

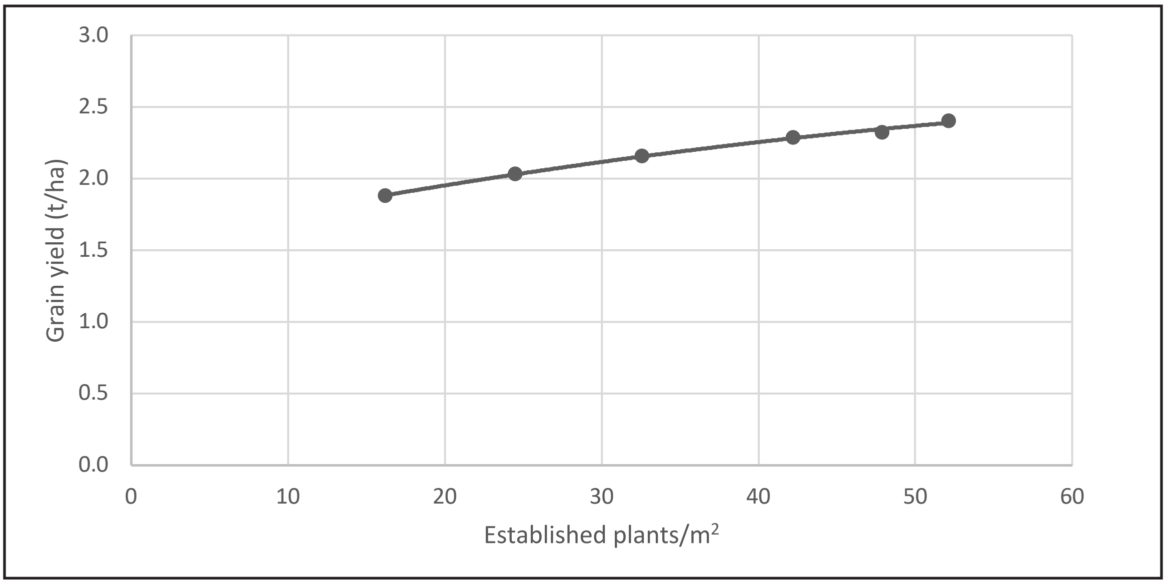

Figure 5. Grain yield response (t/ha) to number of plants established (plants/m²) averaged over both seeders and row spacings in canola. Density: yield P<0.001, LSD 0.16 t/ha.

Table 6. Partial gross margin for various sowing densities (ignoring capital cost of the seeder). Lentil seed $0.67/kg based on grain price of $670/t (7 January 2020), canola seed price $25/kg and grain price $590/t Birchip, letters indicate significant difference.

Targeted sowing density (plants/m^2)	Seed cost ($/ha)	Grain yield (t/ha)	Income ($/ha)
Lentils			
80	21	3.2bc	2123
100	26	3.4ab	2252
120	31	3.5a	2314
140	37	3.5a	2308
Canola			
25	45	2.0cd	1135
35	65	2.2bc	1233
45	82.5	2.3ab	1275
55	102.5	2.3a	1255

The conventional seeder had an average interplant distance (IPD) of 12 cm, and the precision seeder had an average interplant distance of 15 cm (Figure 3, see bars). The variation in these distances was 106% in the conventional wide seeder and 61% (Figure 3, see line) in the precision wide seeder. While the conventional seeder had a smaller average interplant distance, it also had more variation within the data set, highlighting that they were not as evenly spaced.

The canola reached an average establishment of 13 plants/m^2 11 days after sowing (DAS). The conventional seeder established faster than the precision planter. At 34 DAS, the conventional seeder, narrow and wide spacings, had 32 plants/m^2 established and the precision seeder wide row spacing had 26 plants/m^2 (Figure 4).

Grain yield

Canola yield was not different when comparing seeder type, however it differed between the various sowing densities and row spacings ($P<0.001$). Narrow row spacing (2.3 t/ha) yielded 0.2 t/ha more than the wider row spacing (2.1 t/ha), despite wide spacings having higher plant establishment. Canola grain yield was the same for the targeted 45, 55 and 65 plants/m^2 treatments (Figure 5). The targeted densities of 35 and 45 plants/m^2 did not differ in grain yield.

What does this mean?

This project aims to narrow the gap between what is put into the ground and what comes out of the ground. The commercial scale seeder demonstration averaged 58% establishment from conventional seeders and 77% from precision seeders. This shows there is room for improvement in both systems in a low rainfall environment. Establishment was better in the small plot trial that was sown into a moist seedbed, however canola yields were lower than in the seeder demonstration.

In the 2018 small plot trials all canola sowing densities failed to reach full establishment – the highest was just 40% of target. This can be attributed to a dry start and less than optimal field conditions. Conditions in 2019 were more favourable. The lowest observed establishment of 79% of targeted density highlights the importance of good soil moisture at sowing.

When calculating seeding rates, it is important to consider both seed size and expected germination percentage. In the case of the seeder demonstration, seed size was small. Choosing a sowing rate from a previous year's kg/ha target can result in much higher or lower plant numbers than expected from variation in seed size. Calculating the number of seeds for a given weight is essential. Seed quality/germination tests also should be considered so allowances can be made for seed that will not emerge, even under optimal field conditions. When calculating seeding rate, expected field establishment needs to be based on soil moisture and previous experience.

Matching sowing rate to season potential is an important step to optimising yield. The two sowing rates of canola in the seeder demonstration ultimately yielded the same, based on their actual establishment of 33 and 63 plants/m^2. This was contrary to the small plot trials where yield differed across sowing densities. This suggests that if at least 45 plants/m^2 canola is achieved, the crop can compensate for lower plant numbers in yield. However, it might be seasonally dependent as research in 2018, a much drier season, showed canola had a strong yield response to increasing sowing densities. The slightly poorer vigour of the later sown crops might have stopped it from compensating for the lower density as much as the earlier sown crops. Earlier sowing, and the capture of early rain, in the seeder demonstration would have contributed to plants being more vigorous than the small plot trials.

The response of lentils to sowing density showed no yield benefit from sowing at a density higher than 100 plants/m^2 this season. However, visual assessment suggested higher sowing densities may contribute to erectness of the crop which could increase harvestability. In 2018 conditions, there was no yield increase seen in lentils above a planting density of 60 plants/m^2.

In small plot trials a comparison of precision and conventional seeding systems influenced grain yield in 2019, which differs from the results in the dry season of 2018. It was found that the interplant distance with a precision planter was less variable than that sown with a conventional seeder. This may be due to the singulation system in a precision seeder which gives more evenly spaced seeds less competition and greater access to moisture and nutrients. The performance of precision planters in the low rainfall zone is still being tested in winter crops.

Soil moisture is a major driver of seed germination and seedling growth, so establishment of canola and lentils can vary in different seasons. The findings from this year's research are somewhat different to those from last season. As a result, more research is required before decisions are made about significant investments in machinery. Both seasons have highlighted there is room for improvement in the establishment of canola and lentils in the Mallee.

Investment in machinery is a significant capital cost for a farm business. When considering purchasing a new seeder it is important to choose what is best suited to your system based on factors such as row spacing, rotation, stubble load and trash handling ability. The seeder demonstration showed no financial benefit from having one seeding system over another, among those trialled. It also indicated no impact from seeder system or age, instead highlighting the importance of seeder set-up and operation for crop type and conditions.

Higher sowing density of high value crops can increase initial seed costs. Lentil partial gross margin - based on seed cost and grain yield - delivered income of $2312/ha when sown at a density of 120 plants/m^2 (Table 6). But yield at this sowing density was not higher than the sowing rate of 100 plants/m^2. Canola at 45 plants/m^2 had the highest partial income of $1275/ha. There was no increase in yield or income from higher sowing rates. This emphasises the importance of taking into account the cost of seed when increasing sowing rates, especially if it's unlikely to boost grain yield or income.

Acknowledgements

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Sustaining Group J and K herbicides in high break crop intensity rotations

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Location
Maitland
Rainfall
Av. Annual: 506 mm
Av. GSR: 247 mm
2018 Total: 416 mm
2018 GSR: 246 mm
Soil type
Clay
Soil test
pH 6.8
Nutrients on 0-10 cm soil layer (mg/kg): Ammonium N 2, Nitrate N 23, P Colwell 55, K Colwell 541
Plot size
10 m x 1.35 m
Trial design
Randomised complete block design

Key messages

- **Resistance in ryegrass to pre-emergence herbicides such as Boxer Gold® and Sakura® has been confirmed in high break crop intensity (HBCI) systems.**
- **These herbicides need to be rotated with other mode of action herbicides, especially with Group D propyzamide in the break crop phase.**
- **Adoption of practises to stop ryegrass seed set during the crop season, and/or collecting seed with harvest weed seed control (HWSC) systems, are potential options to delay the spread of herbicide resistance.**

Why do the trial?

The availability of improved herbicide tolerant break crop options - such as triazine tolerant (TT) canola, Group B imidazolinone (IMI) tolerant (Clearfield®) canola, PBA Hurricane XT lentil, and now PBA Bendoc faba bean - along with relatively higher pulse prices, improved agronomic and disease characteristics, and harvest efficiency, have resulted in an expansion of the area sown to pulses and canola in South Australia (SA). Heavy reliance on Group A - particular the dim chemistry in break crops - has contributed to increased ryegrass resistance to these herbicides, making its control challenging. Consequently, herbicides with different modes of action (Groups D, J and K) are being used to manage Group A dim-resistant ryegrass in high break crop intensity (HBCI) rotations (rotations having at least two break crops in the last 5 to 6 years). The research studies were carried out to investigate the implications of intensive use of Group J and K herbicides on resistance of ryegrass, and its control, in HBCI rotations in SA.

How was it done?

Ryegrass resistance in high break crop intensity paddocks

A total of 36 focus paddocks with HBCI rotations were selected across the Mid North, Yorke Peninsula, lower Eyre Peninsula, upper Eyre Peninsula, South East and SA Mallee regions. The selected paddocks had either IMI tolerant break crops (PBA Hurricane XT lentil or Clearfield® canola) or non-IMI break crops (conventional lentil, conventional canola/TT canola, field pea, chickpea, faba bean, lupin) grown at least twice in the last 5 to 6 years. Ryegrass seeds were collected prior to harvest in 2017. These were screened for resistance in outdoor pot trials conducted between autumn and spring 2018.

Research trial

A research trial was established at Maitland (Yorke Peninsula) in 2018 that included new pre-emergent herbicide Ultro® (active carbetamide, Group E), currently in development, applied as incorporated by sowing (IBS). Ultro 1700 IBS + clethodim post-emergence (POST) (500 g/ha) was compared to grower practices of Boxer Gold® IBS (2500 g/ha) + clethodim POST (500 g/ha), Sakura® IBS (118 g/ha) + clethodim POST (500 g/ha) and propyzamide IBS (1000 g/ha) + clethodim POST (500 g/ha), for controlling ryegrass in lentil. The experiment was sown on 22 June, 2018. The assessments on ryegrass seed set were just near the crop harvest. The statistical analysis was done with ANOVA through GENSTAT version 20.

What happened?

Herbicide resistance screening

Herbicide resistance screening recorded clethodim (Group A dim) resistant ryegrass in 46% of samples and developing clethodim resistance in a further 21% of samples tested (Figure 1). Such resistance limits the effectiveness of break crops as rotational tools. Resistance development to Group J and K herbicides, Boxer Gold® and Sakura®, was confirmed in ryegrass (Figures 2 and 3) and is of further concern for HBCI rotations. One quarter of the ryegrass populations exhibited resistance to Boxer Gold® (≥20% survivors). Half of the ryegrass biotypes resistant to Boxer Gold® originated from HBCI paddocks on lower Eyre Peninsula where canola is the dominant break crop grown. Biotypes with ≥ 20% survival to Sakura® were not detected, although 1-20% survival in pot trials (developing resistance) was confirmed in one third of ryegrass populations (Figure 2), again predominately from the lower Eyre Peninsula.

Ryegrass resistance levels to Group J and K herbicides observed in this survey were compared to herbicides used in the paddocks in the last five years. The paddock with the highest levels of resistance to Group J and K herbicides had both Boxer Gold and Sakura used twice in the last five years. Further, the second-ranked paddock for resistance had Boxer Gold® used three times, and Sakura® once, in the last five years. These results suggest the judicious use of Group J and K chemistries is required in HBCI rotations, particularly in the break crop phase and the integration of alternative options such as Group D propyzamide should be considered. As a rule of thumb, herbicides from the same mode of action should not be used for two consecutive years on the same land. Also, care must be taken to ensure survivors are not able to set seed, by adopting tactics such as shrouded inter-row spraying, crop topping and wick wiping where possible. In addition to these, harvest weed seed collection measures such as narrow windrow burning, chaff carts, Harrington seed destructor, chaff tramlining and baling need to be explored to reduce ryegrass seed entering the soil seedbank (Walsh *et al*, 2017).

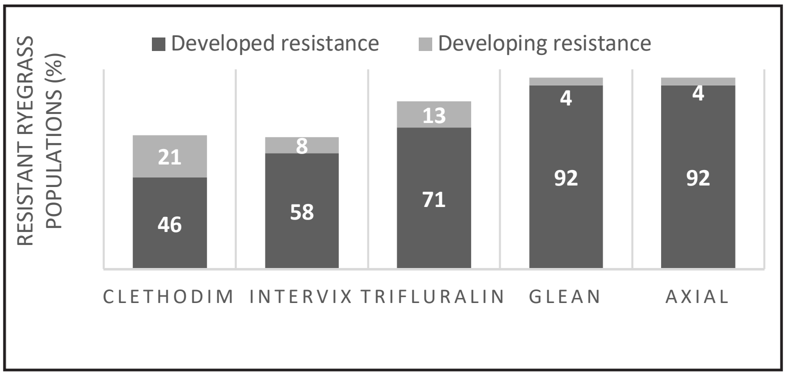

Figure 1. Developed resistance (where ≥ 20% survival was confirmed in pot tests) and developing resistance (where 1-20% survival was confirmed in pot tests) to Group A, B and D herbicides.

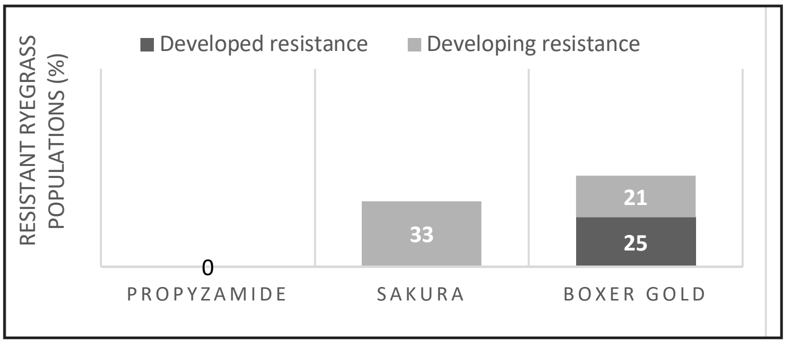

Figure 2. Developed resistance (where ≥ 20% survival was confirmed in pot tests) and developing resistance (where 1-20% survival was confirmed in pot tests) to Group D, J and K herbicides.

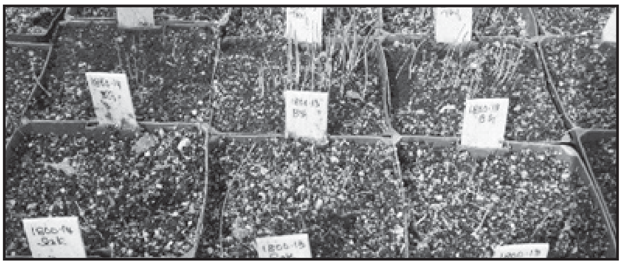

Figure 3. Boxer Gold resistant ryegrass

Figure 4. Sakura resistant ryegrass

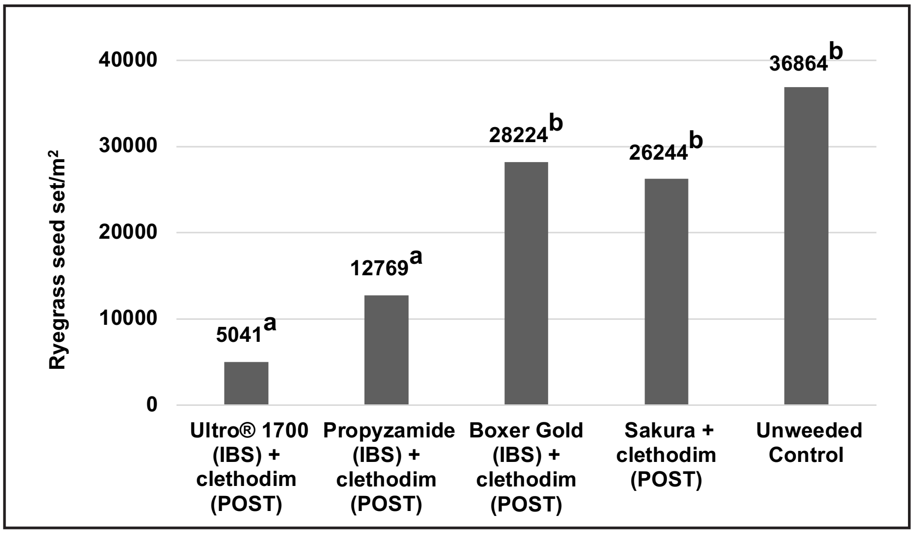

Figure 5. Ryegrass seed set in lentil at Maitland in 2018. Bars labelled with the same letter are not significantly different (P≤0.05).

Research trial results

Boxer Gold and Sakura did not provide statistically different levels of ryegrass set control compared to the untreated control at Maitland in 2018 (Figure 5). In the herbicide resistance screening work discussed earlier, this trial site paddock was found to have ryegrass populations resistant to Group J and K herbicides, and paddock history revealed that both Boxer Gold and Sakura were used twice in this paddock during the last five years. This highlights the magnitude of impact that can result from loss of effectiveness of Group J and K herbicides due to regular use in a relatively short period of time. Developing resistance to these herbicides is a concern for both cereal and break crop phases.

Further, in this experiment, Ultro resulted in the lowest ryegrass seed set in lentil, and was statistically similar to the level of control achieved with propyzamide. Ultro was safe for the lentil crop at the tested rate of 1700 g/ha and recorded the highest yield of 1.64 t/ha amongst different herbicide treatments (data not shown). Registration of this herbicide could reduce selection pressure on Group A, D, J and K herbicides in break crops.

What does this mean?

Resistance development in ryegrass to pre-emergence Group J and K herbicides such as Boxer Gold® and Sakura® has been confirmed in HBCI systems. Diverse integrated weed management strategies including rotating modes of action with Group D propyzamide in break crop phase in HBCI systems, adopting proven strategies for stopping ryegrass seed set such as crop topping, and collecting remaining seed through harvest weed seed collection measures, are important to delay resistance build-up to these herbicides.

Acknowledgements

The research undertaken as part of this project is made possible by the significant contributions of growers through trial cooperation, and strategic investment of GRDC and SARDI in project DAS00168BA.

Reference

Walsh M., Ouzman J., Newman P., Powles S. and Llewellyn R. (2017). High levels of adoption indicate that harvest weed seed control is now an established weed control practice in Australian cropping. Weed Technology 31: 341-347.

Section 4

Cereals

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New wheat varieties in 2019

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Wheat NVT

The 2020 South Australia Crop Sowing Guide (https://grdc.com.au/2020-south-australian-crop-sowing-guide) has the current information on all varieties including the 2019 recent releases including Vixen, and the Clearfield varieties Sheriff CL Plus and Razor CL Plus. In 2019 there have also been several new slightly slower developing milling wheat varieties, Catapult and RockStar, released. Only the 2019 released variety descriptions are listed in this article compiled from the 2020 South Australia Crop Sowing Guide.

Catapult was released in 2019 by AGT as a variety for late April/early May sowing. Catapult offers wide adaptation and has a slightly slower development pattern suited for earlier planting opportunities in late April to early May. Yield evaluation of Catapult from earlier sowing is limited in SA and more evaluation is required. Initial data suggests Catapult produces grain with high test weights and low screenings and is suitable for wheat on wheat situations, having good Yellow leaf spot resistance. Seed available from AGT Affiliates, retailers or through Seed Sharing™. (EPR $3.25/t GST ex).

Razor CL Plus is an imidazolinone herbicide tolerant (Clearfield® Plus) ASW wheat released by AGT. Razor CL Plus is an early developing variety, slightly quicker than Mace. The long-term performance of Razor CL Plus suggests it is the highest yielding Clearfield® variety and on average is 3% higher than Mace. Razor CL Plus is rated SVS for Septoria tritici blotch, S to Leaf rust, and MS to Stripe rust but MR to CCN. Seed is available from AGT affiliates. (EPR $3.30/t GST ex).

RockStar has been released in 2019 by InterGrain. RockStar offers wide adaptation but has a slightly slower development pattern suited for earlier planting opportunities in late April to early May. Yield performance from May to June sowing dates in 2018 suggests that RockStar yields similarly or slightly less than Scepter. Yield evaluation of RockStar from earlier sowing is limited in SA and more evaluation is required. RockStar is rated MRMS to Stripe rust and Yellow leaf spot, S to Powdery mildew and Leaf rust, and MSS to Septoria. RockStar is available for planting in 2020 from local resellers and Seedclub members. (EPR $3.50/t GST ex).

Sheriff CL Plus is an imidazolinone herbicide tolerant (Clearfield® Plus) APW wheat released by InterGrain in 2018. Sheriff CL Plus is a mid to late-flowering variety, is similar to LongReach Trojan in developmental speed and can be sown slightly earlier than the other Clearfield® Plus wheat varieties. The long-term NVT performance of Sheriff CL Plus suggests it yields similarly to Mace and has stable yields across most regions. Sheriff CL Plus is rated SVS to Leaf rust and Powdery mildew, MSS to stem and Stripe rust, S to Septoria tritici blotch, MRMS to Yellow leaf spot, and MS to CCN. Seed is available for planting in 2020 from local resellers or InterGrain Seedclub members. (EPR $4.25/t GST ex).

Vixen is an early flowering variety that develops slightly quicker than Scepter. Vixen was released by InterGrain in 2018 and has an AH Classification in SA. Long-term data suggests performance is similar to Scepter, but it performed slightly above Scepter in 2016 evaluation. The variety's development speed is suited to mid-May to later sowings. Vixen is rated SVS to Leaf rust and Powdery mildew, MRMS to stem and Stripe rust, S to Septoria tritici blotch, MRMS to Yellow leaf spot, and S to CCN. Vixen seed is approved for grower to grower trading and seed is available through local resellers or InterGrain Seedclub members. (EPR $3.50/t GST ex).

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Eyre Peninsula 2019 NVT wheat trial yields in t/ha and expressed as percentage of site mean

Region	**Lower EP**						**Upper EP**									
Nearest Town	**Cummins**		**Kimba**		**Minnipa**		**Mitchellville**		**Nunjikompita**		**Penong**		**Streaky Bay**		**Warramboo**	
Variety Name	**t/ha**	**%**	**t/ha**	**%**	**t/ha**	**%**	**t/ha**	**%**	**t/ha**	**%**	**t/ha**	**%**	**t/ha**	**%**	**t/ha**	**%**
Beckom	6.35	107	0.32	98	2.06	119	1.14	106	1.13	103	0.39	89	2.37	103	2.07	111
Catapult	5.54	93	0.32	99	1.74	101	0.97	90	1.07	98	0.41	94	2.26	99	2.01	108
Chief CL Plus	5.52	93	0.26	79	1.47	85	0.77	71	1.06	97	0.34	77	2.10	92	1.47	79
Cobalt	4.56	77	0.36	112	1.41	81	1.04	96	1.10	101	0.54	123	2.40	105	1.75	94
Corack	6.06	102	0.29	90	1.33	77	1.18	110	1.03	94	0.36	82	2.14	93	1.58	85
Cosmick	5.67	95	0.40	123	1.81	104	1.27	118	1.19	109	0.50	114	2.31	101	1.99	107
Cutlass	5.13	86	0.21	65	1.50	87	0.75	69	0.99	90	0.47	108	2.11	92	1.72	93
Devil	5.66	95	0.39	120	1.65	95	1.18	109	1.15	105	0.44	99	2.56	112	1.92	103
DS Darwin	5.25	88	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DS Pascal	5.70	96	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Emu Rock	5.86	98	0.45	138	1.91	110	1.59	147	1.11	101	0.50	114	2.42	105	1.94	104
Grenade CL Plus	5.74	96	0.32	99	1.74	101	1.09	102	1.06	97	0.44	100	1.99	87	2.00	108
Kord CL Plus	4.99	84	0.27	84	1.42	82	1.04	97	0.95	87	0.40	91	2.08	91	1.63	87
LRPB Arrow	6.69	112	0.31	96	1.78	103	0.89	83	1.14	104	0.38	87	2.27	99	1.74	93
LRPB Cobra	6.64	112	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LRPB Havoc	6.86	115	0.24	75	1.66	96	1.17	108	0.99	90	0.31	71	2.28	100	1.79	96
LRPB Scout	6.00	101	0.35	108	2.16	125	1.06	99	1.15	105	0.48	109	2.35	103	2.23	120
LRPB Trojan	6.29	106	0.25	76	1.57	91	0.97	90	1.02	93	0.46	104	2.22	97	1.63	87
Mace	5.54	93	0.30	93	1.68	97	1.06	98	1.15	105	0.36	83	2.28	99	1.80	97
Razor CL Plus	6.22	105	0.37	114	1.81	105	0.96	89	1.17	107	0.43	98	2.41	105	2.02	109
RockStar	6.61	111	0.39	121	2.03	117	0.81	75	1.19	109	0.48	110	2.47	108	2.17	117
Scepter	5.54	93	0.32	98	1.70	98	1.18	110	1.17	107	0.43	99	2.48	108	1.78	95
Sheriff CL Plus	6.36	107	0.30	93	1.85	107	0.87	81	1.09	100	0.45	101	2.36	103	1.98	106
Shield	6.17	104	0.44	136	1.82	105	1.02	95	1.08	98	0.50	113	2.30	100	1.98	106
Vixen	7.35	123	0.43	134	1.94	112	1.68	156	1.17	107	0.49	112	2.60	113	2.44	131
Wallup	5.52	93	0.25	76	1.40	81	1.21	112	1.02	94	0.31	70	1.89	82	1.65	89
Wyalkatchem	6.58	111	0.29	91	1.84	107	0.78	72	1.12	102	0.40	91	2.18	95	1.80	97
Yitpi	4.30	72	0.26	81	1.79	104	1.02	94	0.88	81	0.52	119	2.20	96	1.68	90
Zen	5.80	97	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Site Mean (t/ha)	5.95		0.32		1.73		1.08		1.09		0.44		2.29		1.86	
CV (%)	3.58		6.43		5.08		8.01		3.68		5.89		4.50		6.51	
Probability	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001	
LSD (t/ha)	*0.35*		*0.04*		*0.15*		*0.15*		*0.07*		*0.04*		*0.17*		*0.21*	
Sowing Date	16/05/2019		02/05/2019		08/05/2019		08/05/2019		14/05/2019		03/05/2019		07/05/2019		07/05/2019	
Trial Comments	Interpret results with caution, some shattering, esp in Cobalt, Kord CLPLUS and Yitpi		Uniform but severely droughted trial. Interpret results with caution				Trial highly droughted, interpret results with caution				Trial was highly droughted with mean yield 0.44 t/ha. Interpret results with caution					

Source: www.nvtonline.com.au

Eyre Peninsula 2019 NVT barley trial yields in t/ha and expressed as a percentage of site mean

Variety Name	**Wharminda**		**Darke Peak**		**Elliston**		**Minnipa**		**Streaky Bay**	
	t/ha	**%**	**t/ha**	**%**	**t/ha**	**%**	**t/ha**	**%**	**t/ha**	**%**
Alestar	0.84	71	1.01	66	3.03	82	1.52	76	2.58	86
Banks	1.21	102	1.38	91	3.69	100	2.18	109	3.09	104
Bass	1.25	106	1.61	106	3.54	96	1.90	95	2.79	94
Buff	1.58	133	1.69	111	3.70	101	1.89	94	3.00	101
Commander	0.80	68	1.55	102	3.45	94	1.66	83	2.95	99
Compass	1.71	144	1.89	124	4.13	112	2.27	113	3.21	108
Fathom	1.59	134	1.95	127	3.52	96	2.20	110	3.06	103
Fleet	1.41	119	1.42	93	3.77	103	1.84	92	3.13	105
Flinders	1.19	100	-	-	-	-	-	-	-	-
Granger	1.20	101	1.12	74	3.31	90	1.61	81	2.62	88
Hindmarsh	1.39	117	1.65	108	3.71	101	2.17	108	3.12	105
Keel	1.51	127	1.45	95	3.39	92	2.05	102	3.35	112
La Trobe	1.37	115	1.65	108	3.71	101	2.23	111	3.19	107
Leabrook	1.61	136	1.66	109	3.94	107	2.36	118	3.12	105
Oxford	0.47	40	-	-	-	-	-	-	-	-
RGT Planet	0.74	62	0.97	64	3.66	99	1.76	88	2.79	94
Rosalind	1.25	105	1.53	100	4.25	116	2.41	121	3.27	110
Scope	0.95	80	1.08	71	3.25	89	1.72	86	2.67	90
Spartacus CL	1.38	116	1.70	111	3.71	101	2.21	110	3.11	104
Site Mean (t/ha)	1.19		1.53		3.68		2.00		2.98	
CV (%)	6.96		9.59		3.58		3.94		4.70	
Probability	<0.001		<0.001		<0.001		<0.001		<0.001	
LSD (t/ha)	*0.14*		*0.25*		*0.22*		*0.17*		*0.22*	
Sowing Date	16/05/2019		16/05/2019		14/05/2019		08/05/2019		07/05/2019	
Trial Comments	Trial affected by some shattering, interpret results with caution, particularly for RGT Planet, Keel, Hindmarsh and Flinders		Trial affected by some shattering, interpret results with caution, particularly for RGT Planet, Keel, Hindmarsh and Fleet		Data reanalysed 14/01/20 using additional plot variation data					

Source: www.nvtonline.com.au

Management of flowering time and early sown slow developing wheats

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Key messages

- **Different winter varieties are required to target different optimum flowering windows.**
- **Best yields of winter wheats sown early are similar to Scepter sown in optimal window.**
- **If sowing early use the right winter cultivar for the right yield and flowering environment.**
- **Highest yields for winter wheats come from early – late April establishment.**
- **Mid - slow developing spring varieties are less suited to pre 20 April sowing.**

Why do the trials?

Timely operations are key to maximising farm profit, and sowing is one of the most time-critical operations. This is because there is only a short period (~10 days) in spring during which crops can flower and yields be maximised. This period is referred to as the optimal flowering period and its timing and length varies with location and climate. During the optimal flowering period, combined yield loss from drought, heat, frost and insufficient radiation are minimised, and yield maximised. Increasing farm sizes and cropped area and declining autumn rainfall have made it increasingly difficult to get crops flowering during the optimal period.

Sowing early with appropriate cultivars is one management strategy to increase the amount of farm area that flowers during the optimal period and thus farm yield can be maximised. Sowing earlier requires cultivars that are slower developing to take advantage of early establishment opportunities. They are ideally sown into a moist seed bed following breaking rain or preceding a convincing forecast of enough rain to allow germination. This should not be confused with dry sowing which will typically use fast developing cultivars sown into dry seed beds that will establish when breaking rains fall.

Winter wheats for early sowing

For sowing prior to 20 April, winter cultivars are required, particularly in regions of high frost risk. Winter wheats will not progress to flower until their vernalisation requirement is met (cold accumulation), whereas spring cultivars will flower too early when sown early. The longer vegetative period of winter varieties also opens opportunities for grazing. Winter wheat cultivars allow wheat growers in the southern region to sow much earlier than currently practiced, meaning a greater proportion of the farm can be sown on time.

Management of Early Sown Wheat experiments

The aim of this series of the GRDC Management of Early Sown Wheat experiments is to determine which of the new generation of winter cultivars have the best yield and adaptation in different environments and what is their optimal sowing window. Prior to the start of the project in 2017 the low–medium rainfall environments had little exposure to the new winter cultivars, particularly at really early sowing dates (mid-March). Three different experiments have been conducted in the southern region in low–medium rainfall environments during 2017 and 2019, including collaboration in NSW for additional datasets presented in this paper.

How was it done?

Experiment 1: Which wheat cultivar performs best in which environment and when they should be sown?

- Target sowing dates: 15 March, 1 April, 15 April and 1 May (10 mm supplementary irrigation to ensure establishment).
- Locations: SA - Minnipa, Booleroo Centre, Loxton, Hart. Vic - Mildura, Horsham, Birchip and Yarrawonga. NSW - Condobolin, Wongarbon, Wallendbeen.
- Up to ten wheat cultivars - The new winter wheats differ in quality classification, development speed and disease rankings (Table 1).

Table 1. Summary of winter cultivars, including Wheat Australia quality classification and disease rankings based on the 2020 SA Crop Sowing Guide.

Cultivar	Release Year	Company	Development	Quality	Disease Rankings			
					Stripe Rust	Leaf Rust	Stem Rust	YLS
Kittyhawk	2016	LRPB	Mid winter	AH	RMR	MS	MRMS-S	MRMS
Longsword	2017	AGT	Fast winter	Feed	RMR	MSS	MR	MRMS
Illabo	2018	AGT	Mid-fast winter	AH/APH*	RMR	S	MS	MS
DS Bennett	2018	Dow	Mid - Slow winter	ASW	RMR	S	MRMS	MRMS
ADV15.9001	?	Dow	Fast winter	?	-	-	-	-
Nighthawk	2019	LRPB	Very slow spring	?	RMR	MSS	RMR	MS
Cutlass	2015	AGT	Mid spring	APW/AH*	MS	RMR	R	MSS
Trojan	2013	LRPB	Mid-fast spring	APW	MR	MRMS	MRMS	MSS
Scepter	2015	AGT	Fast spring	AH	MSS	MSS	MR	MRMS

**SNSW only*

What happened?

Different winter cultivars are required to target different optimum flowering windows

Flowering time is a key determinant of wheat yield. Winter cultivars are very stable in flowering date across a broad range of sowing dates, this has implications for variety choice as flowering time cannot be manipulated with sowing date in winter wheats like spring wheat. This means that different winter varieties are required to target different optimum flowering windows. The flowering time difference between winter cultivars are characterised based on their relative development speed into three broad groups fast, mid-fast, mid and mid-slow for medium-low rainfall environments (Table 1 and Figure 1).

For example at Birchip each winter variety flowered within a period of 7-10 days across all sowing dates, whereas spring cultivars were unstable and ranged in flower dates over one month apart (Figure 1). In this Birchip example the fast–mid developing winter wheats with development speeds similar to Longsword and Illabo are best suited to achieve the optimum flowering period 10-20 September for Birchip.

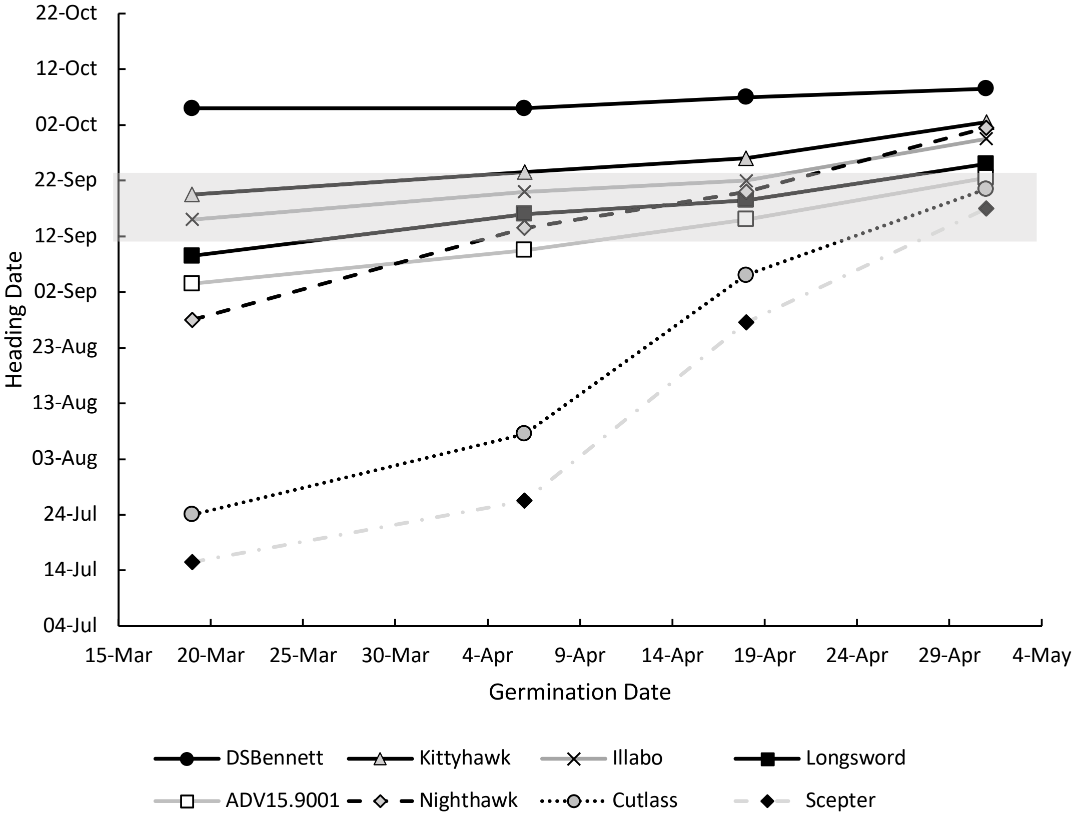

Figure 1. Mean heading date responses from winter and spring cultivars at Birchip in 2018 and 2019 across all sowing times, grey box indicates the optimal period for heading at Birchip.

In other lower yielding environments such as Loxton, Minnipa and Mildura the faster developing winter cultivar ADV15.9001 and Longsword was better suited to achieve flowering times required for the first 10 days in September.

Best yields of winter wheats sown early are similar to Scepter sown in optimal window.

- Across all experiments the best performing winter wheat yielded similar to the fast developing spring variety Scepter sown at the optimal time (last few days of April or first few days of May, used as a best practice control) in 21 out of 28 sites, greater in 5 and less than in 2 environments (Figure 2).
- The best performing winter wheat yielded similar to the best performing slow developing spring variety (alternative development pattern) at 24 sites, greater at 2 and less than at 2 sites.

The best performing winter cultivar depends on yield environment and development speed

The best performing winter wheat cultivars depended on yield environment, development speed and the severity and timing of frost (Table 1). The rules generally held up that winter cultivars that are well-adjusted to a region yielded similar to Scepter sown in its optimal window, these results demonstrate that different winter wheats are required for different environments and there is genetic by yield environment interaction.

- In environments less than 2.5 t/ha the faster developing winter wheat Longsword and ADV15.9001 was generally favoured (Figure 3).
- In environments greater than 2.5 t/ha the mid–slow developing cultivars were favoured; Illabo in the Mid North of SA, and DS Bennett at the Vic and NSW sites (Figure 4).

The poor relative performance of Longsword in the higher yielding environments was explained by a combination of flowering too early and having inherently greater floret sterility than other cultivars irrespective of flowering date.

Sites defined by severe September frost and October rain included Yarrawonga, Mildura and Horsham in 2018, in this scenario the slow developing cultivar DS Bennett was the highest yielding winter wheat and had the least amount of frost induced sterility. The late rains also favoured this cultivar in 2018 and mitigated some of the typical yield loss from terminal drought (i.e. Birchip 2019). Nonetheless the ability to yield well outside the optimal flowering period maybe a useful strategy for extremely high frost prone areas for growers wanting to sow early.

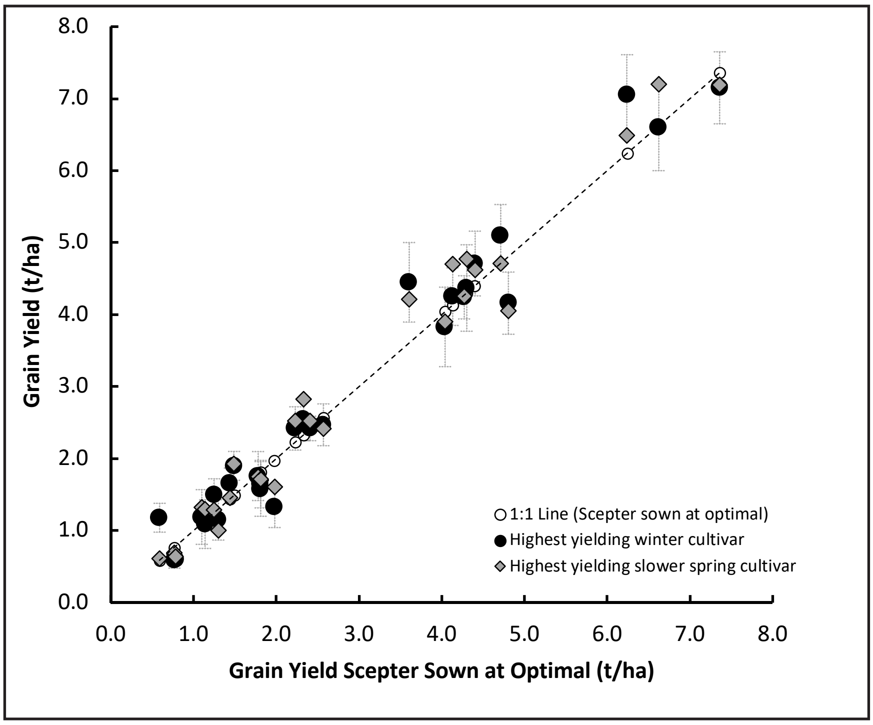

Figure 2. Grain yield performance of Scepter wheat sown at its optimal time (late April-early May) in 28 environments (2017–2019) compared to the performance of the best performing winter wheat. Error bars indicate LSD (P<0.05).

Table 2. Summary of grain yield performance of the best performing winter and alternate spring cultivar in comparison to Scepter sown at the optimum time (late April-early May). Different letters within a site indicate significant differences in grain yield.

Site	Year	Grain yield of Scepter sown ~1 May (t/ha)	Highest yielding winter cultivar			Highest yielding slower spring cultivar		
			Grain yield (t/ha)	Cultivar #	Germ date	Grain yield (t/ha)	Cultivar #	Germ date
Yarrawonga*	2018	0.6 b	1.2 a	DS Bennett	16-Apr	0.6 b	Cutlass	16-Apr
Booleroo	2018	0.8 a	0.6 a	Longsword	4-Apr	0.7 a	Trojan	2-May
Booleroo	2019	0.8 a	0.6 a	ADV15.9001	05-Apr	0.6 a	Cutlass	01-May
Loxton	2018	1.1 a	1.2 a	Longsword	19-Mar	1.3 a	Cutlass	3-May
Loxton*	2019	1.1 a	1.1 a	ADV15.9001	15-Mar	1.3 a	Cutlass	01-May
Minnipa	2018	1.3 a	1.5 a	Longsword	3-May	1.3 a	Trojan	3-May
Mildura	2019	1.3 a	1.2 a	ADV15.9001	29-Apr	1.0 a	IGW6566	15-Apr
Mildura*	2018	1.4 b	1.7 a	DS Bennett	1-May	1.5 ab	Nighthawk	1-May
Mildura	2017	1.5 b	1.9 a	Longsword	13-Apr	1.9 a	Cutlass	28-Apr
Minnipa	2019	1.8 a	1.8 a	ADV15.9001	05-Apr	1.7 a	Cutlass	05-Apr
Horsham*	2018	1.8 a	1.6 a	DS Bennett	6-Apr	1.7 a	Trojan	2-May
Hart	2019	1.8 a	1.6 a	Illabo	05-Apr	1.7 a	Nighthawk	18-Apr
Booleroo	2017	2.0 a	1.3 b	DS Bennett	4-May	1.6 b	Cutlass	4-May
Minnipa	2017	2.2 a	2.4 a	Longsword	18-Apr	2.5 a	Cutlass	5-May
Loxton	2017	2.3 a	2.6 ab	Longsword	3-Apr	2.8 b	Nighthawk	3-Apr
Hart	2018	2.4 a	2.4 a	Illabo	17-Apr	2.5 a	Nighthawk	17-Apr
Condobolin	2018	2.6 a	2.5 a	DS Bennett	19-Apr	2.4 a	Trojan	7-May
Yarrawonga	2019	3.6 b	4.5 a	ADV15.9001	15-Mar	4.2 a	Nighthawk	05-Apr
Birchip	2018	4.0 a	3.8 a	Longsword	30-Apr	3.9 a	Trojan	30-Apr
Hart	2017	4.1 a	4.3 a	Illabo	18-Apr	4.7 b	Nighthawk	18-Apr
Yarrawonga	2017	4.3 a	4.2 a	DS Bennett	3-Apr	4.3 a	Cutlass	26-Apr
Wongarbon	2017	4.3 a	4.4 a	DS Bennett	28-Apr	4.8 a	Trojan	13-Apr
Tarlee	2018	4.4 a	4.7 a	Illabo	17-Apr	4.6 a	Nighthawk	17-Apr
Birchip	2019	4.7 a	5.1 a	DS Bennett	01-May	4.7 a	Nighthawk	01-May
Horsham	2019	4.8 a	4.2 b	Longsword	05-Apr	4.1 b	Nighthawk	05-Apr
Wallendbeen	2017	6.2 b	7.1 a	DS Bennett	28-Mar	6.5 b	Cutlass	1-May
Birchip	2017	6.6 b	6.6 b	DS Bennett	15-Apr	7.2 a	Trojan	15-Apr
Horsham	2017	7.4 a	7.2 a	DS Bennett	16-Mar	7.2 a	Trojan	28-Apr

**stem and/or reproductive frost substantially affected yield*
#Cultivars Trojan and ADV15.9001 were not included at all sites

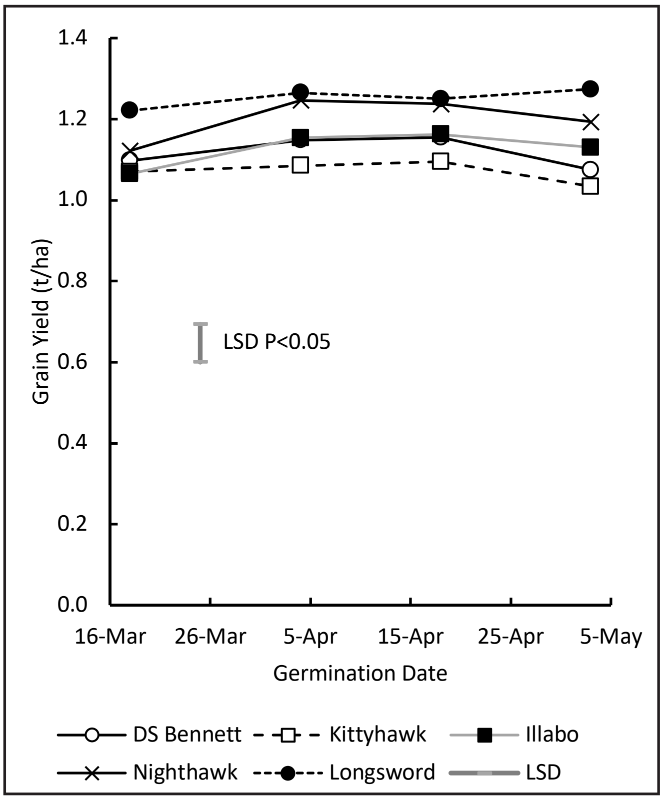

Figure 3. Mean yield performance of winter wheat in yield environments less than 2.5 t/ha (16 sites in SA/Vic)

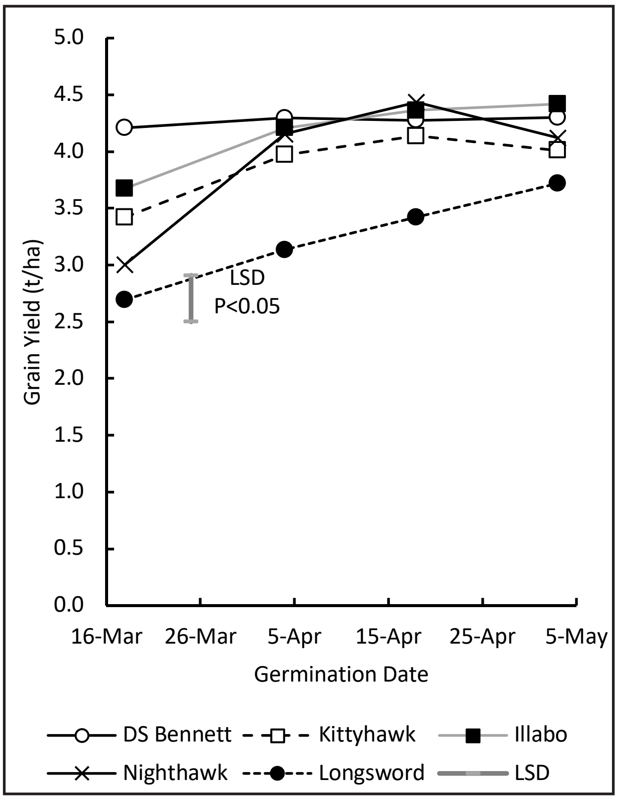

Figure 4. Mean yield performance of winter wheat in yield environments greater than 2.5 t/ha (5 sites in SA/Vic)

Highest yields for winter wheats come from early–late April establishment

- Across all environments the highest yields for winter wheats generally came from early-late April establishment and results suggested that the yields may decline from sowing dates earlier than April and these dates may be too early to maximise winter wheat performance (Table 2, Figure 3 and Figure 4). The cultivar DS Bennett maintained it's better than other cultivars from March establishment.
- Mid-slower developing spring wheat cultivars (i.e. Cutlass) performed best from sowing dates after 20 April, and yielded less than the best performing winter cultivars when sown prior to 20 April. This reiterates slow developing spring varieties are not suited to pre 20 April sowing in low-medium frost prone environments.
- The very slow developing spring Nighthawk yielded similar to the best performing winter cultivar in both yield environments from mid-April establishment dates.

More details on experiment one can be found here: http://agronomyaustraliaproceedings.org/images/sampledata/2019/2019ASA_Hunt_James_173.pdf

What does this mean?

Growers in the low-medium rainfall zones of the southern region now have winter wheat cultivars that can be sown over the entire month of April and are capable of achieving similar yields to Scepter sown at its optimum time. However, grain quality of the best performing cultivars leaves something to be desired (Longsword=feed, DS Bennett=ASW). Sowing some wheat area early allows a greater proportion of farm area to be sown on time. Growers will need to select winter wheats suited to their flowering environment (fast winter in low rainfall, mid and mid-slow winter in medium rainfall) and maximum yields are likely to come from early–mid April planting dates.

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 (GRDC Management of Early Sown Wheat 9175069), the author would like to thank them for their continued support. The project is led by La Trobe University in partnership with the South Australian Research and Development Institute (SARDI), Hart Field Site Group, Moodie Agronomy, Birchip Cropping Group, Agriculture Victoria, FAR Australia, Mallee Sustainable Farming and in collaboration with New South Wales DPI and Central West Farming Systems.

National Hay Agronomy - what variety, when to sow and what N rate to use?

Alison Frischke[1], Genevieve Clarke[1] and Georgie Troup[2]

[1]BCG (Birchip Cropping Group); [2]DPIRD (Department of Primary Industries and Regional Development, Western Australia)

Location
Kalkee North
Rainfall
2019 (Nov-Oct): 363 mm
2019 (Apr-Oct): 254 mm
Soil type
Clay Loam
Paddock history
2018: Duram wheat
Nutrition
Available nitrogen (0-100cm) 30kg N/ha
Plot size
7 m x 1.8 m x 3 reps x 30 cm row spacing

Key messages

- **Hay yield was optimised by sowing either Mulgara, Wintaroo, Yallara or Brusher at the start of May.**
- **Delaying sowing from 1 May to 6 June reduced hay yield by 1.5 t/ha.**
- **WA hay varieties Williams and Carrolup were lower yielding when sown early, yet yielded similarly to Mulgara, Wintaroo and Brusher when sowing was delayed.**
- **Hay yield was optimised when 120 kg N/ha was applied.**
- **Stem thickness increased as applied N increased to 60 kg N/ha, before plateauing as N increased to 150 kg N/ha**

Why do the trial?

Hay can provide the highest gross margin crop in the program, while reducing business and production risk. Hay reduces risk by diversifying income across additional markets and selling periods and, due to the earlier harvest, hay crops can conserve moisture for subsequent crops. Deciding to cut hay can provide opportunities for frosted, water limited and heat-affected crops that are unlikely to fill grain, while reducing the weed seedbank at the same time.

Oaten hay accounts for almost 75 per cent of fodder exported from Australia each year. The National Hay Agronomy project is a four-year investment by the AgriFutures™ Export Fodder Program, led by Western Australia's Department of Primary Industries and Regional Development, with BCG, Agriculture Victoria, NSW DPI and SARDI. The project aims to improve understanding of how agronomic practices affect export oaten hay production and quality. This will help growers better manage oaten hay crops to meet export market specifications and develop a competitive advantage in our export fodder markets.

The aim of this research is to evaluate hay production and quality of oat varieties at different times of sowing and under different nitrogen (N) nutrition strategies.

How was it done?

A replicated field trial was sown with oats using a complete randomised block trial design. The treatments and sowing dates are listed in Table 1. The targeted plant density was 320 plants/m^2 and the trial had three replicates. The trial was sown using small plot equipment with knife points + splitter boot (70 mm split), press wheels and 30 cm row spacing. The fertiliser used was Granulock® Supreme Z + Flutriafol (200 mL/100 kg) @ 60 kg/ha at sowing, and seed treatments of Vibrance® @ 360 mL/100 kg and Gaucho® @ 240 mL/100 kg. The trial was managed as per best practice for herbicides, insecticides and fungicides.

Assessments included establishment counts, NDVI crop biomass, hay biomass at GS71, plant height, lodging, leaf greenness (SPAD chlorophyll measure) and stem diameter. NIR (including DairyOne calibration) was being analysed at the time of writing.

What happened?

Hay yield was influenced by variety selection, sowing date and rate of applied nitrogen. An interaction between sowing date and variety selection reflected the different maturity types within the trial - the ranking of varieties changed as sowing was delayed. An interaction between variety and nitrogen rate indicated that there were different sensitivities to applied N within the varieties in the trial.

Sowing in early May produced an additional 1.5 t/ha of hay than June sowing in 2019 (Table 2). All varieties yielded higher at TOS 1 except Carrolup.

The highest yielding TOS 1 varieties were Mulgara, Wintaroo, Brusher and Yallara, which averaged more than 8 t/ha (Table 2). The early finish to the 2019 spring meant the early-mid season variety Yallara finished better than expected.

Table 1. Treatments, time of sowing (TOS), oat variety and nitrogen rate (kg N/ha), Kalkee 2019.

Time of sowing	Oat variety	Nitrogen rate (kg N/ha applied as 2/3 at seeding, 1/3 at 6 weeks after germination)
TOS 1: 1 May TOS 2: 6 June	Brusher Carrolup Durack Forester Koorabup Mulgara Williams Wintaroo Yallara	10 (Mulgara, Wintaroo, Yallara only) 30 60 90 120 (Mulgara, Wintaroo, Yallara only) 150 (Mulgara, Wintaroo, Yallara only)

Table 2. Oaten hay yield (t/ha) response to TOS and N rate. Letters indicate significant difference.

Variety	Hay yield (t/ha)				
	Time of sowing		Nitrogen rate (kg N/ha)		
	TOS 1	TOS 2	30N	60N	90N
Brusher	8.1^{abc}	6.3^{hijk}	6.0^{ijkl}	7.9^{bc}	7.8^{bc}
Carrolup	7.1^{efg}	6.5^{ghi}	5.5^{l}	7.7^{bcd}	7.2^{cdefg}
Durack	7.8^{bcd}	5.8^{jk}	5.7^{kl}	6.9^{defgh}	7.7^{bc}
Forester	6.7^{gh}	5.7^{k}	5.7^{l}	6.5^{hijk}	6.5^{ghik}
Koorabup	7.5^{cde}	5.7^{k}	5.8^{jkl}	6.6^{fghi}	7.5^{bcd}
Mulgara	8.6^{a}	6.6^{gh}	6.0^{ijkl}	8.0^{ab}	8.5^{a}
Williams	7.4^{def}	6.4^{hij}	6.0^{ijkl}	7.2^{cdef}	7.4^{bcde}
Wintaroo	8.2^{ab}	6.8^{fgh}	6.7^{efghi}	7.9^{bc}	7.9^{bc}
Yallara	8.2^{abc}	5.9^{ijk}	6.2^{ijkl}	7.3^{bcdef}	7.6^{bcd}
Average	**7.7**	**6.2**	**6.0**	**7.3**	**7.6**
Sig. diff.	*<0.001*				
TOS Variety	*<0.001*				
TOS x Variety	*0.011*				
N	*<0.001*				
TOS x N	*ns*				
Variety x N	*0.05*				
TOS x Variety x N	*ns*				
LSD (P=0.05)	*0.37*				
TOS	*0.45*				
Variety	*0.25*				
TOS x Variety	*0.66*				
N	-				
TOS x N	*0.74*				
Variety x N	-				
TOS x Variety x N					
CV%	*9.2*				

The lowest yielding was late-maturing Forester (6.2 t/ha), which is well adapted for high rainfall and irrigated regions. In other low-medium rainfall regions Forester generally fails to finish for hay by starting to discolour before it reaches the hay cutting, watery ripe stage. This is the general experience right across southern Australia from WA to southern NSW.

A new variety Koorabup (formerly 05096-32) with early-mid to mid-season maturity, was expected to yield better from the shorter finish than it did.

Nitrogen response

Yield increased as N rate increased from 30 to 60 kg N/ha for all varieties, but only Koorabup and Durack responded to the increase to 90 kg N/ha (Table 2).

The largest yield responses to increasing N from 30 to 60 kg N/ha were by Brusher, Carrolup and Mulgara, and Koorabup. Mulgara yielded the highest with 90 kg N/ha. Forester's response to increasing N was low, again because its maturity is too late.

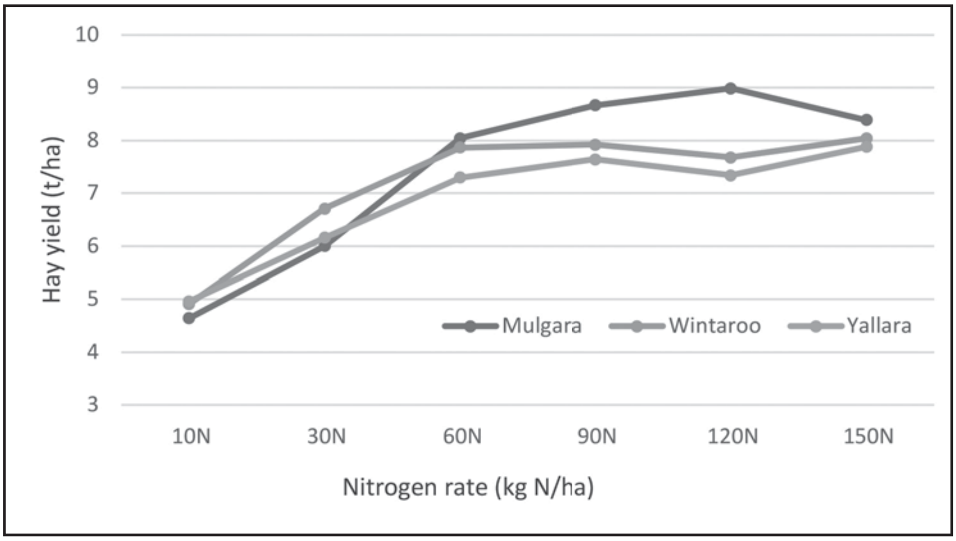

Figure 1. Mean oaten hay yield (t/ha) response to six nitrogen rates, Kalkee 2019 (P=0.024, LSD=0.79 t/ha, CV=9.7%).

Hay yield rose as N rate increased until 60 kg N/ha in Mulgara, Wintaroo and Yallara. Yield then plateaued and no further yield benefit was obtained from higher rates of N (Figure 1).

Hay quality

Plant height: The dry finish stalled plant height in general. Height responded to TOS x Variety x N (P=0.017). An earlier TOS allows plants to have a longer growing season before maturing and hence reach greater heights. May sown plants averaged 81.1 cm compared with early June sown plants at 67.8 cm. The tallest varieties were TOS 1 Mulgara, Durack, Wintaroo and Brusher above 88 cm. As N rate increased from 30 to 60 kg N/ha, plant height increased by 5 cm.

Lodging: There were no issues with lodging for any treatments in 2019.

Leaf greenness (SPAD chlorophyll measure): Greenness of hay is an indicator of plant health at cutting i.e. whether plants have been heat or water stressed, or if hay has been weather damaged, and forms part of the subjective analysis that determines hay price. Leaf greenness was highest for Williams, closely followed by Mulgara, Brusher and Koorabup, while Carrolup had the least colour. Later sown June varieties were greener than May sown ($P<0.001$), with the largest changes due to sowing time measured in Koorabup and Carrolup ($P<0.01$). Raising N from 30 to 60 kg N/ha increased greenness ($P<0.05$) for Brusher, Carrolup, Durack, Forester and Mulgara. There was no further response to 90 kg N/ha.

Stem thickness: Thinner stems (<6 mm) with lower fibre and higher water-soluble carbohydrates make better quality hay. Stem thickness responded to TOS ($P<0.001$), variety ($P<0.001$) and N rate ($P<0.05$). Later sowing reduced stem thickness from 4.73 mm to 3.98 mm. Varieties with the finest stems were Koorabup and Brusher, both under 4 mm. Raising N from 30 to 60 kg N/ha increased stem thickness from 4.22 to 4.41 mm. There was no further response to 90 kg N/ha.

What does this mean?

A combination of an adapted variety and the right agronomy will maximise the production and quality of oaten hay crops. Varieties with early-mid season maturity will perform best in the southern Mallee and Wimmera. Production of a late season variety, such as Forester, won't be optimised because it must be cut before peak biomass is reached in order to achieve hay quality.

Sowing early produces higher yielding hay crops. Better quality can be achieved when adequate N is applied in response to seasonal conditions, rather than large amounts applied early which are at risk of not being used if the season dries off. Despite good winter growing conditions, the dry finish meant 60 kg N/ha maximised yield and quality for all varieties, and the standard N rate of about 90-100 kg was more than adequate in a season like 2019.

This is the first year of a four-year research program. Results are indicative of the 2019 season and should be considered on the basis of growing conditions during this one season. The trial will be repeated in 2020 to evaluate these agronomic practices under a different set of seasonal conditions.

Acknowledgements

This research is part of the 'National Hay Agronomy project', funded by the AgriFutures™ Export Fodder Program. It is a national collaboration between DPIRD, SARDI, Agriculture Victoria, NSW DPI and grower groups including BCG.

National Hay Agronomy - PGR effect on 2019 hay production

Alison Frischke[1], Genevieve Clarke[1] and Georgie Troup[2]

[1]BCG (Birchip Cropping Group) and [2]DPIRD (Department of Primary Industries and Regional Development, Western Australia)

Location
Kalkee North, VIC
Rainfall
2019 (Nov-Oct): 363 mm
2019 (Apr-Oct): 254 mm
Soil type
Clay Loam
Paddock history
2018: Durum wheat
Nutrition
Available nitrogen (0-100cm) 30kg N/ha
Plot size
7 m x 1.8 m x 3 reps x 30 cm row spacing

Key messages

- **Hay yield and height was reduced by PGR Moddus® Evo application.**
- **Stem thickness and lodging was not influenced by PGR application in 2019 due to the dry finish.**

Why do the trial?

The National Oat Breeding Program variety trials in Victoria are conducted annually, but there has been little recent evaluation of agronomic practices beneficial for hay production. A practice that needs field assessment is the use of a plant growth regulator (PGR) to manage hay production. PGR application is intended to reduce the internode length, shortening plant height and increasing straw strength, to reduce the likelihood of lodging which is detrimental to hay making logistics and quality.

The National Hay Agronomy project is a four-year investment by the AgriFutures™ Export Fodder Program, led by Western Australia's Department of Primary Industries and Regional Development working with BCG, Agriculture Victoria, NSW DPI, and SARDI.

The project aims to understand how agronomic practices affect export oaten hay production and quality. This will help growers better manage oaten hay crops to meet export market specifications and develop a competitive advantage in our export fodder markets.

The aim of this research was to evaluate the effect of a plant growth regulator (Moddus® Evo) on hay yield and quality to determine the role of PGRs in the export fodder industry.

How was it done?

Two replicated field trials were sown on 6 June 2019 with oats using a complete randomised block trial design. The treatments are listed in Table 1 and the rates of the plant growth regulator Moddus Evo. The targeted plant density was 320 plants/m^2 and the trial had three replicates. The trial was sown using small plot equipment with knife points + splitter boot (70 mm split), press wheels and 30 cm row spacing. The fertiliser used was Granulock® Supreme Z + Flutriafol (200 mL/100 kg) @ 60 kg/ha at sowing, and seed treatments of Vibrance® @ 360 mL/100 kg and Gaucho® @ 240 mL/100 kg. The trial was managed as per best practice for herbicides, insecticides and fungicides.

Assessments included establishment counts, NDVI crop biomass, hay biomass at GS71, plant height, lodging, leaf greenness (SPAD chlorophyll measure), stem diameter. NIR (including DairyOne calibration) was being analysed at the time of writing.

What happened?

At Kalkee in 2019, applications of Moddus Evo reduced hay yield and height, but did not increase stem thickness (Table 2).

Table 1. Oat variety and plant growth regulator Moddus evo rates at Kalkee North in 2019.

Oat variety	PGR rate (mL/ha)
Brusher Forester Koorabup Mulgara Williams Yallara	0 200 400

Table 2. Oaten hay yield, plant height and stem thickness with different PGR rates. Letters indicate significant difference.

Variety	Hay yield (t/ha)			Plant height (cm)			Stem thickness (mm)		
PGR rate (mL/ha)	**0**	**200**	**400**	**0**	**200**	**400**	**0**	**200**	**400**
Koorabup	6.6	6.1	5.1	72.3	63.1	50.8	4.6	4.0	3.7
Brusher	7.4	6.3	6.3	71.4	52.8	52.3	4.0	5.0	4.9
Forester	6.1	5.6	5.0	53.8	47.3	39.4	4.8	5.2	5.3
Mulgara	8.1	6.7	6.3	82.2	61.8	50.7	5.2	5.0	4.8
Williams	6.9	5.6	4.8	62.3	49.2	43.4	4.6	5.0	4.8
Yallara	7.4	6.8	6.2	67.6	57.1	48.0	4.8	4.8	4.8
Sig. diff. Variety	*<0.001*			*<0.001*			*P=0.046*		
Moddus	*<0.001*			*<0.001*			*ns*		
Variety x moddus	*ns*			*P=0.004*			*ns*		
LSD (P=0.05)									
Variety	*0.3*			*4.1*			*0.6*		
Moddus	*0.4*			*2.3*			*ns*		
Variety x moddus	*ns*			*5.8*			*ns*		
CV%	*9.2*			*5.8*			*16.3*		

The trial was June sown, and there were no measured changes to crop maturity. The dry finish to the season restricted overall crop height and lodging did not occur.

In Western Australia, 2019 trials recorded a similar lack of response to Moddus Evo due to the dry conditions. However, previous preliminary trials have measured a stem thickness increase and a subsequent reduction in lodging, indicating the response is seasonally dependent.

It is not beneficial to apply a plant growth regulator to a hay crop in a lower rainfall season when plant height is constrained and lodging will be less of a risk. However, applying a plant growth regulator has shown to be of benefit in more favourable seasons when lodging is more likely, with any compromises to hay yield outweighed by the reduction in lodging.

This trial will be repeated in 2020 to evaluate the agronomic practice under a different set of seasonal conditions.

Acknowledgements

This research is part of the 'National Hay Agronomy project', funded by AgriFutures™ Export Fodder Program. It is a national collaboration between DPIRD, SARDI, Agriculture Victoria, NSW DPI and grower groups including BCG.

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BCG

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Section 5

Nutrition

Proximal sensing technologies for soils and plants on Eyre Peninsula

Fabio Arsego[1], Amanda Cook[1], Neil King[1], Ian Richter[1], Helena Oakey[2] and Annie Conway[2]
[1]SARDI, Minnipa Agricultural Centre; [2]Biometry Hub, University of Adelaide

Key messages

- **Proximal sensing reflectance data predicts soil moisture with reasonable accuracy from samples taken at depths (0-10, 10-30, 30-60, 60-100 cm) across 46 Eyre Peninsula locations.**
- **Moderate relationships were found between % organic carbon, pH(water) and soil spectral data.**
- **Reflectance data have been proven useful for predicting the amount of crop macronutrients, including nitrogen, phosphorus, potassium and sulphur.**
- **Further experimental data is required to test the reliability of the existing predictive models of soil absorbance and crop reflectance as a means to predict nutrient content.**

Why do the trial?

This research was done to develop predictive formulas that can be used by growers to estimate in-season soil nutrients from soil samples taken at different depths and crop nutrient content from proximal sensing (PS) data.

The upper Eyre Peninsula (UEP) is a challenging environment for growers, due to the irregular rainfall patterns which are coupled with lower soil fertility. Additionally, calcareous soils with poor structure and low water holding capacity provide additional restrictions for plant growth, as growers currently use granular fertilisers which require good soil moisture conditions to enable the uptake of nutrients. Topsoils from calcareous soils may dry quickly after rain events, which may explain poor water use and nutrient extraction efficiency.

PS technologies have the potential to support grower's nutrient management decisions by monitoring in-season soil and crop water and nutrient content (Allen *et al*. 2017, Arsego *et al*. 2017). PS uses a wide range of wavelengths to predict soil and crop nutritional status in a non-destructive, quick, and inexpensive way. PS technology is mostly limited to laboratory use. The development of small, portable PS devices may allow the use of this technology in farm paddocks in the near future. In this study, we combined different UEP trials to develop predictive models for PS for crop nitrogen, crop nutrient content and soil moisture.

How was it done?

A total of 15 trials were established across 3 seasons (2017-19) in Cummins, Lock, Minnipa, Nunjikompita, Streaky Bay, Cungena and Condada (Table 1). A randomised complete block design with three replicates was used for all trials.

Tissue samples

Biomass cuts were sampled at GS31 (stem elongation) at the 15 trials. The GS31 biomass cuts (1/2 m^2) were dried at 35 degrees in the oven until a constant weight. The dry biomass samples were ground and sent to the laboratory for determination of nitrogen content. The ground tissue samples of GS31 biomass cuts from Nunjikompita, Cungena, Streaky Bay and Condada were tested for macro and micronutrients (nitrogen, phosphorous, potassium, copper, magnesium, iron, manganese, sodium, boron, sulphur and zinc) content at the laboratory.

Table 1. Trial details for the 15 EP trials tested in 2017-19.

Season	Site *Grower* Soil type Plot size	Sowing date	Cultivars	Treatments	Spectral probe used (number of samples)	GSR (mm)
2017	Cummins *Modra* Clay loam 5 m x 1.6 m x 3 reps	21 June	Scepter, Mace, Halberd and Spear	Rainfed, Irrigation (50 mm), non-fertilised and 50 N at stem elongation	FOV* (48), Leaf clip (48)	278
2017	Lock *Burrows* Grey sandy loam 5 m x 1.6 m x 3 reps	6 June	Scepter, Mace, Halberd and Spear	Rainfed, Irrigation (50 mm), non-fertilised and 50 N at stem elongation	FOV* (48), Leaf clip (48)	191
2017	Minnipa *MAC N10* Red sandy clay loam 5 m x 1.6 m x 3 reps	30 May	Scepter, Mace, Halberd and Spear	Rainfed, Irrigation (50 mm), non-fertilised and 50 N at stem elongation	Leaf clip (48)	141
2018	Cummins *Green* Clay loam 5 m x 1.6 m x 3 reps	15 May	Scepter, Mace, Halberd and Spear	Rainfed, Irrigation (50 mm), non-fertilised and 120 N at stem elongation	Leaf clip (48)	288
2018	Lock *Burrows* Grey sandy loam 5 m x 1.6 m x 3 reps	22 May	Scepter, Mace, Halberd and Spear	Extra 20 mm of irrigation at sowing. Rainfed, Irrigation (50 mm), non-fertilised and 120 N at stem elongation	Leaf clip (48)	231
2018	Minnipa *MAC N10* Red sandy clay loam 5 m x 1.6 m x 3 reps	22 May	Scepter, Mace, Halberd and Spear	Extra 20 mm of irrigation at sowing. Rainfed, Irrigation (50 mm), non-fertilised and 120 N at stem elongation	FOV* (48)	178
2018	Nunjikompita *Howard* Red calcareous sandy loam 1.6 m x 10 m x 3 reps	8 May	Scepter	50 kg/ha MAP/DAP with the seed, 50 kg/ha MAP/DAP 3 cm below the seed, normal seeding rate (60 kg/ha) and high seeding rate (80 kg/ha)	Leaf clip (24)	128
				50 kg/ha DAP, 50 kg/ha MAP, 50 kg/ha Urea, 100 kg/ha TSP, 200 kg/ha SSP, 200 kg/ha Complete Nutrient Mix, control at sowing	Leaf clip (36)	
				Fluid Phosphorous (Phosphoric Acid) normal rate (equivalent to 5 kg/ha), high rate (equivalent to 8 kg/ha), Granular phosphorus (Triple P, 50 kg/ha) at sowing	Leaf clip (24)	

2019	Condada *Cook* Red sandy loam 12 m x 2 m x 3 reps	6 May	Scepter	Phosphoric acid applied at sowing (water rate of 80 L/ha): 0, 5, 10 and 40 units P; 2. Granular urea applied by stem elongation (units N): 0, 10, 30, 60	FOV* (48)	182
				50-100 kg/ha DAP, 200 kg/ha DAP with high seeding rate (80 kg/ha), 50-100-200 kg/ha MAP balanced with urea, 50 kg/ha DAP with fluid trace elements (Zn Cu, Mn), 50 kg/ha MAP balanced with urea and fluid trace elements (Zn Cu, Mn), normal seeding rate (60 kg/ha), high seeding rate (80 kg/ha), Fluid fertiliser (phosphoric acid) with fluid trace elements (Zn Cu, Mn) applied at sowing	FOV* (39), contact probe (39)	
2019	Streaky Bay *Wheaton* Grey calcareous sandy loam 12 m x 2 m x 3 reps	8 May	Scepter	Phosphoric acid applied at sowing (water rate of 80 L/ha): 0, 5, 10 and 40 units P; 2. Granular urea applied by stem elongation (units N): 0, 10, 30, 60	FOV* (48), contact probe (48)	206
				50-100 kg/ha DAP, 200 kg/ha DAP with high seeding rate (80 kg/ha), 50-100-200 kg/ha MAP balanced with urea, 50 kg/ha DAP with fluid trace elements (Zn Cu, Mn), 50 kg/ha MAP balanced with urea and fluid trace elements (Zn Cu, Mn), normal seeding rate (60 kg/ha), high seeding rate (80 kg/ha), Fluid fertiliser (phosphoric acid) with fluid trace elements (Zn Cu, Mn) applied at sowing	FOV* (39), contact probe (39)	
2019	Cungena *Tomney* Grey calcareous sandy loam 12 m x 2 m x 3 reps	7 May	Scepter	Phosphoric acid applied at sowing (water rate of 80 L/ha): 0, 5, 10 and 40 units P; 2. Granular urea applied by stem elongation (units N): 0, 10, 30, 60	FOV* (48), contact probe (48)	158
				50-100 kg/ha DAP, 200 kg/ha DAP with high seeding rate (80 kg/ha), 50-100-200 kg/ha MAP balanced with urea, 50 kg/ha DAP with fluid trace elements (Zn Cu, Mn), 50 kg/ha MAP balanced with urea and fluid trace elements (Zn Cu, Mn), normal seeding rate (60 kg/ha), high seeding rate (80 kg/ha), Fluid fertiliser (phosphoric acid) with fluid trace elements (Zn Cu, Mn) applied at sowing	FOV* (39), contact probe (39)	

**FOV = field of view/field gun*

DAP = di ammonium phosphate, MAP = mono ammonium phosphate, SSP = single super phosphate, TSP = triple super phosphate

Soil samples

Soil samples were collected from the 15 trials and from 36 additional points in the EP soil moisture probe network paddocks. Soil moisture was calculated by using gravimetric method for all samples, which were collected with three sub-samples per replicates at sowing, and one sample per plot at maturity. In the case of the soil moisture probe network, soil cores up to 100 cm were collected pre-sowing and at harvest. A volumetric estimate was also calculated considering the bulk density information from the nearest APSOIL sites. At Cummins, Lock, Minnipa, Streaky Bay, Condada and Cungena soil samples were collected up to 90-100 cm depth. At Nunjikompita, the soil sampling depth was limited by limestone at a depth of 60 cm onwards. At all sites, additional soil samples were collected using the same methods described above. However, these soil samples were dried in an oven (35 degrees until constant weight), sieved and sent to the laboratory for nutrient content.

Spectral data collection

Spectral data was collected for biomass and soil samples using a PS technology (i.e. a SR-3500 spectroradiometer from Spectral Evolution). Readings with the spectroradiometer were done with clear sky by collecting four spectral readings per plot using a 25^{o} (field of view) bare fibre optic in the field at noon time (10am- 3pm) for the case of biomass. Furthermore, on cloudy days, a leaf clip probe was used to measure four random young leaves per plot. Lastly at Cungena, Streaky Bay and Condada trials, spectral data was only collected on ground tissue samples at GS31 using a contact probe. Soil spectral data was recorded using a contact probe, measuring four readings per soil sample, for both gravimetric and oven dried soil.

Spectral data analysis

Spectral data were pre-treated using standard methodology (Esbensen and Swarbrick 2018). Each spectral dataset was randomly split in two subsets: 1) calibration and 2) validation. The calibration subset represented 75 % of the whole dataset and was used to develop the predictive model. The predictions were calculated using partial least square (PLS) regression in the Unscrambler X (CAMO version 10.5) to calculate (i) the relationship between spectral data and nutrient data and (ii) the relationship between spectral data and soil nutrient data. The validation subset consisted of 25 % of the dataset and was used to evaluate the predictive power of the PLS model.

What happened?

Spectral readings performed with the contact probe

Soil moisture

As a first step, a multi-site PLS of soil moisture versus spectral data analysis was undertaken considering 46 locations across the EP. The model had a moderate predictive power R^2 = 0.7 with and error of the estimation of 10.4 mm (Figure 1a). This relationship showed higher variability for values over 60 mm. The wider spread may be attributed to: 1) the greater variability of soil types and soil moisture conditions at pre-sowing and post-harvest across the Eyre Peninsula and 2) the lower EP soil types which are characterised by high soil moisture and clay content.

Soil nitrate

A multi-site analysis considering sites from the soil moisture probe network and 2019 trials was performed to test the relationship between soil nitrate and soil spectral data (Figure 2). Similar to soil moisture, a moderate accuracy model (R^2 = 0.7-0.75) was obtained for the relationship between soil nitrate and spectral readings (Figure 2). Further studies should focus on increasing range of variability and further validate the predictive model across different environment conditions, soil types and soil moisture scenarios.

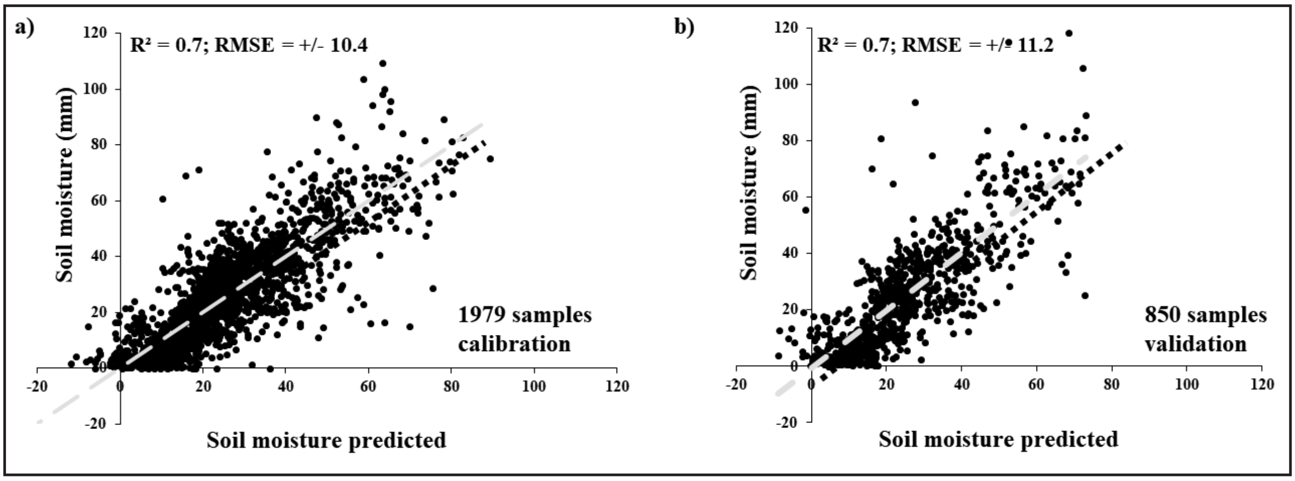

Figure 1a. Relationship between soil moisture (reference, mm) and the spectral (1b predicted) data from the 46 locations on the EP in 2018. RMSE = root mean square error. The black dotted line is the 1:1 line.

Soil phosphorus buffering index

The relationship between soil phosphorus buffering index (PBI) and soil spectral data was tested using the sites from the soil moisture probe network and 2019 trials (Figure 3). The calibration model was able to explain more than 80% of the variability in the soil phosphorus buffering index (Figure 3a), as expected, a drop of 0.1 R^2 can be observed between the calibration and validation datasets (Figure 3b). It is important to note that the soils that were used for the analysis included both calcareous and non-calcareous soils.

Other soil characteristics

The relationship between spectral data and soil nutrients was further tested, including but not limited to nutrients such as: pH (Figure 4 a-b) and % organic carbon (Figure 4 c-d). The calibration models explained between 70 and 80% of the variability in the soil pH (Figure 4a) and % of organic carbon (Figure 4b). In this case, the R^2 and accuracy were similar between calibration and validation datasets (Figure 4 a-d).

Phosphorus, potassium, sulphur and copper in plant tissue

Potassium and sulphur showed the highest relationship between the laboratory analysis and PS readings (Figure 5a-b and e-f), followed by phosphorus and copper (Figure 5c-d and g-h). Of all the nutrients, copper showed the lowest predictability and the highest difference between the calibration and validation datasets (Figure 5g-h). The use of the contact probe on ground tissue had a higher predictive power for potassium, sulphur, copper and phosphorus compared to the leaf clip predictions at Nunjikompita in 2018 (EPFS Summary 2018 p197), possibly due to better nutrient mobility within the plant.

Spectral readings performed with field gun and leaf clip probes

Nitrogen in plant tissues (N%)

A multi environment partial least square analysis was performed considering 2017-19 trial data from Cummins, Lock, Minnipa, Nunjikompita, Streaky Bay, Cungena and Condada to establish a strong relationship between nitrogen (N%) and spectral data (Figure 6). A total of 349 and 243 samples were used to develop the calibration models for field of view/field gun and leaf clip. Samples were split between tissue samples scanned with the field of view/field gun (Figure 6a) and leaf clip spectral probes (Figure 6b).

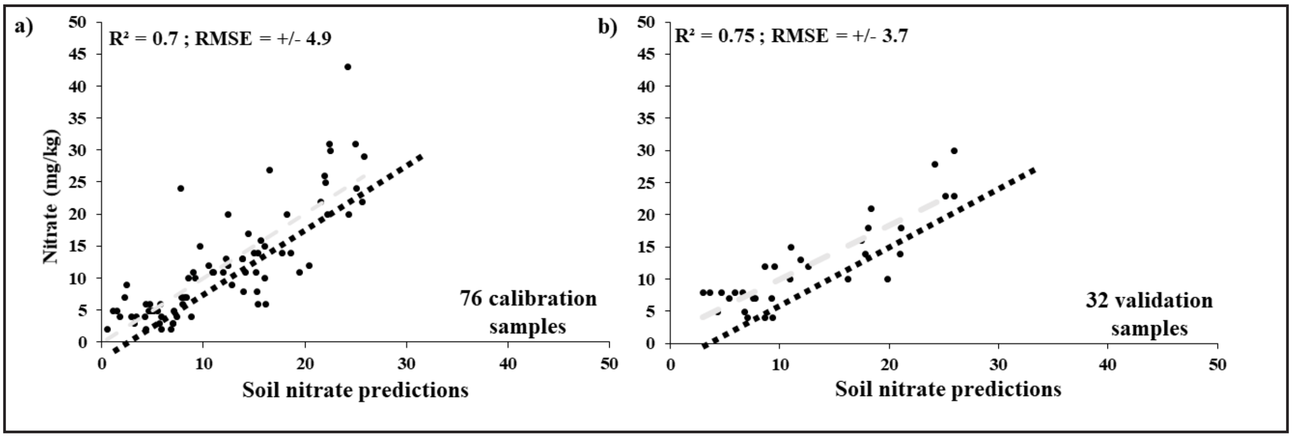

Figure 2a. Relationship between soil nitrate (reference, mg/kg) and the spectral (2b predicted) data from the 46 locations on the EP in 2018. RMSE = root mean square error. The black dotted line is the 1:1 line.

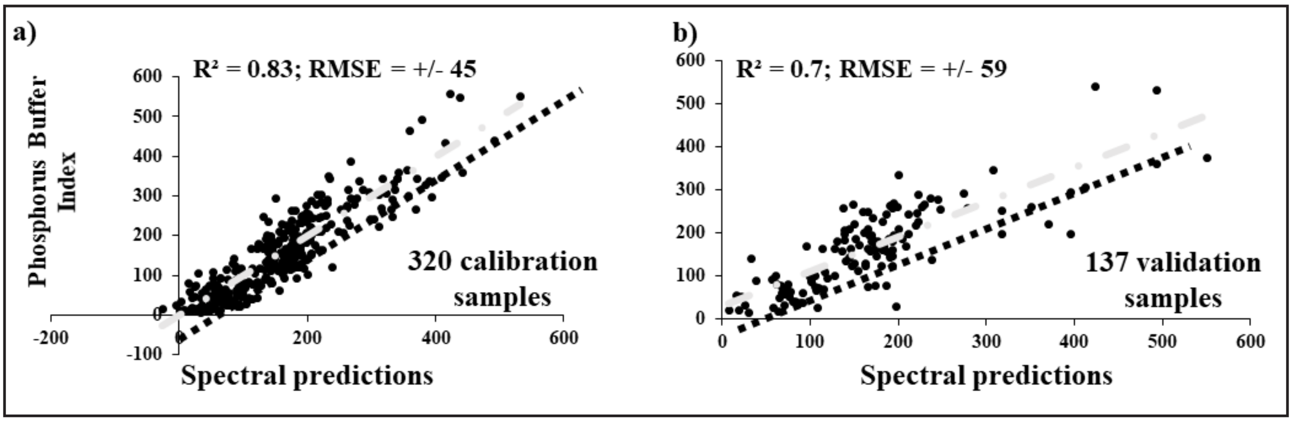

Figure 3a. Relationship of soil phosphorus buffering index and the spectral (3b predicted) data from the soil moisture probe network sites and 2019 trials. RMSE = root mean square error. The black dotted line is the 1:1 line.

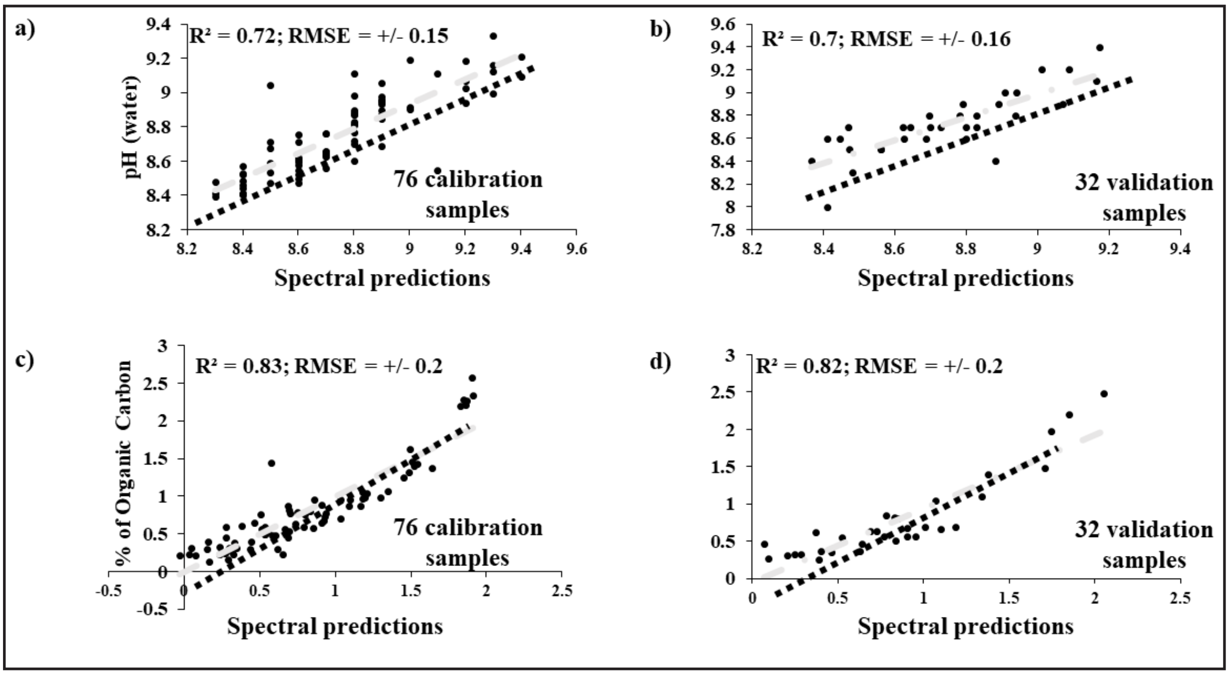

Figure 4. The relationship of lab measurements of soil pH (a-b) and organic carbon % (c-d) and the spectral (predicted) data from the soil moisture probe network sites and 2019 trials. RMSE = root mean square error. The black dotted line is the 1:1 line.

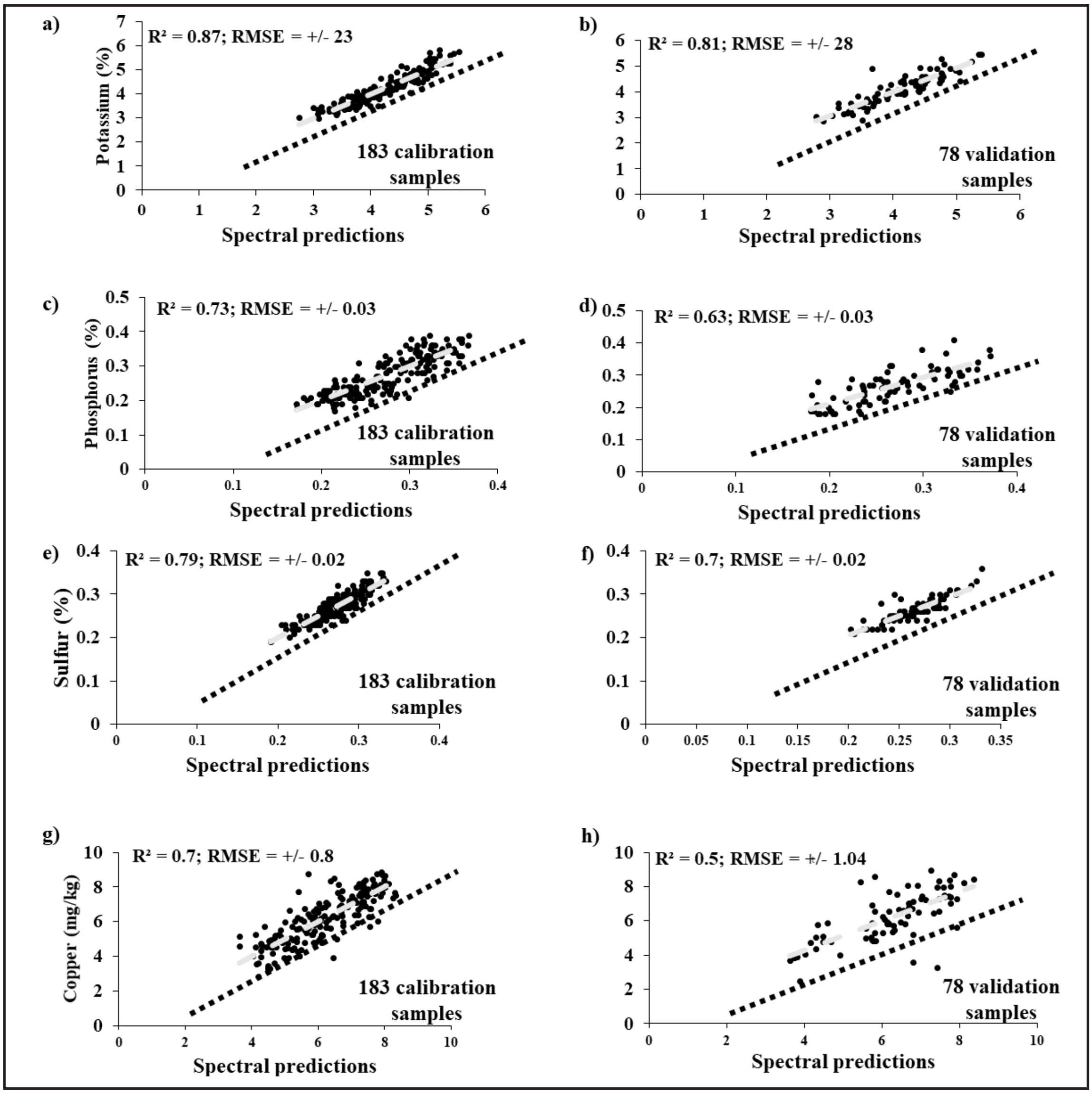

Figure 5a-h. The relationship between crop nutrients (lab reference) and spectral data (predicted) data from Streaky Bay, Cungena and Condada in 2019 trials. RMSE = root mean square error. The black dotted line is the 1:1 line.

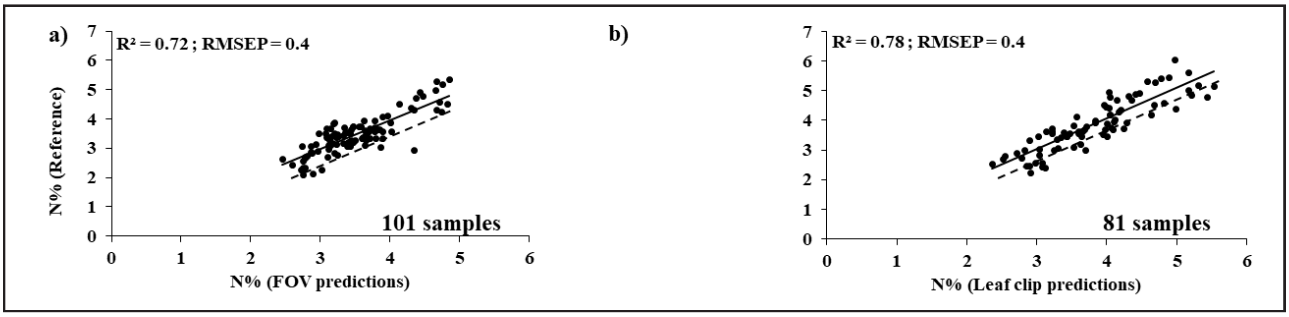

Figure 6a-b. Predictions of crop nitrogen (reference) from spectral (predicted) data using field of view (FOV, a) and leaf clip (b). RMSE = root mean square error. The black dotted line is the 1:1 line.

What does this mean?

This research indicates that PS technology could provide a useful method for estimating different soil characteristics of agronomic interest and crop nutrient content in a fast, cheap and reliable method. Given the number of samples and different locations used in the analysis, spectral predictions of soil moisture appear to be reliable and stable across EP. Special attention should be taken when working with wet soil conditions, especially with above 60 mm of soil moisture due to higher variability. Soil nutrients have shown a moderate relationship between lab and spectral estimates, especially phosphorus buffering index. Nutrients such as % organic carbon and pH, were also analysed and a calibration model is feasible for a wide variety of soils of the EP.

PS of crop nitrogen levels have shown a strong relationship across EP locations as previously observed in the literature (Ecarnot *et al*., 2013, Silva-Perez *et al.*, 2018). In calcareous soils, a moderately stable relationship was also found between PS data and nutrients other than nitrogen, especially potassium and sulphur.

Further research and studies are needed to test the reliability of the predictive models which have been developed on soil and crop nutrient content over further seasons.

Acknowledgements

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References

Allen, D. J., Ware, A, & Porker, K. “New technologies for wheat crop monitoring on the Eyre Peninsula” Eyre Peninsula Farming Systems Summary 2017, p. 120-126

Arsego, F., Ware, A., C. Mariano & V. O. Sadras. “Estimating water and N co-limitation levels of wheat using remote sensing technologies across upper Eyre Peninsula” Eyre Peninsula Farming Systems Summary 2017, p. 127-130

Arsego, F., et al., “Proximal sensing technologies on soils and plants on Eyre Peninsula” Eyre Peninsula Farming Systems Summary 2017, p. 197-202

Ecarnot, Martin, Frédéric Compan, and Pierre Roumet. “Assessing leaf nitrogen content and leaf mass per unit area of wheat in the field throughout plant cycle with a portable spectrometer.” Field Crops Research 140 (2013): 44-50

Monjardino, M., et al. “Are farmers in low-rainfall cropping regions under-fertilising with nitrogen? A risk analysis”. Agricultural Systems (2013): 116: 37-51

Sadras, V. O., & Roget, D. K. “Production and environmental aspects of cropping intensification in a semiarid environment of southeastern Australia”. Agronomy Journal, 96(1) (2004): 236-246

Silva-Perez, Viridiana, et al. “Hyperspectral reflectance as a tool to measure biochemical and physiological traits in wheat.” Journal of Experimental Botany 69.3 (2018): 483-496

Soriano-Disla, José M., et al. “Evaluation of the performance of portable visible-infrared instruments for the prediction of soil properties.” Biosystems Engineering 161 (2017): 24-36

Stenberg, Bo, et al. “Visible and near infrared spectroscopy in soil science.” Advances in agronomy. Vol. 107. Academic Press, (2010): 163-215

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Calibration of the commercial soil test for P on a red calcareous loam

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Location
Minnipa
Minnipa Ag Bureau
Rainfall
Av. Annual: 324 mm
Av. GSR: 241 mm
2019 Total: 235 mm
2019 GSR: 205 mm
Yield
Potential: 2.1 t/ha (W), 1.3 t/ha (C)
Actual: 1.7 t/ha (W), 0.25 t/ha (C)
Paddock history
2018: Wheat before canola, canola before wheat trial
2017: Pasture
2016: Pasture
2015: Pasture
Soil type
Red sandy clay loam
Soil test
pH$_{(H20)}$ 8.4, PBI 79, K 523 mg/kg
Plot size
20 m x 2 m x 4 reps x 25.5 cm row spacing
Trial design
Completely randomised design, 2 bays deep x 44 plots long x crop type (wheat or canola)
Yield limiting factors
Low rainfall, frost

Key messages

- **With low rainfall and poor growth at many sites, crops required little P to maximise grain yield.**
- **On a red sandy clay loam at Minnipa, wheat only needed a Colwell P value of 10-15 mg/kg to achieve maximum grain yield without P fertiliser.**
- **Canola appears to have a lower critical P level than wheat.**

Why do the trial?

Soil testing for N, P, K and S is a key strategy for monitoring soil fertility of cropping soils as well as for refining fertiliser application strategies for future crops. For this to be successful, the relationship between the soil test and likely response to applied nutrients needs to be well calibrated. Many of these calibrations were developed from fertiliser trials conducted over 20 years ago and have provided robust guidelines on many soil types, but mostly for cereals. Since these trials were conducted cropping systems have changed significantly and altered the face of soil fertility in the Australian grains industry. A detailed re-examination of those existing guidelines is needed to ensure they are still relevant in current farming systems.

As part of the GRDC funded MPCN2 (More Profit from Crop Nutrition) program, a review of data in the Better Fertilizer Decisions for Cropping (BFDC) database showed gaps exist for key crops, soils and regions. Most of these gaps relate to crops that are (i) new to cropping regions or are a low proportion of cropped area, i.e. break crops, (ii) emerging nutrient constraints that had previously been adequate in specific soil types and (iii) issues associated with changing nutrient profile distribution. This project (UQ00082) is closing gaps in the BFDC database using replicated trials. Trials have been established on sites selected for nutrient responses and run over multiple years to develop soil test-crop response relationships. By using wheat as a benchmark alongside a break crop, we should be able to extend the relevance of the guidelines beyond the conditions at the trial site.

How was it done?

A P deficient site on a red sandy clay loam was selected near Pildappa on upper Eyre Peninsula. Soil P status was very low at < 6 ppm Colwell P in the top 10 cm. On 7 May 2018, P fertiliser treatments were applied at 11 rates from 0 - 200 kg P/ha to create a range of soil P reserves.

Two identical trials were sown at the site in 2018, one with Mace wheat as the benchmarking crop and Stingray canola for comparison.

In 2019, 44T02 canola was seeded over the wheat trial and Mace wheat over the canola. Crops were inter-row seeded on the previous crop rows with no P fertiliser. Both crops received urea banded under the seed row @ 49 kg/ha and wheat received an extra 11 kg/ha of urea with the seed.

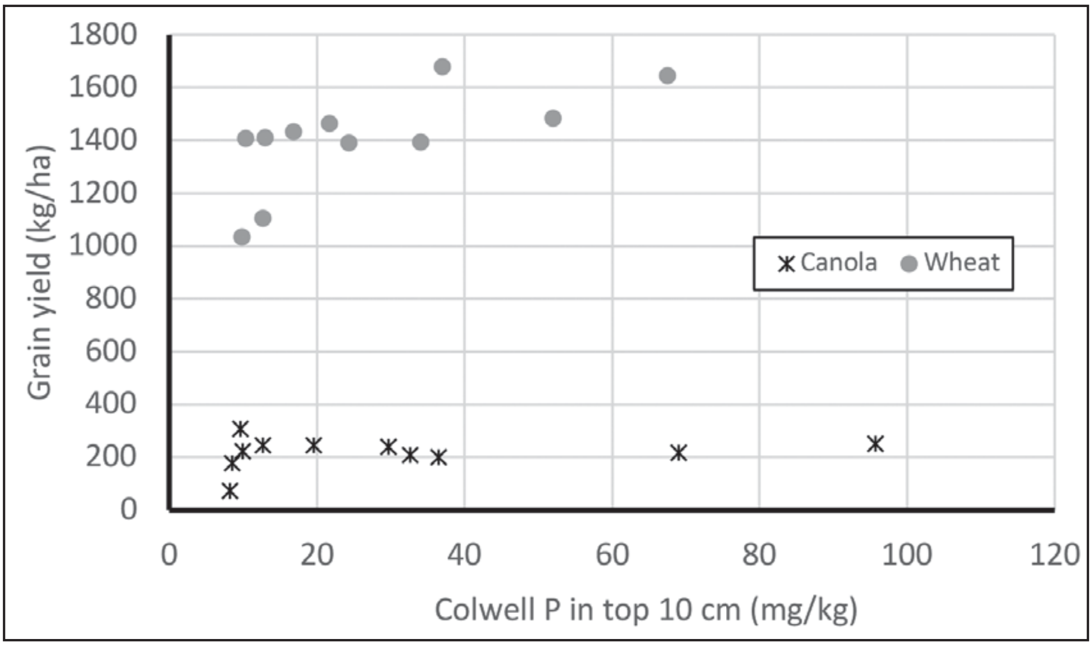

Figure 1. Grain yield of wheat and canola with increasing Colwell P in the topsoil at Pildappa, SA in 2019.

What happened?

Despite periods of very severe water stress during the season, both crops grew substantially better where soil tests were high for P (above 15 mg/kg in the top 10 cm for wheat, and above 10 mg/kg for canola). Canola appeared to be more stressed than wheat during the dry periods and the grain yield of canola was very poor, especially relative to wheat. Maximum grain yields for wheat were 1.6 t/ha compared with 0.3 t/ha for canola. Wheat grain yields were reduced by more than 30% (or nearly 0.5 t/ha) by P deficiency, for canola the reduction was more than 70% (or about 0.15 t/ha) (Figure 1).

Colwell P values in 2019 were approximately half of those recorded in 2018 but most were still much higher than untreated levels. This shows that while P is strongly fixed in this red calcareous sandy loam, applications of P in one year can still have benefits at least into the year after application.

What does this mean?

The minimum Colwell P soil test for wheat in 2018 was about 11 mg/kg. Below this value, wheat would suffer substantial yield penalties if grown without P fertiliser. The same figure estimated from the 2019 wheat crop is about 15 mg/kg. Both of these critical levels are substantially lower than the current standard of 20-25 mg/kg for mallee-type soils. These values are probably low due to the very low production levels experienced in both seasons. Under these conditions, crops require very little P to maximise growth.

The canola was not harvested in 2018 so its sensitivity to low soil P levels could not be compared to wheat in that year, but in 2019 its critical level was lower than wheat (approximately 10 mg/kg compared to 15 mg/kg for wheat). This suggests that canola can grow without the need for P fertiliser at lower soil P reserves than wheat. However, it does not necessarily mean that canola should be grown with lower rates of P than wheat because the optimum rate for P fertiliser is determined by many factors such as value of the commodity and the long term goal for soil P reserves, not just crop sensitivity.

For this project, 2020 will be a critical year because it is the last growing season for the project and so far our data set for calibrating soil tests in current farming systems consists entirely of seasons drier than average and in many cases extremely dry. 2020 is our last chance to estimate soil critical levels for N, P, K and S under wetter conditions and thus have a more balanced data set.

Acknowledgements

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Soil and plant testing for profitable fertiliser use

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Key messages

- **Soil P and N status are highly variable across paddocks. Depending on variability, soil sampling intensity should be increased to sample more than one zone in a paddock.**
- **Low production zones tended to have lower soil P and higher soil N levels, suggesting that nutrient inputs might require adjustment to improve profitability.**
- **In 2019 the yield response in the Mallee to P fertiliser was highly variable across the paddock and was closely correlated to soil P status (Colwell with inclusion of PBI interpretation/DGT - proviso, only one paddock had been analysed at the time of writing).**

Why do the trial?

Precision Agriculture for variable rate fertiliser application demands a knowledge of the soil available nutrient variation across a paddock and an understanding of the likely responses to applied nutrients. Soil testing is shifting from surface sampling (0-10 cm) to deep sampling (GRDC Farm Survey 2016) however, farmers and advisers appear to be unsure on how to interpret soil test results to optimise fertiliser returns, especially with variable rate application of fertiliser. In 2016, it was estimated 15% of paddocks were regularly tested, as opposed to 40% in 2008 (GRDC pers. comm.)

How was it done?

Landmark, independent consultants and Farming Systems Groups including EPARF are partners in the project to raise understanding and awareness around issues dealing with nitrogen (N) and phosphorus (P) responses with variable rate fertiliser application, inclusive of undertaking intensive soil testing in different production zones across paddocks. APAL laboratories are undertaking the soil and plant analysis. CSIRO are analysing yield maps, performing the statistical analysis of yields achieved on the P and N rate strips, and reviewing the economic implications of 'informed' P rate applications based on soil testing.

Paddock trials 2019

Over 300 paddock-based trials were established in 2019 in SA and Victoria from close to 700 sampling zones. Production zones in paddocks were defined either by using historical yield maps or the farmers' long-term knowledge of the paddock. For two production zones in each paddock, a 1 ha soil sampling area was selected – the two zones were located in-line with the sowing direction. Sampling intensity for each 1 ha soil sampling area were 36 topsoil samples for available P (0-10 cm: Colwell, DGT, PBI) and six deep cores (0-10, 10-30, 30-60, 60-90 cm) for available N (NO_3 and NH_4) with the samples combined for each depth to generate one soil test value. Chloride was included in the analysis to determine whether sub-soil salinity inhibited yield.

In 150 of the 333 paddocks sampled in 2019, farmers sowed P rate strips across the paddock, ensuring the strips crossed the 1 ha soil sampling grids. Available soil P status and likely fertiliser P response rates were calculated from Colwell and DGT in association with PBI. The rates of P applied were informed by the soil test result and most sown strips included a 0 rate, farmer rate and double the farmer rate of applied P in situations predicted to be P responsive, and the inclusion of a half farmer rate for situations predicted to be non-P responsive. The P strips received the same N as applied by the farmer for the rest of the paddock. Tissue samples to check on tissue P status and possible nutrient deficiencies along with dry matter estimates were collected from each fertiliser rate strip between growth stage (GS) 16 and 32.

Fertiliser N response

In 2019 a number of paddocks also had different top-dressed N strips applied to generate N rate trials in paddocks where soil N variability was high, these were applied at the same time as the farmers applied in-crop urea. As with the P scenario, N trials had rates of N applied as informed by the starting soil N profile and most sown strips included a 0 rate, farmer rate and double the farmer rate of applied N in responsive situations, and the inclusion of half farmer rate for non-responsive situations.

Harvest and statistical analysis

Yield monitor data were used to calculate the yield for each P and N fertiliser rate strip. The yield achieved for each fertiliser rate strip within each 1 ha soil sampling area was used to correlate crop yield to soil P and N status. Harvest strip data within each of the two soil sampling zones was analysed for significant difference using a moving average t-test (Lawes and Bramley 2012) enabling the evaluation of nutrient treatment responses between zones and within zones. A partial gross margin analysis will be undertaken to calculate the change in income achieved from the different fertiliser rate strips.

What happened?

Soil N and P status 2019

A brief snapshot of the nutrient status across the Southern region revealed high variability of both N and P between the two production zones in each sampled paddock. There were opportunities identified within each agroecological zone for the establishment of both N and P trials. As an overall summary the N status was generally good and supported at least the production of a 2 t/ha wheat crop (Figure 1), without factoring in immobilisation/mineralisation. In general, the N status was higher for the low production areas which indicates N build up due to lower N removal caused by a soil constraint or low yields in seasons prior.

At a paddock level, P deficiency is driven by the ability of different soils to fix/absorb P sources as estimated from the PBI (Phosphorus Buffer Index). Quite often low production zones were associated with low extractable P, high PBI and relatively high soil N due to less utilisation of N sources and subsequent removal (Figure 2). In these circumstances simple replacement fertiliser strategies are unbalanced and are creating a wider gap between yield production zones.

Improved gross margins from more efficient fertiliser applications are expected if different production zones are assessed for the ability of the soil to provide the crop with adequate nutrients.

Paddock trials 2019

An example of the experimentation is presented for a paddock sown to wheat (Scepter - sowing date 15/5/2019) in the Victorian Mallee.

Soil P results

Soil P results for Colwell and DGT P, and PBI (Phosphorus Buffering Index, see Burkitt *et al*. 2002) are detailed in Table 1. In Zone 1 both soil tests predicted marginal P while in Zone 2 the DGT P soil test predicted deficient soil P. PBI was relatively high in Zone 2.

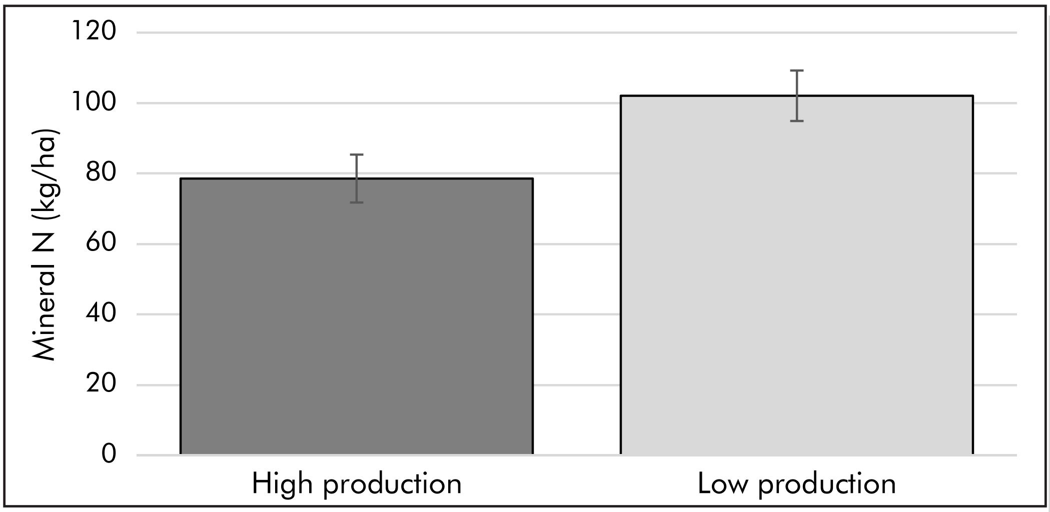

Figure 1. Overall soil mineral N status across the Southern region for allocated high production and low production zones within paddocks before the 2019 sowing season. Using the rule of thumb of 40 kg N/ha required for 1 t/ha grain, the low production zone supported 2.0 t/ha compared with 2.5 t/ha for the high production zone. Error bars represents standard error across all sampling sites in each zone.

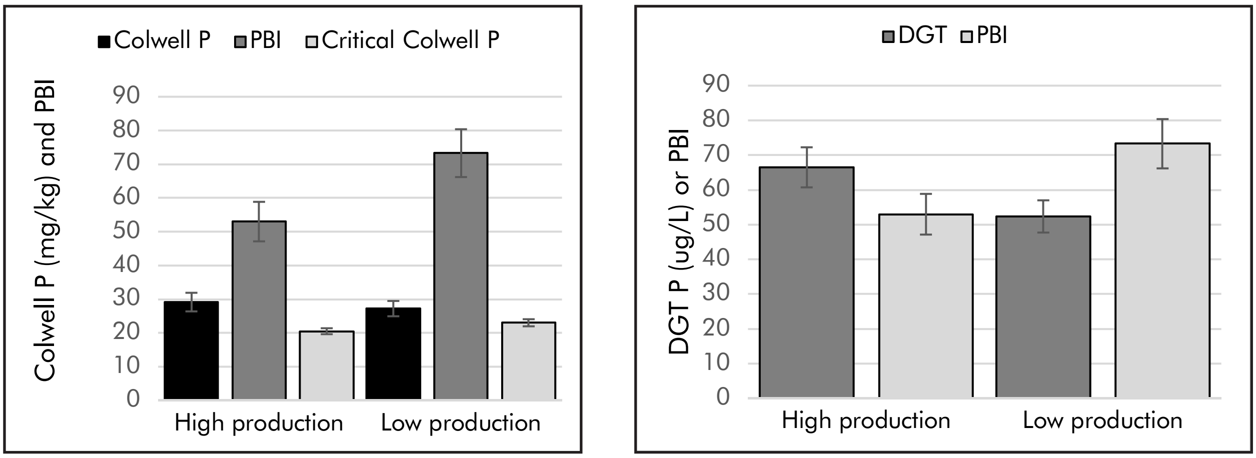

Figure 2. Overall soil P status across the southern region for allocated high and low production zones within each paddock as assessed by Colwell P (left) and DGT (right) together with PBI for each zone. Critical Colwell P was determined by the relationship generated in Moody, 2007. Critical DGT value for wheat is 64 ug/L (95% CI = 53-78 ug/L). Error bars represents standard error across all sampling sites in each zone.

Table 1. Mallee paddock - P test result pre-sowing 2019 (Colwell, DGT and PBI) for Zone 1 and 2.

P Test	Zone 1	Zone 2
Colwell P (mg/kg)	22	30
DGT P (μg/L)	42	12
PBI	64	135

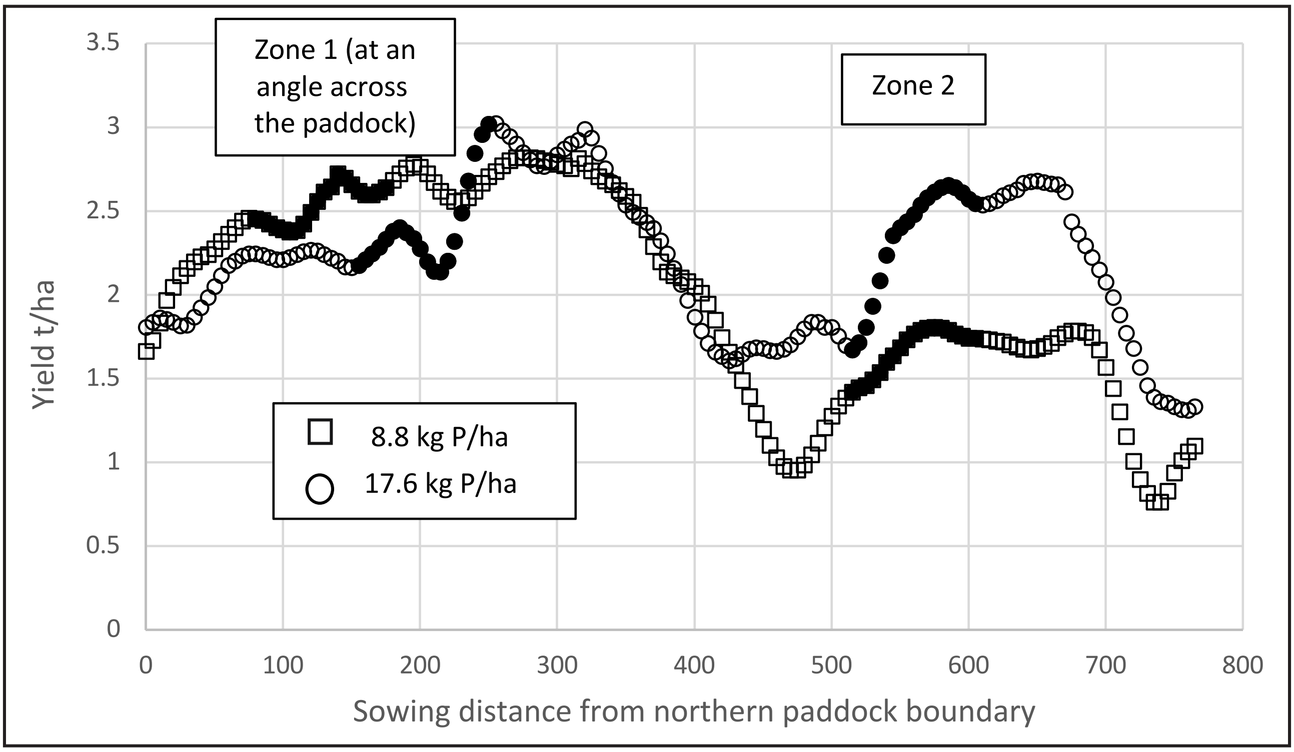

Figure 3. Strip yield (t/ha) for two rates of fertiliser P applied from paddock boundary to boundary, crossing two soil sampling areas. Solid black circles and squares indicate the yield achieved within the soil sampling areas for Zone 1 and 2.

Table 2. Yield response to four rates of fertiliser P applied at sowing in two zones.

	Average yield (t/ha) within production zone		Average yield (t/ha) entire strip
Rate (P kg/ha)	Zone 1	Zone 2	
0	2.51	1.76^a	2.16
4.4	2.60	1.76^a	2.24
8.8	2.59	1.67^a	2.01
17.6	2.32	2.34^b	2.22
Sign. difference	*ns*	*$P<0.05$*	

Zone 2: ^{a} and ^{b} denote significant difference

P rate trial

Four rates of P (as MESZ) were applied at sowing with double seeder width strips across the paddock through each zone (fertiliser applied at 0, 4.4. 8.8 and 17.6 kg P/ha) (all strips had urea at 45 kg/ha, 20.7 kg N/ha, applied at sowing). Urea at 75 kg/ha (34.5 kg N/ha) was top-dressed on the trial area on 28/6/2019.

Harvest yield map data was used to analyse the yield differences between P treatments in each of the two soil sampling areas (1 ha areas located in two distinct production zones in line of sowing). Statistical analysis was based on the t-test for comparing two strips (example Figure 3).

A significant difference in yield gain was found only in Zone 2 for the high rate of P applied (17.6 kg P/ha) (Table 2).

What does this mean?

Soil nutrient status is highly variable across paddocks and these initial results indicate that we need to sample more than one soil type/ production zone in a paddock. Indicative results indicate that intensive soil sampling of different production zones provides significant benefit in terms of P application (results from the N rate application strips had not been analysed at the time of writing).

This research project is ongoing until 2022, so further information and results will be available for paddocks monitored on Eyre Peninsula during the season.

References

Burkitt LL, Moody PW, Gourley CJP and Hannah MC 2002. A simple phosphorus buffering index for Australian soils. Aust. J. Soil Research 40, 497-513

Lawes RA and Bramley RGV 2012. A simple method for the analysis of on-farm strip trials. Agronomy Journal 104: 371-377

Moody, PW 2007. Interpretation of a single-point P buffering index for adjusting critical levels of the Colwell soil P test. Australian Journal Soil Research 45: 55-62

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Section 6

Section Editor:
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Weeds

Demonstrating integrated weed management strategies to control barley grass in low rainfall zone farming systems

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[1]SARDI, Minnipa Agricultural Centre; [2]University of Adelaide.

Location
Minnipa Agricultural Centre, paddock S3
Rainfall
Av. Annual: 324 mm
Av. GSR: 241 mm
2019 Total: 254 mm
2019 GSR: 234 mm
Soil type
Red sandy loam
Paddock history
2019: Compass barley
2018: Scepter wheat
2017: Volga vetch
Rainfall
27 m x 620 m x 3 reps (3 paddock seeder strips (27 m each) wide)

Key messages

- **In 2019 the IMI system had the lowest barley grass plant numbers.**
- **The Cultural Control strategy did not achieve the desired outcome of having a more even seed spread and increased competition in the inter row for barley grass weed control.**
- **The medic pasture produced low dry matter compared to the cereal systems, had the highest barley grass population and the lowest competitive ability with the barley grass.**
- **The loss of Group A herbicides to control barley grass within local pasture systems has the potential to change rotations and decrease farm profitability.**

Why do the trial?

Barley grass possesses several biological traits that make it difficult for growers to manage it in the low rainfall zone, so it is not surprising that it is becoming more prevalent in field crops in SA and WA. A survey by Llewellyn *et al*. (2015) showed that barley grass has now made its way into the top 10 weeds of Australian cropping in terms of area infested, crop yield loss and revenue loss.

The biological traits that make barley grass difficult for growers to manage in low rainfall zones include:

- early onset of seed production, which reduces effectiveness of crop-topping or spray-topping in pastures,
- shedding seeds well before crop harvest, reducing harvest weed seed control effectiveness compared to weeds such as ryegrass which has a much higher seed retention,
- increased seed dormancy, reducing weed control from knockdown herbicides due to delayed emergence, and
- increasing herbicide resistance, especially to Group A herbicides, used to control grass weeds in pasture phase and legume crops.

Barley grass management is likely to be more challenging in the low rainfall zone because the growing seasons tend to be more variable in terms of rainfall, which can affect the performance of the pre-emergence herbicides. Furthermore, many growers in these areas tend to have lower budgets for management tactics, and break crops are generally perceived as more risky than cereals. Therefore, wheat and barley tend to be the dominant crops in the low rainfall zone. This project is undertaking coordinated research with farming systems groups across the Southern and Western cropping regions to demonstrate tactics that can be reliably used to improve the management of barley grass.

How was it done?

On 27 March 2019 a meeting was held between seven growers, four MAC staff, one consultant and Dr. Gurjeet Gill to discuss the issue of barley grass in upper EP farming systems. A three year broad acre management plan (2019-21) was developed to be implemented with five different strategies to be tested and compared in a replicated broad acre farm trial on the MAC farm (Table 1).

These management strategies will be tested over the three year rotation with the focus on barley grass weed management and weed seed set.

Three replicated broad acre strips of three seeder widths (27 m wide) were sown in MAC paddock S3 on 17 May. Barley was sown at a seeding rate of 65 kg/ha, with GranulockZ fertiliser at 50 kg/ha, and 1.2 L/ha glyphosate, 1.5 L/ha trifluralin and 400 g/ha diuron. The 'Higher cost' chemical strategy hay cut barley was sown at 95 kg/ha, and the 'Cultural control' double seeding rate was inter row sown with a final seeding rate of 120 kg/ha and was only sprayed with 1.2 L/ha glyphosate. The IMI strategy with Scope barley was sprayed on the 16 July with 700 ml/ha Intervix.

The self-regenerating medic pasture was sprayed on 17 May with propyzamide @ 1 L/ha, followed with Targa Bolt @ 190 ml/ha, Broadstrike @ 25 g/ha and clethodim @ 250 ml/ha on 2 July. Due to high levels of barley grass escapes it was also sprayed with paraquat @ 1.2 L/ha on 3 September. The hay cut occurred on 26 September prior to which it was sprayed with 1.8 L/ha Weedmaster DST on 3 September.

Crop establishment, dry matter, barley grass numbers, barley grass seed set, grain yield and quality were assessed during the growing season. The dry matter hay cut was taken on 26 September and the other dry matter cuts a week later on 3 October. Late barley grass samples were taken and panicles sent to Roseworthy for the assessment of barley grass seed set and herbicide resistance testing. The 27 m strips were harvested with the plot header (3 times) per treatment on 28 October and grain quality was assessed.

What happened?

There were differences in plant establishment with the higher seeding rates resulting in an increase in barley plant numbers, as shown in Table 1. The highest plant establishment was in the Higher cost chemical strategy (sown at 95 kg/ha for a hay cut), and the Cultural Control strategy (sown at 120 kg/ha).

The Cultural Control strategy was a double sown system, with 60 kg/ha barley seed spread on top of the ground and 60 kg/ha sown over the top to give a total seeding rate of 120 kg/ha. Although this strategy had higher plant numbers, the seeding system did not achieve the desired outcome of greater seed distribution to increase competition with weeds, due to seed being buried in a dry part of the raised furrow reducing the germination. The cultural control strategy resulted in similar barley grass weed control as the district practice.

Barley grass weed numbers increased between 25 June and 28 August, indicating late germination patterns requiring a vernalisation (cold) are present in this population. Barley grass weed numbers were lowest in the IMI strategy. The medic pasture systems had the highest barley grass weed population with an average of 127 barley grass weeds/m2. Despite using propyzamide @ 1 L/ha on 17 May with 7.8 mm of rainfall in the following two days to activate the chemical, weed control in the pasture phase was disappointing. Some barley grass had already germinated before the application of propyzamide, which could have reduced its efficacy.

Table 1. The five different management strategies and crops for each season (2019-2021) at Minnipa Agricultural Centre, paddock S3.

Strategy	2019	2020	2021
District Practice	Compass barley	Self-regenerating medic pasture (Gp A)	Scepter wheat
IMI system	Scope barley (with IMI (Gp B) applied)	Sultan sown medic pasture (IMI tolerant)	Razor CL wheat (IMI tolerant)
Higher cost herbicide	Compass barley for hay cut sown at higher seeding rate	Scepter wheat (Gp K - Sakura) with harvest weed seed control (HWSC) chaff lines and burning	Spartacus barley (with IMI if needed)
Two Year Break	Self-regenerating medic pasture (Gp A)	TT canola (Gp C, Triazines)	Scepter wheat with harvest weed seed control (chaff lines and burning)
Cultural Control	Compass barley at double seeding rate	Self-regenerating medic pasture (Gp A)	Scepter wheat with no row spacing for competition and HWSC

IMI = imidazolinone herbicides (Gp B).

Table 2. Plant and barley grass weed numbers, dry matter, yield and grain quality in GRDC Low Rainfall Barley Grass Management farm trial, 2019.

Barley grass weed control strategy, barley variety and seeding rate (kg/ha)	Crop establishment 25 June (plants/m^2)	Early barley grass numbers 25 June (plants/m^2)	Late barley grass numbers 28 Aug (plants/m^2)	Late dry matter 3 Oct (t/ha)	Yield 28 Oct (t/ha)	Protein (%)	Screenings (%)
District Practice Compass (70 kg/ha)	134	2.3	8.5	6.0	2.08	14.2	4.4
IMI system Scope (70 kg/ha)	128	1.7	0	5.0	1.06	15.1	10.5
Cultural Control Compass (120 kg/ha)	187	3.7	8.3	5.5	1.84	13.5	4.0
Higher cost herbicide (hay) Compass (95 kg/ha)	164	3.3	3.6	6.8*	-	-	-
Two Year Break Self -regenerating medic pasture	146	123.5	129.5	0.9	-	-	-
LSD (P=0.05)	*28*	*29.6*	*8.0*	*0.9*	*0.4*	*1.1*	*1.2*

**Sampled on 26 August*

The pasture system also received Targa Bolt @ 190 ml/ha, Broadstrike @ 25 g/ha and clethodim @ 240 ml/ha on 2 July, with poor barley grass weed control. Poor efficacy of the Group A herbicides is likely to be associated with resistance to this group. Paraquat @ 1.2 L/ha was sprayed in the pasture phase on 3 September to prevent weed seed set.

Compass barley sown at 95 kg/ha for a hay cut produced the greatest dry matter, with the Scope barley producing significantly lower dry matter and grain yield than Compass. Grain protein in Scope barley was higher than Compass, which was most likely due to its lower yield and higher screenings. The medic pasture produced lower dry matter compared to the cereal systems and had a lower competitive ability with barley grass compared to barley.

What does this mean?

Barley grass seed germination occurred between late June and August indicating a late germinating population that avoids early weed control with pre-sowing herbicide applications. Germination patterns of the barley grass populations from different low rainfall regions has been assessed at Roseworthy as part of this research project.

The Cultural Control strategy with a double inter row sown system @ 120 kg/ha did not reduce the barley grass numbers compared to the district practice system, as it did not achieve the desired outcome of having a more even seed spread and increased competition in the inter row for barley grass weed control.

The IMI system had the lowest barley grass weed numbers indicating the Group B system is still working at MAC, and is an effective strategy. However, the IMI herbicide system tends to be quite prone to evolution of resistance in weeds. Therefore strategic use of the IMI herbicide system must be used to maximise the effectiveness and long term use of this system. Growers also need to be aware of herbicide breakdown and plant back periods, especially in low rainfall seasons to avoid bare paddocks.

The medic pasture produced lower dry matter compared to the cereal systems. It also had the highest barley grass weed population and the lowest competitive ability with the barley grass compared to the barley systems. The high levels of barley grass escapes when sprayed with Group A herbicides indicated herbicide resistance is becoming a major issue on MAC and in this region. The loss of Group A chemicals within our pasture break system has the potential to totally change farming systems. Currently farmers on upper EP rely on self-regenerating medic based systems with a profitable livestock enterprise, with grass control applied to prevent weed seed set in spring. The loss of the ability to control barley grass weeds using Group A herbicides will result in medic pasture having to be sprayed out using glyphosate in spring. This will reduce the feed base and carrying capacity, incur later sowing times in the cropping phase to gain weed control or more cropping dominate systems with other break crops (canola, vetch, lentils) and alternative herbicide groups which will increase risk and impact on profitability.

To ensure Group A resistance is kept in check, farmers may want to make sure any suspected resistant plants are dealt with in pasture systems by following up with a knockdown herbicide as early as possible to prevent seed set. Always have follow up options to control any survivors and to preserve Group A herbicides. Using alternative chemical groups by including canola or introducing Clearfield systems as a different rotational break may also be an option. The loss of Group A herbicides within current farming systems may result in high barley grass seed bank carry over. Reducing the weed seed bank is pivotal to managing all grass weeds.

If barley grass herbicide resistance is suspected, the first step is to test the population to know exactly what you are dealing with. This project has the ability to test barley grass populations for suspected herbicide resistance over the next two seasons, so contact Amanda Cook if you would like an Eyre Peninsula population tested. This paddock scale MAC research is ongoing for the next two seasons to assess the different barley grass weed management strategies.

Acknowledgements

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Survey of current management practices of barley grass in low rainfall zone farming systems

Amanda Cook[1], Gurjeet Gill[2], Naomi Scholz[1], Catherine Borger[3], Birchip Cropping Group (BCG), Central West Farming Systems (CWFS), Eyre Peninsula Agricultural Research Foundation (EPARF), Grain Orana Alliance Inc (GOA), Kellerberrin Demonstration Group, Lakes Information and Farming Technology, Mallee Sustainable Farming Systems Group (MSF), Mingenew Irwin Group (MIG), South East Premium Wheat Growers Association (SEPWA), Upper North Farming Systems Group (UNFS), WA No-till Farmers Association (WANTFA)

[1]SARDI, Minnipa Agricultural Centre; [2]University of Adelaide; [3]DPIRD, Northam WA

Key messages

- **The survey received 224 responses from growers aligned with the different farming systems groups participating in this project.**
- **39% of the grower respondents identified barley grass as having a medium to high impact on their cropping systems.**
- **40% of the grower respondents feel that barley grass emergence patterns have changed over the last 10 years and that it now emerges later in the season.**
- **51% of growers thought barley grass had become more common in their cropping paddocks. Some of the factors responsible for the increase in barley grass include delayed emergence and early seed-set, low efficacy of pre-emergence herbicides, particularly during dry starts to seasons, resistance to group A herbicides, continuous cereals in the system and wide crop row spacing.**

Why do the survey?

Barley grass is now one of the top 10 weeds of Australian cropping in terms of area infested, crop yield loss and revenue loss (Llewellyn et al. 2016). Barley grass has several biological traits that make it difficult for growers to manage it in the low rainfall zone, so it is not surprising that it is becoming more prevalent in field crops in SA and WA.

Through recent GRDC investment, the research project ‘Demonstrating and validating the implementation of integrated weed management strategies to control barley grass in the low rainfall zone farming systems’ (hereby referred to as GRDC Low Rainfall Barley Grass) has commenced. An initial grower survey of current practice and attitudes towards barley grass was undertaken in 2019 to be used as the baseline to assess changes in grower attitudes and any change in practices after the completion of the three-year project.

How was it done?

An electronic survey was developed by Amanda Cook, Naomi Scholz, Gurjeet Gill and Catherine Borger using Survey Monkey and distributed via email to the grower members of different farming systems groups collaborating in the GRDC Low Rainfall Barley Grass project. The survey was used to collect information on grower current management practices and attitudes towards barley grass.

The survey link was sent to grower groups on 4 July 2019 and closed on 20 September, giving farming systems groups 10 weeks to promote the survey to growers. The survey closed before the start of field days and crop walks, and before discussing the project and any outcomes from the 2019 GRDC Low Rainfall Barley Grass project.

What happened?

There were 224 grower respondents to the initial GRDC Low Rainfall Barley Grass survey through the farming systems grower groups across the southern and western cropping regions. The first survey question asked respondents which Farming Systems group they most commonly associated with. Respondents identified Birchip Cropping Group (BCG) 3%, Central West Farming Systems (CWFS) 4%, Eyre Peninsula Agricultural Research Foundation (EPARF) 27%, Grain Orana Alliance Inc (GOA) 8%, Kellerberrin Demonstration Group 4%, Lakes Information and Farming Technology 2%, Mallee Sustainable Farming Systems Group (MSF) 8%, Mingenew Irwin Group (MIG) 1%, South East Premium Wheat Growers Association (SEPWA) 4%, Upper North Farming Systems Group (UNFS) 11%, WA No-till Farmers Association (WANTFA) 10%, and ‘other’ 19%. Of the ‘other’ groups, 13% were Western Australian growers.

The second survey question asked growers how big an impact barley grass had in the cropping and pasture phase of the farming system. 10% of responses indicated barley grass had a high impact as a weed within their crop and 11% within the pasture phase (Figure 1). 29% indicated barley grass had a medium impact as a weed within their cropping phase, and 17% within the pasture phase. 17% indicated barley grass had a low impact as a weed within their cropping phase, and 8% within the pasture phase, and 8% indicated it was not an issue.

The third survey question asked growers about barley grass management strategies, and the level of effectiveness of current management strategies (low, moderate, high or don't use). The highest rating for effectiveness of management strategies for barley grass were rotation/break crops, two-year breaks, pasture or crop topping, spraying grasses out of crop and cereal choice e.g. barley. The management strategies for barley grass management which were not used were burning, narrower row spacing, harvest weed seed control or hay cutting. Other management strategies which may have been used (as a medium strategy) were crop competition by increasing seeding rate, sowing later or sowing early.

The fourth survey question asked growers about the level of effectiveness of current herbicides for barley grass management. Grass selective herbicides in pastures and other break crops had the highest level of effectiveness of current herbicides, followed by prosulfocarb (Sakura).

The fifth survey question asked if growers thought the barley grass germination pattern had changed over the last 10 years. 40% of growers thought barley grass now germinates later in crop, 19% thought the germination pattern was unchanged, 15% thought barley grass now germinated earlier in their farming systems and 26% were unsure.

The next question asked if barley grass had become more common in cropping paddocks. 51% of growers thought barley grass had become more common in their cropping paddocks, 43% said it was not more common, and 6% were unsure.

The next survey question asked if growers thought they may have herbicide resistance issues in barley grass. 23% of growers thought they may have herbicide resistance issues in barley grass, 53% thought they didn't have herbicide resistance issues, and 24% were unsure. Of the 23% of growers that thought they may have herbicide resistance issues, most were concerned about Group (Gp) A resistance, mostly fop's but also some dim's. Other herbicides growers were concerned about were Gp B (including IMI), Gp L (paraquat), Gp M (glyphosate) and Gp D (trifluralin).

The eighth question asked growers about their current row spacing and seeding system. Current row spacings for cropping ranged from 15-70 cm (6"-19.5") with 43% having 30 cm (12") wide rows, 23% having 25 cm (10") and 20% having 22.5 cm (9") row spacing. 88% of growers used direct drill knife point systems, and 9% used disc seeding systems, with 3% using conventional cultivation systems. Of the direct drill systems, five growers were using paired row or splitter systems to increase seedbed utilisation.

The final survey question asked growers the current wheat and barley seeding rates used. Wheat seeding rates ranged from 27 kg/ha to 120 kg/ha with 47% falling in the 60-70 kg/ha seeding rate range (60 kg/ha 18%, 65 kg/ha 12%, 70 kg/ha 17%). Barley seeding rates ranged from 34 kg/ha to 120 kg/ha again, with 47% falling in the 60-70 kg/ha seeding rate range (60 kg/ha 18%, 65 kg/ha 13%, 70 kg/ha 16%).

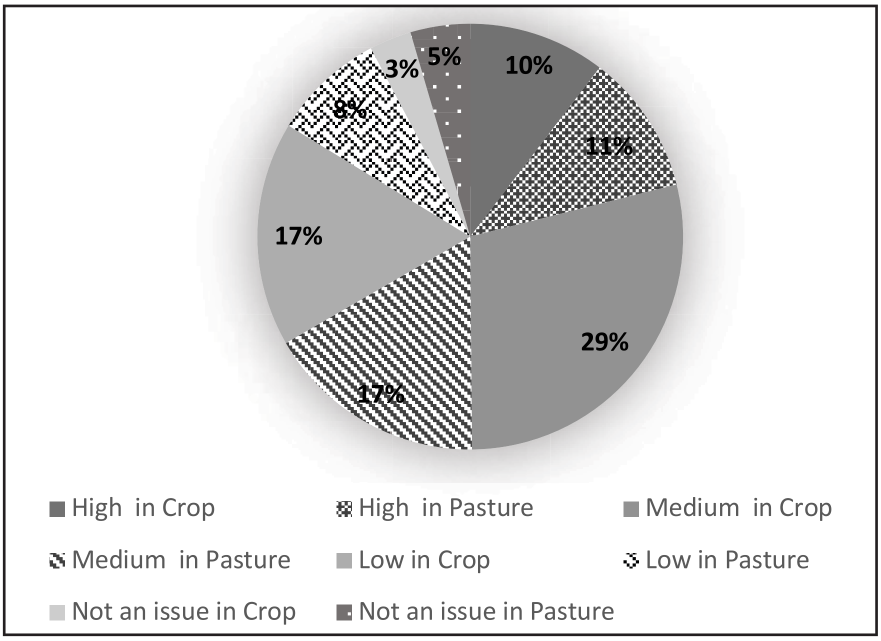

Figure 1. Growers response to the impact of barley grass as a weed within the crop or pasture phase.

The final question gave growers the opportunity to suggest possible contributing factors to the increase in barley grass on farms in the regions. Some of these responses have been presented below with the number of other similar responses indicted in brackets (number of growers):

- Pre-emergent chemical effectiveness and herbicide efficacy is limited in dry conditions (11 growers) and low rainfall starts presents a challenge to grass control in the cropping cycle. A pre-emergent chemical with good activity on barley grass in wheat and barley is needed.
- The diverse nature of its ability to set seed and its time of germination are making it hard to manage (4). There are many factors with non-wetting sand (4) that make this worse due to varied germinations (8) and lack of pre-emergent activation.
- Seems to be mostly a problem when sheep and pasture is in the rotation (7). Spray topping is not as effective (7), even with two applications, need a pre-emergent in wheat that is good on barley grass. Sakura is a costly option (4).
- Resistance to group A chemistry has developed from a year in year out pasture-wheat rotation (4).
- Failure from grass sprays in pasture phases are becoming more common in rotations, one year in one year out (4).
- Slowly turning into a major problem. Using double pasture breaks (3), canola and brown manure vetch (3) to get higher success in control. Requires vigilance and fussiness which includes at this stage spot-spraying resistant (tested and verified) patches as well as paddock hygiene.
- Easy to control with rotation or IMI system/Clearfield varieties (10), but developing IMI herbicide resistance will be an issue (3). We choose rotation because the IMI system reduces crop rotation options. Barley grass soon becomes a problem in continuous cereals. In dry seasons Clearfield varieties are a game changer.
- We have found patches of barley grass less tolerant to some knockdowns i.e. need more robust rates to achieve a good kill.
- It is persisting longer in the seed bank and coming up later than normal (4), this change has been quite quick over the last 5-7 years.
- Some newer barley varieties e.g. LaTrobe, Spartacus have more upright early growth, seem less competitive and have low early vigour - not as good for competing with weeds. Need wheat and barley varieties with good early vigour, and prostrate growth up to mid tillering.
- Weed seed collection not an option because it sheds seed too early, hay might be option or silage. Later germination hard because pre-ems not working, Sakura and Avadex too high a cost.
- Pre-ems are the only effective option where Group A has failed. Sets seed too early for anything else.
- Disc and wide rows results in more staggered germination of barley grass in season and following crops. Same method results in less early crop competition (2). Non wetting sands storing seed banks (4) especially through a run of dry seasons. Dry sowing has denied a pre-emergent knockdown (8).
- Without Sakura we would have real problems. But it will only work so long. Would like to be able to terminate pastures earlier but can't because need livestock feed.
- Have only had problems recently due to dry sowing (8) most of the crop. In years where there is early rain, have no issues with barley grass. Also hay freeze pastures before barley grass seed set so have driven down numbers for a long time now. They are only creeping in from the edges when dry sowing.

What does this mean?

The initial grower survey of current practice and attitudes towards barley grass across the southern and western low rainfall zones was undertaken as the baseline to assess changes in grower attitudes, and any change in practices after the completion of the GRDC 'Demonstrating and validating the implementation of integrated weed management strategies to control barley grass in the low rainfall zone farming systems' project. Some of the major factors responsible for the increase in barley grass identified by the growers include: delayed emergence and early seed-set, low efficacy of pre-emergence herbicides particularly during dry starts to seasons and, resistance to group A herbicides, continuous cereals in the system and wide crop row spacing.

Each region has developed a three-year management plan for a farm based replicated demonstration to implement current strategies to manage barley grass in the local area. The outcomes from the research will be extended over the course of the project. A barley grass survey for herbicide resistance and germination patterns will also be undertaken within the project. Growers can contact their local farming systems group (listed above) if they have suspected barley grass resistance which they would like tested.

References

Llewellyn, *et al* (2016) Impact of weeds on Australian grain production.

Acknowledgements

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Capturing barley grass seeds in broad acre paddocks

Amanda Cook, Ian Richter and Neil King
SARDI, Minnipa Agricultural Centre

Location
Condada: Matt Cook
Rainfall
Av. Annual: 324 mm
Av. GSR: 241 mm
2019 Total: 224 mm
2019 GSR: 209 mm
Paddock history
2019: Scepter wheat
2018: Emu Rock wheat
2017: Self-regenerating grass free medic pasture
Soil type
Red Sandy loam
Plot size
Paddock monitoring

Key messages

- **In 2019, approximately 40% of barley grass seeds had already dropped on the ground before the first swathing opportunity.**
- **Barley grass seed retention declines with every successive week and by crop maturity retained only 20% of its seed on the head.**
- **If growers are aiming to collect grass seed using harvest weed seed management strategies (chaff carts or windrows) they need to harvest grassy paddocks as early as possible to maximise weed seed collection.**

Why do the trial?

Barley grass continues to be a major grass weed in cereal cropping regions on the upper Eyre Peninsula (EP). Swathing a cereal crop involves cutting and collecting the cereal crop and weeds into windrows at 20 to 40% grain moisture and allowing it to dry. Having the weed seeds cut and in the windrow before the seed heads shatter and before tillers fall over (lodging), may allow greater weed seed collection when using a chaff cart or windrows. Swathing early then harvesting for weed seed collection needs further evaluation as it may provide farmers with another tool for integrated weed management, especially for barley grass that matures and sheds seed before crops ripen.

How was it done?

Crop and weeds were cut at 17 cm height (front cutting height) at four quadrats over the harvest period to assess barley grass seed retention. Crop and grass weeds were separated to measure weight and weed seed head length, number of barley grass seeds and calculate potential weed seed capture. Surface soil was also collected, and barley grass seeds were cleaned from the soil sample and weighed to calculate the weed seed which would have dropped before swathing or was below 17 cm in height.

What happened?

At Minnipa, on the upper EP, the 2019 growing season rainfall was decile 4 (below average). The season had an early break in late April and ideal May seeding conditions, with just below average rainfall for winter. However, spring was drier than normal, but 42 mm of rain in late September enabled crops to maximise grain fill, resulting in above average grain yields.

Swathing wheat at Heddle's did not occur in 2019 due to low grass weed numbers. However, data for barley grass seed drop in crop before harvest was still captured by monitoring grass patches in a cereal crop weekly over a six week period from the beginning of harvest (1 October) at Cook's (Table 1).

Plant cuts and soils were collected using 50*50 cm quadrants, with four samples collected per timing, to assess the amount of barley grass which could have been captured if early swathing of a cereal crop had occurred.

The results obtained in 2019 are largely consistent with assessments in previous years (Figure 1).

Table 1. Wheat plants and barley grass seeds/m² from the beginning of harvest 2019 at Cook's.

Date	Grain moisture (%)	Wheat (plants/m²)	Barley grass seed heads/m² above 17 cm	Barley grass seeds/m² above 17 cm	Barley grass seed heads/m² below 17 cm	Total Barley grass seeds/m² below 17 cm	Barley grass seeds/m² for weed seed collection* (%)
1 Oct	25.5	145	77	1621	77	1138	59
10 Oct	-	119	60	1466	17	735	67
18 Oct	29.2	99	85	631	28	2041	24
25 Oct	25.7	117	34	461	5	584	44
1 Nov	15.9	91	218	1390	36	3862	26
7 Nov	10.8	125	47	368	13	1399	21

**(Barley grass seeds/m² above 17 cm)/(Barley grass seeds/m² above 17 cm + Total Barley grass seeds/m² below 17 cm) multiplied by 100*

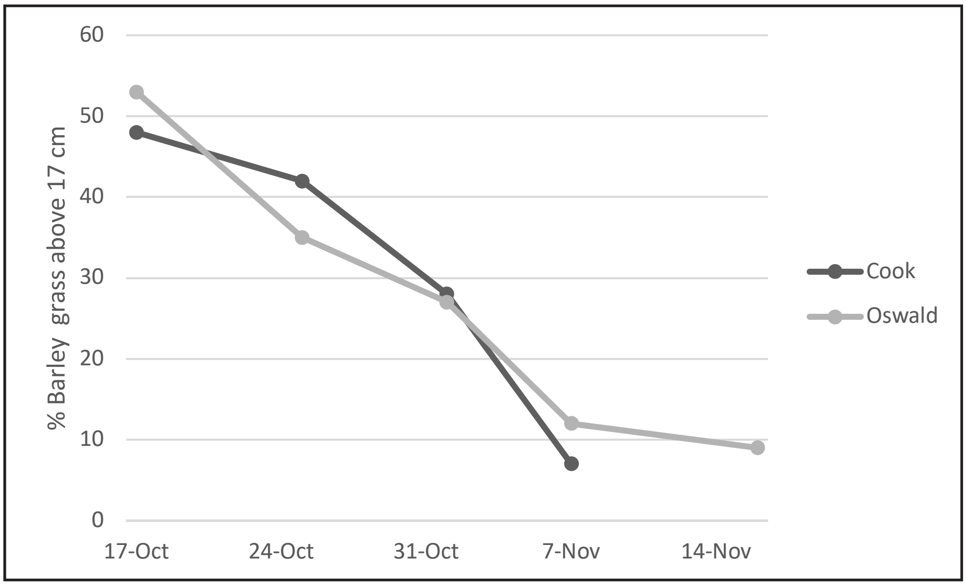

Figure 1. Barley grass seed/m² for potential harvest weed seed capture above 15 cm at harvest 2017 at Cook's and Oswald's.

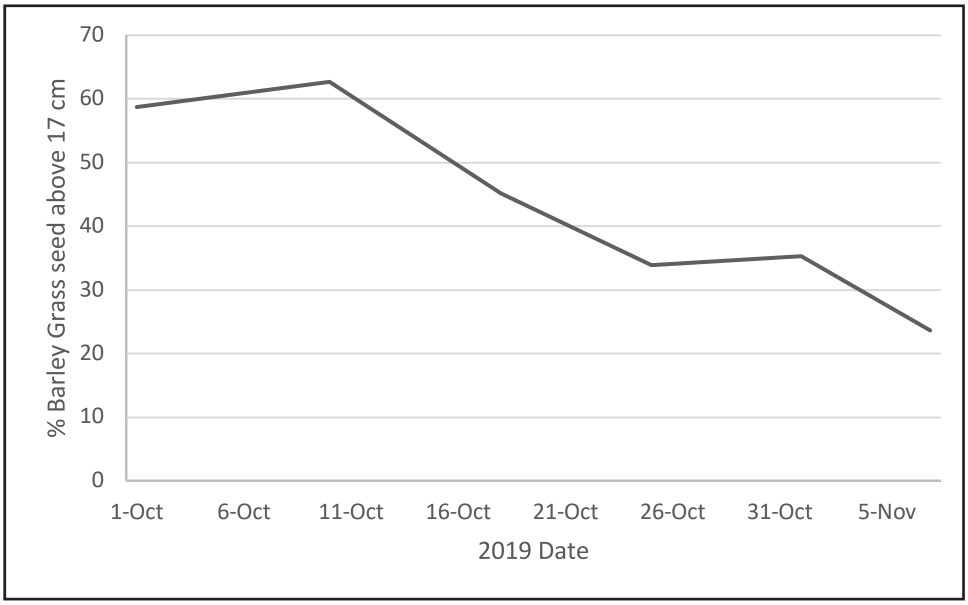

Figure 2. Barley grass seeds (%) for potential harvest weed seed capture above 17 cm at harvest 2019 at Cook's.

In the 2016 season, 65% of barley grass seed had already dropped onto the ground by 27 October in Heddle's swathed paddock. In 2017 the amount of barley grass seed which could potentially be collected using swathing of the crop was 50% when grain moisture was above 25% (Figure 1). In 2017 harvest generally started in the Minnipa area in late October/early November, and only 30-40% of barley grass seed was still in the heads or above 15 cm during this time.

At harvest 2019, the first opportunity for swathing a cereal crop was early October with the grain moisture being around 25%. At this stage, the opportunity to collect barley grass seed heads into the swathing row was approximately 60% (i.e. 40% had already shed). Over the next three weeks the amount of barley grass seed which could be collected dropped back to 35%. By 5 November when the paddock was harvested the potential to collect barley grass seed heads into the harvester at 17 cm cutting height was 21%.

What does this mean?

The grass weed seed collection data showed the opportunity to collect barley grass weed seed is greater earlier in the season. Swathing a cereal crop may be an option to increase barley grass weed seed capture rather than waiting until full crop maturity. The barley grass seed retention will decline with every successive week and likely to be between 10-20% at full crop maturity. If growers are aiming to collect grass seed using harvest weed seed management strategies (chaff carts or windrows), they need to harvest grassy paddocks as early as possible to maximise the weed seed collection.

This is the final season of this research to increase knowledge of barley grass weed seed management in current farming systems.

Acknowledgements

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Monitoring barley grass in broad acre paddocks

Amanda Cook[1], Scott Gillet[2], Terry Traeger[3], Ian Richter[1], and Jake Hull[1]

[1]SARDI, Minnipa Agricultural Centre; [2]Wisdom Data and Mapping, Loxton; [3]Drone View Photography, Cleve

Location
Minnipa Ag Centre, paddock S4
Rainfall
Av. Annual: 324 mm
Av. GSR: 241 mm
2019 Total: 254 mm
2019 GSR: 234 mm
Paddock history
2019: Scepter wheat
2018: Volga vetch
2017: Spartacus barley

Location
Minnipa Ag Centre, paddock N5S
Paddock history
2019: Self-regenerating medic pasture
2018: Scepter wheat
2017: Self-regenerating medic pasture

Location
Minnipa Hill
Rainfall
Av. Annual: 324 mm
Av. GSR: 241 mm
2019 Total: 237 mm
2019 GSR: 233 mm
Paddock history
2019: Self-regenerating medic pasture
2018: Scope barley
2017: Mace wheat

Location
Yaninee
Rainfall
Av. Annual: 233 mm
Av. GSR: 226 mm
Paddock history
2019: Scepter wheat
2018: Mace wheat
2017: Self-regenerating medic pasture

Key messages

- **UAV imagery with skilled specialist analysis has the potential to identify weed issues in paddocks.**
- **It was easier to identify grass weed patches in legume and pasture crops than cereal crops.**
- **Data capture and analysis for analytical purposes such as grass weed mapping in individual paddocks will be beyond most farm enterprises unless farmers have a special interest in this area.**
- **Grass patches were more reliably identified using UAV data captured at higher resolutions.**
- **Barley grass resistance to Group A herbicides has been detected several times throughout the project, so be aware it may be present in current farming systems.**

Why do the trial?

Barley grass continues to be a major grass weed in cereal cropping regions on upper Eyre Peninsula (EP). The use of unmanned aerial vehicle (UAV) technology to identify and assess barley grass populations in paddocks and monitor potential resistant populations may be a useful tool for farmers. This approach was tested in three paddocks on upper EP Minnipa Agricultural Centre (MAC), Minnipa Hill and Yaninee using a UAV during the 2017, 2018 and 2019 growing seasons at three different timings, with paddock transects conducted to verify grass weed density in paddocks. In 2019 grass weed escape paddocks were targeted at MAC and Condada in the final flights.

The aim of the research was to determine if the UAV imagery could monitor the grass weed populations across seasons in crops and pastures, if resistant weed patches were continually in the same area of the paddock and if the information could be useful for farmers to adopt this method to better target grass weed control.

How was it done?

In-crop paddock monitoring for grass weed populations

Grass weeds were assessed in crop or pasture at eight paddock-marked GPS points, and in 2018 and 2019 the sites were also marked in the paddock with a large corflute sign visible in the imagery, with six or more counts taken at each sample point and each timing during the season. This was used to verify the UAV data captured at two times during the cropping season. Extra sampling points in the paddock were targeted if more information was needed to verify the imagery. The paddock photos were captured on an iPad with 'Avenza Maps' linked to the location in the paddock.

In 2019, grass weed assessments were undertaken on:

- North's Minnipa Hill Pasture Paddock (self-regenerating medic pasture) 4 June, 16 June
- MAC S4 (Scepter wheat) 3 June, 16 June, 6 August
- Yaninee (Scepter wheat) 4 June

Location
Condada
Rainfall
Av. Annual: 224 mm
Av. GSR: 209 mm
Paddock history
H12
2019: Self-regenerating medic pasture
2018: Sown grazing cereal
2017: Self-regenerating medic pasture
H5
2019: Lentils
2018: Mace wheat
2017: Self-regenerating medic pasture
Soil types
Red loams
Plot size
Paddock monitoring

- MAC North 5 South (self-regenerating medic pasture) 27 August
- Condada (lentils) 28 August
- Condada (self-regenerating medic pasture) 28 August

UAV imagery

UAV data were captured twice in each paddock during the 2019 cropping season. The UAVs used were either a DJI Matrice 100 with both NIR and RGB sensors or a Mavic Pro with RGB sensors. In 2019 the UAVs were flown at a height of 120 metres and a smaller 10 ha area at 40 metres to increase the detail of the information captured. Due to the low barley grass weed numbers in the paddocks the final flight targeted paddocks with barley grass weed escapes in pulse and pasture paddocks.

'Training features' were created which highlighted areas of high weed infestation within the image. These areas were identified by matching photos from the ground with the aerial imagery. Originally, training features also aimed to identify other features such as clean crop areas, but the training process was found to be more accurate when a single type of weed pixel was the focus of analysis. This currently needs to be done separately for each image flown, which is a labour-intensive process.

Data analysis of UAV imagery

To analyse weed locations at a whole paddock level using the UAV imagery, geospatial analysis tools were used to automate the selection of likely weed infestation areas. A map of the paddock with the UAV coverage was generated from ArcGIS Desktop as a geo-pdf to enable collection and analysis of field data. This is a map file which can be used in a range of devices. With this file loaded to the 'Avenza Maps' app on a tablet, photos and comments with GPS locations were collected. This data was then added to ArcGIS and used to interpret the UAV mapping.

The Spatial Analyst extension within ESRI's ArcGIS Desktop software was used to carry out a 'Maximum Likelihood' spatial classification. This classification uses small parts of the image selected by the user as 'training features' for deciding which category each pixel of the image most likely fits into. This classification method is based entirely on the spectral (colours through different bands of light) characteristics of the imagery. Training features were created which highlighted areas of high weeds, low weeds/crop features and bare ground.

What happened?

In 2019 the initial paddocks monitored were two cereal crops and one self-regenerating medic pasture at North's block on Minnipa Hill. The self-regenerating medic pasture initially had high grass weed numbers.

A paddock at Yaninee was wheat sown on 7 May with Scepter wheat @ 60 kg/ha and 18:20:0:0 at 50 kg/ha, and pre-emergent herbicides of 1 L/ha Treflan and 800 ml/ha Ultramax. Post emergent herbicides were MCPA LVE @ 400 ml/ha, 5 g/ha Ally and ZMC micromiz chelate @ 3 L/ha. The wheat was harvested on 12 November and yielded 1.5 t/ha at H1 grade.

MAC paddock S4 was sown on 14 May with Scepter wheat at 70 kg/ha and 50 kg/ha of Granulock Z fertiliser. Pre-emergent herbicides applied were of 1.2 L/ha Roundup DST, 40 ml/ha Hammer, Jetti Duo @ 1.8 L/ha and Ester 680 LVE at 450 ml/ha. The seed was pre-treated with 0.105 L/t Gaucho and 0.084 L/t of Vitaflo. Post emergent herbicide of Tigrex @ 750 ml/ha was applied on 17 June.

At Minnipa the 2019 growing season rainfall was 234 mm, decile 4 (below average), with the crop yielding 2.14 t/ha due to timely September rain which maximised grain fill.

UAV flights were conducted on the dates shown in Table 1. MAC S4, North's Minnipa Hill and Yaninee were flown early. The pasture was flown again after a grass herbicide application but with only low grass weed numbers and grasses dying, so only the two flights were undertaken in these paddocks in 2019. As a result of the low grass weed numbers the final flights in August targeted paddocks in which grass weed escapes were visible at Condada (lentils and pasture) and MAC North 5 South (pasture) to capture and identify the grass weed escapes.

Analysis of UAV imagery in 2019

'Training features' were created which highlighted areas of high weed infestation within the image. These areas were identified by matching photos from the ground with the aerial imagery (example Figure 1 a-c). For each site imaged at higher resolution (drone flown at 40 m height) patches of likely barley grass where identified and marked using cross referencing with photos taken on the ground. Grass patches within a measurable distance from fixed points such as fence posts were also identified.

Table 1. UAV image capture flights conducted at 40 m and 120 m above the ground in 2019.

Location	Crop	Flights		
North’s Minnipa Hill	Medic pasture	4 June	16 June	
MAC S4	Scepter wheat	3 June	16 June	6 August
Yaninee	Scepter wheat	4 June		
Condada	Lentils			28 August
Condada	Medic pasture			28 August
MAC N5S	Medic pasture			27 August

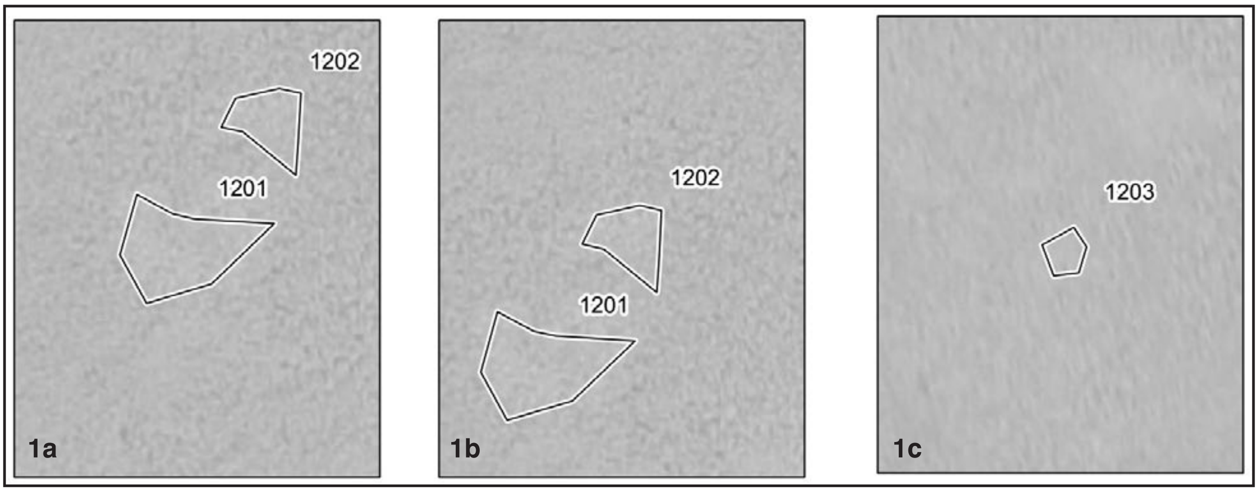


Figure 1 (a, b and c). Training ‘features’ (area with barley grass) in North’s Minnipa Hill pasture paddock sample sites flown at 40 m above ground level, 2019.

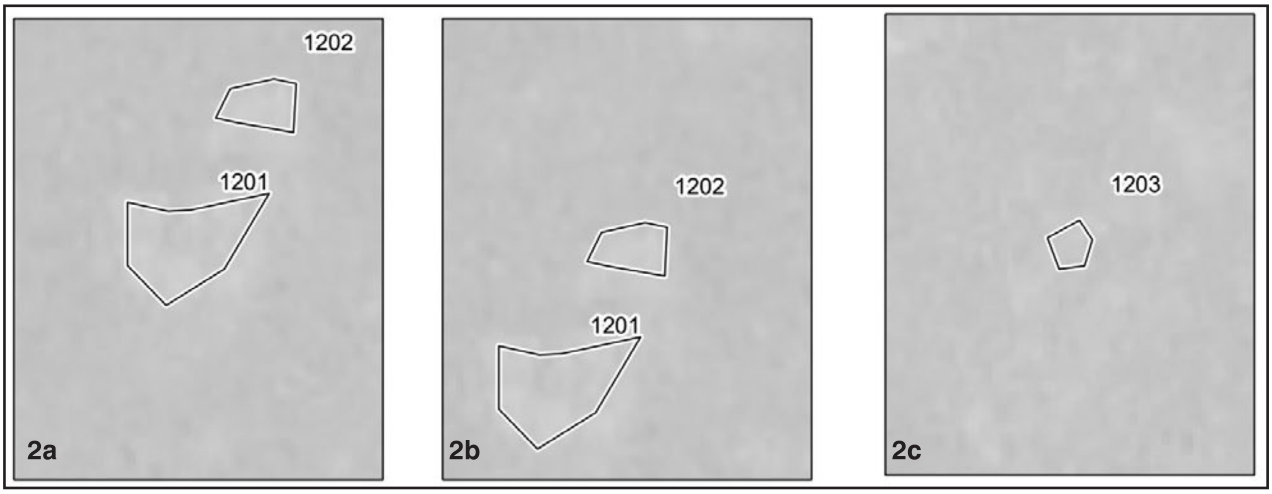


Figure 2 (a, b and c). North’s Minnipa Hill pasture paddock sample sites flown at 120 m above ground level, 2019.

In the higher resolution imagery these patches were easily identified. Cross referencing these with the medium resolution imagery (drones flown at 120 m height), the same patches of grass were marked using comparative features in the imagery (example Figure 2 a-c)).

The initial analysis was then run, and a representative sample area was compared for each set of images. The black layer in the images below (example Figure 3) shows the initial “Maximum Likelihood” analysis output, or the increased likelihood of grass weeds being present.

2019 North’s Minnipa Hill pasture paddock

Imagery was collected from Norths on Minnipa Hill on 7 August 2019 at both 40 m and 120 m heights.

Sample sites were selected from the 40 m imagery and replicated in the imagery flown at 120 m as show below (Figure 1-4).

Condada – lentil paddock

A paddock at Condada was imaged at both 40 m and 120 m on 28 August 2019.

Overall the North’s Paddock (Figures 1-4) and the Condada paddock (Figures 5-8) sample comparison analysis output based on the 40 m samples and the 120 m samples does have some overlap, however they appear to be producing highly dissimilar results, with less detail and detection of grass weeds in the 120 m analysis.

Condada pasture paddock

A pasture paddock at Condada was flown at both 40 m and 120 m heights on 28 August 2019.

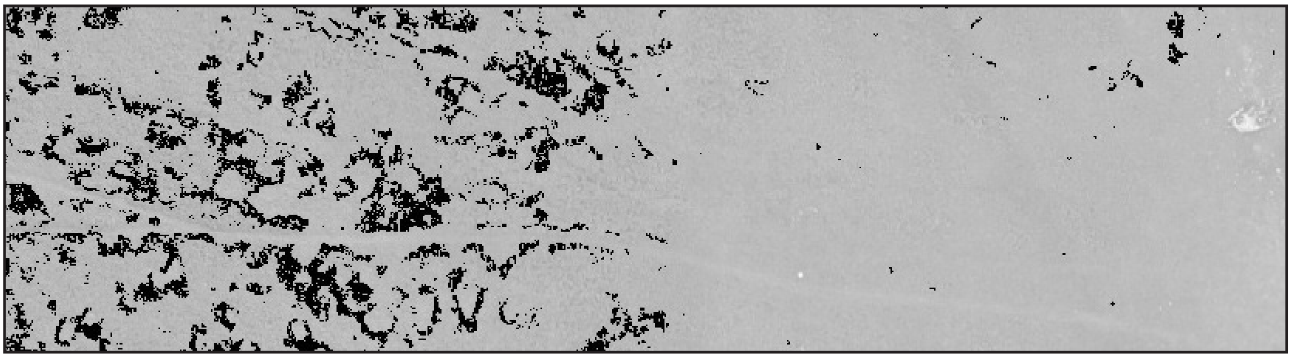


Figure 3. North's Minnipa Hill pasture paddock, sample output strip flown at 40 m above ground level, 2019.

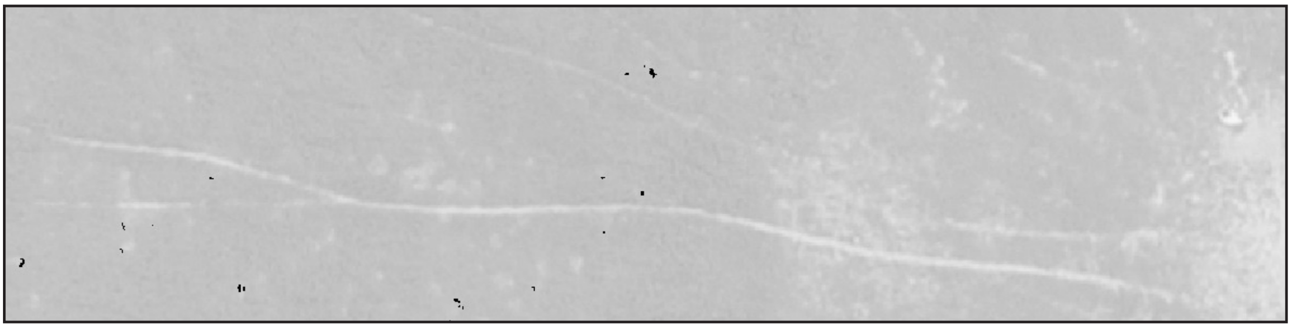


Figure 4. North's Minnipa Hill pasture paddock, sample output strip flown at 120 m above ground level, 2019.

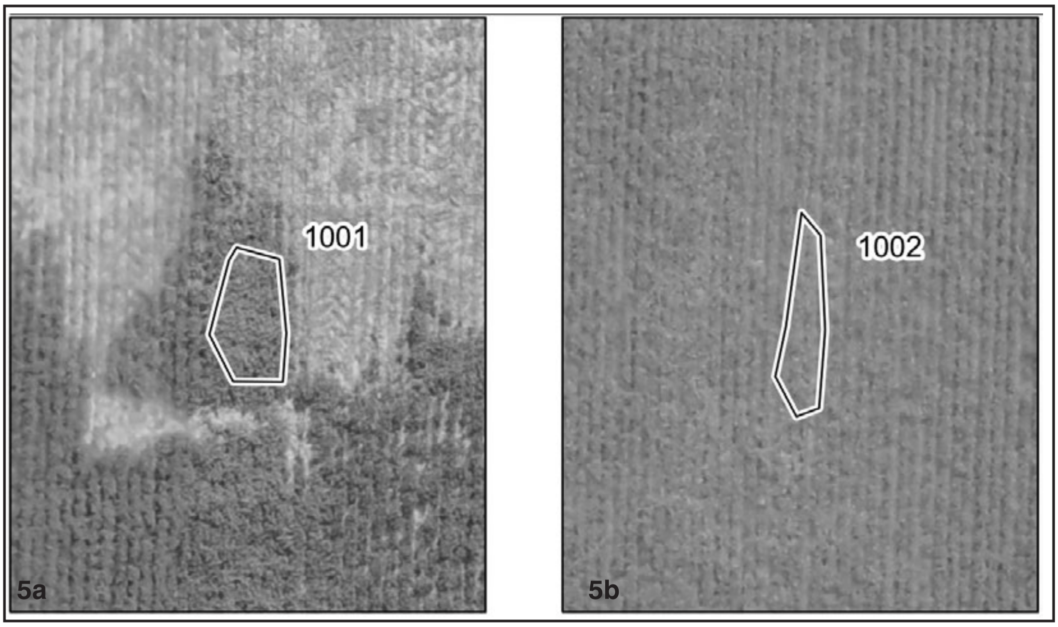


Figure 5 (a and b). Training 'features' (a - lentils and b – barley grass) in Condada lentil paddock imagery flown at 40 m above ground level, 2019.

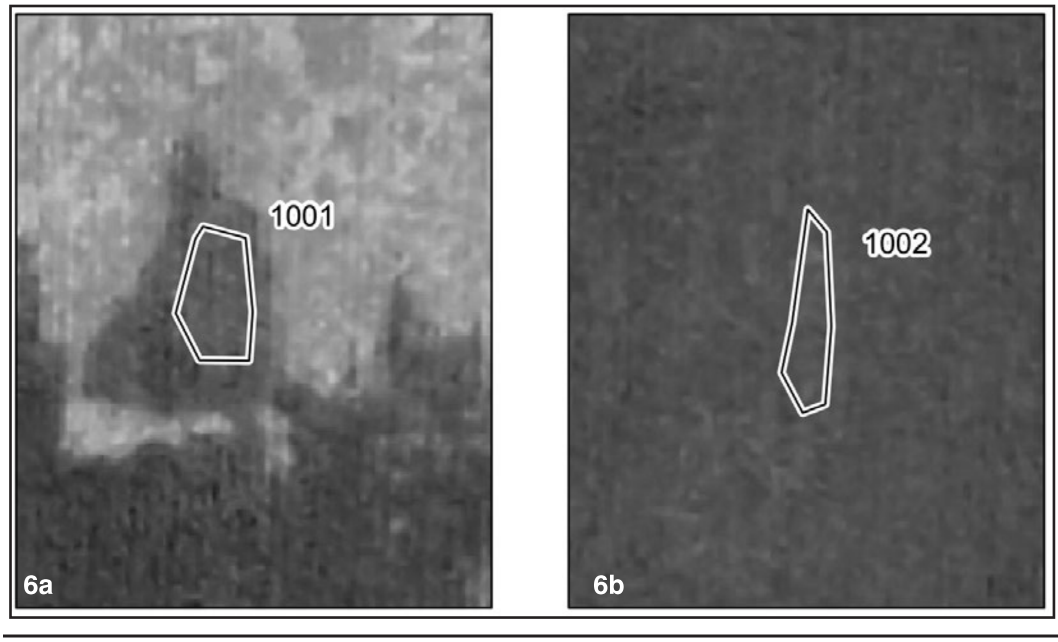


Figure 6 (a and b). Condada lentil paddock imagery flown at 120 m above ground level, 2019.

Figure 7. Condada lentil paddock, sample output strip flown at 40 m above ground level, 2019.

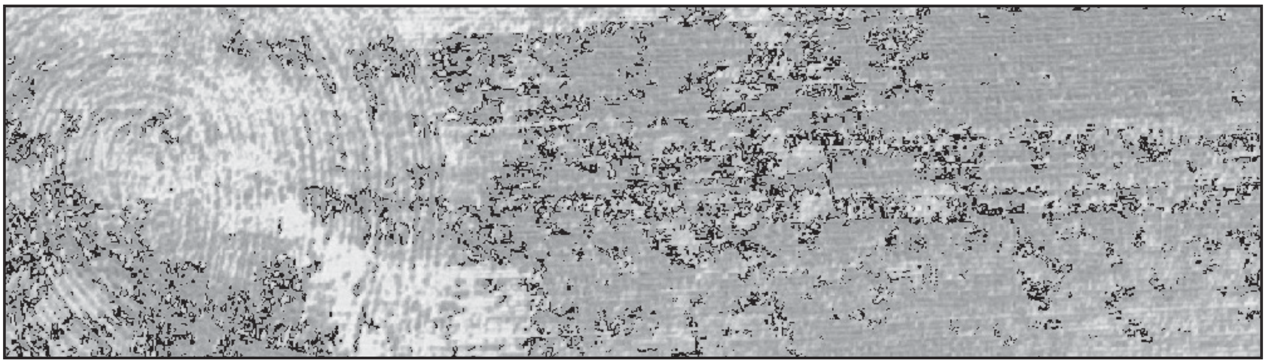


Figure 8. Condada lentil paddock, sample output strip flown at 120 m above ground level, 2019.

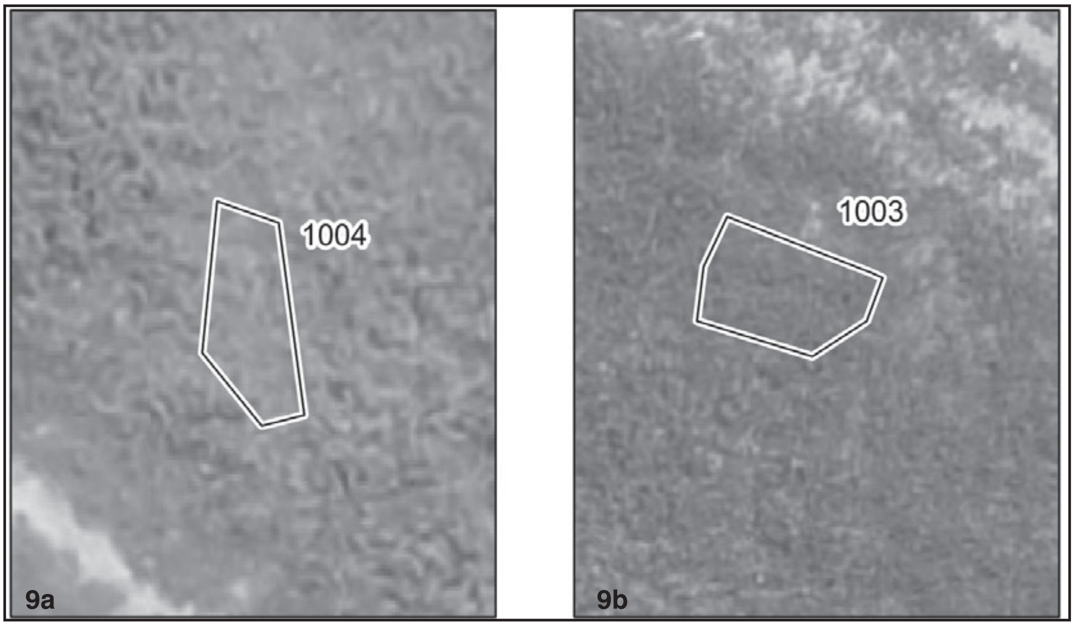


Figure 9 (a and b). Condada pasture paddock imagery flown at 40 m above ground level in 2019.

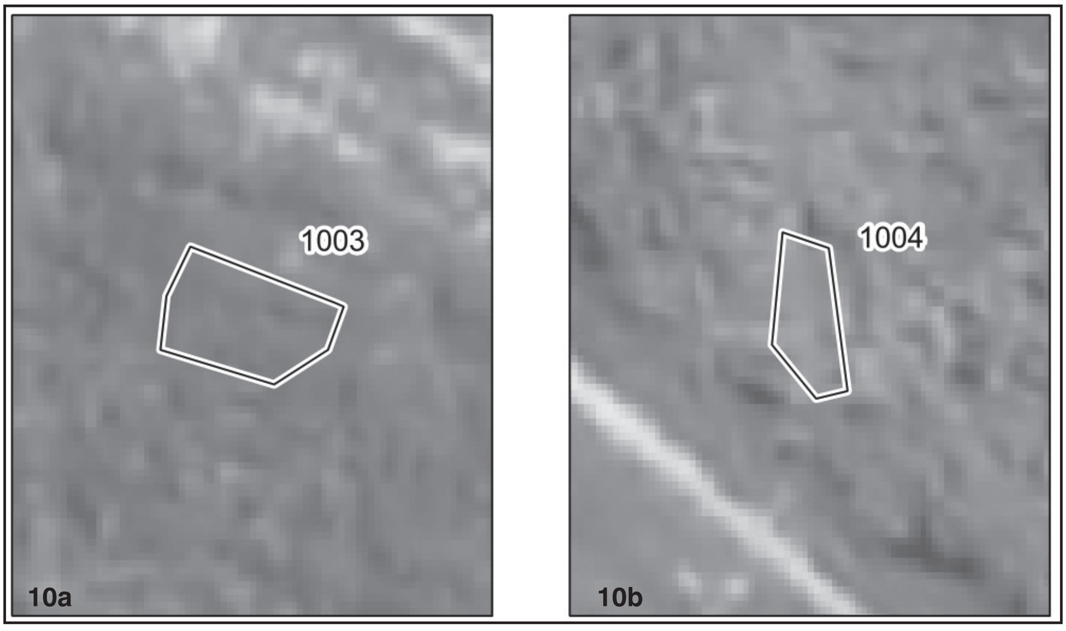


Figure 10 (a and b). Condada pasture paddock imagery flown at 120 m above ground level, 2019.

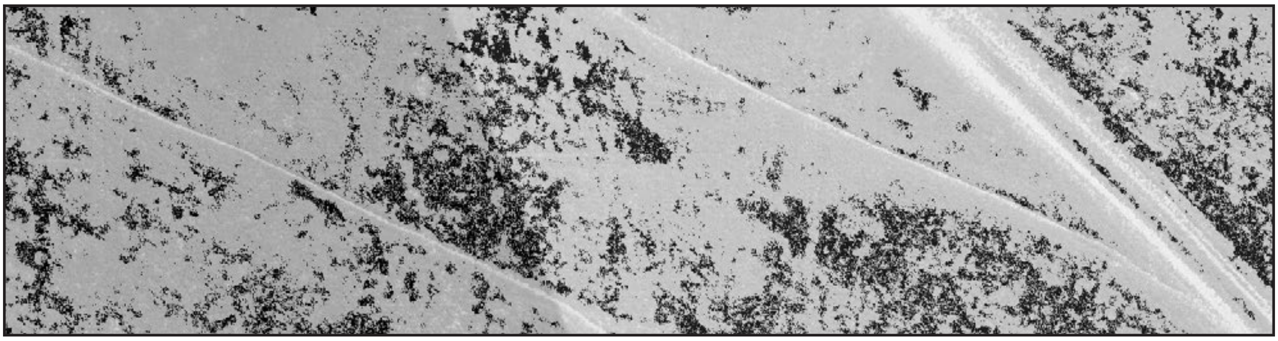


Figure 11. Condada pasture paddock, sample output strip flown at 40 m above ground level, 2019.

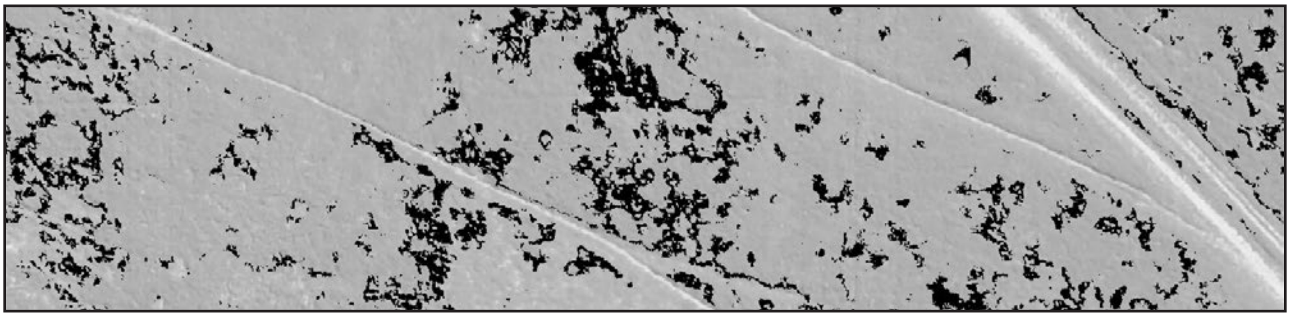


Figure 12. Condada pasture paddock, sample output strip flown at 120 m above ground level, 2019.

The Condada pasture paddock 2019 sample comparison of the analysis output based on the 40 m samples and the 120 m samples appear to be producing similar results. There are differences, but the broad scale pattern similarity looks to repeat in other areas of the imagery.

Overall sample comparison

It was investigated if the 120 m resolution flight could produce the same outputs as the imagery flown at 40 m, which would allow a greater paddock area to be covered at lower cost for the data capture. The initial comparisons of the two flight resolutions at North's Minnipa Hill and Condada lentils did not show a reliable pattern, with the 40 m resolution being more accurate in detecting the grass weeds. At the Condada pasture site the comparison of different resolutions yielded similar results. Further comparisons will be carried out with varying input parameters, however the initial comparisons do not seem promising at the lower resolution imagery taken 120 m above ground level.

The MAC S4 paddock, which has previously shown resistance to Group A herbicides, had large areas of barley grass weed patches survive herbicide applications, and some smaller circular patches in the southern end in 2018 (Figure 13 (a, b and c)).

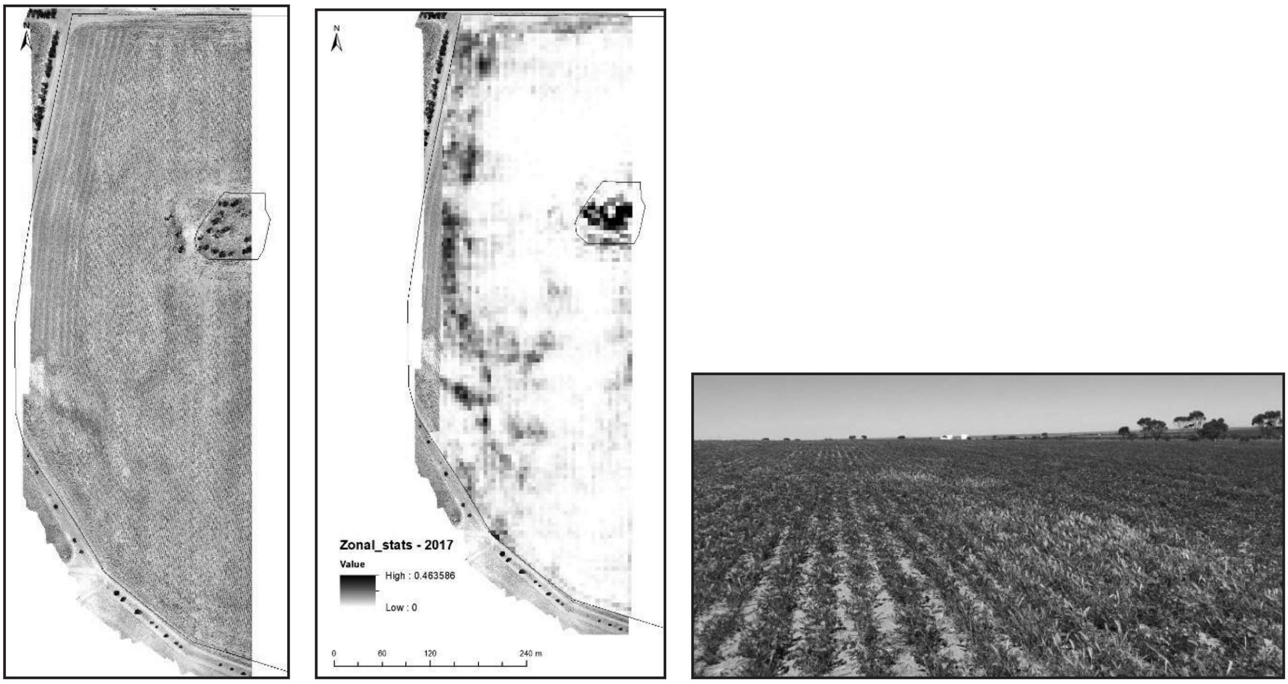
Comparing the barley grass weed density map in MAC S4 in 2019 (Figure 14) higher grass weed infestation can be observed along the western boundary, matching the patterns observed in 2018 (Figure 13 b).

A comparison of the 2017 weed map area in MAC S4 was made with the 2018 maps and the western half of the paddock was imaged both years so these are compared. Some similarities in occurrence patterns can be observed, but differences in crops sown, barley in 2017 and vetch in 2018 may also have an impact. The vetch crop in 2018 may have been less competitive with weeds. The area of heaviest weed growth in the 2017 imagery has been cut for vetch hay in the 2018 image, indicating the area is likely to have been higher in weeds in both seasons. For the 2019 season the same pattern can be mostly observed. Some drift in infestation, along with some reductions can be seen in the top corner of the image, potentially highlighting movements in weed infestation between seasons.

The maps used in the analysis can be accessed at http://wisdomdata.com.au/sagit-weeds-project/.

What does this mean?

UAV imagery may provide an opportunity to assist in targeted grass weed management. Current UAV technology is cheap to purchase and has high resolution. However the time and effort of collecting data over large paddock areas, the size of files, and the expertise required for overlaying the images and analysing the data, and variable image quality may limit the adoption by farmers. If farmers personally have the time and the interest to acquire these skills, or are willing to pay for the data capture and analysis, the technology may be used for targeting grass weed management and monitoring grass weed areas. The cost of the data capture and analysis was approximately $6,000 per paddock.



13a 13b 13c

Figure 13 (a) MAC S4 paddock in 2018 and (b) the barley grass weed density map. Figure 13c Photo of 2018 Group A resistant barley grass patches, September 2018.

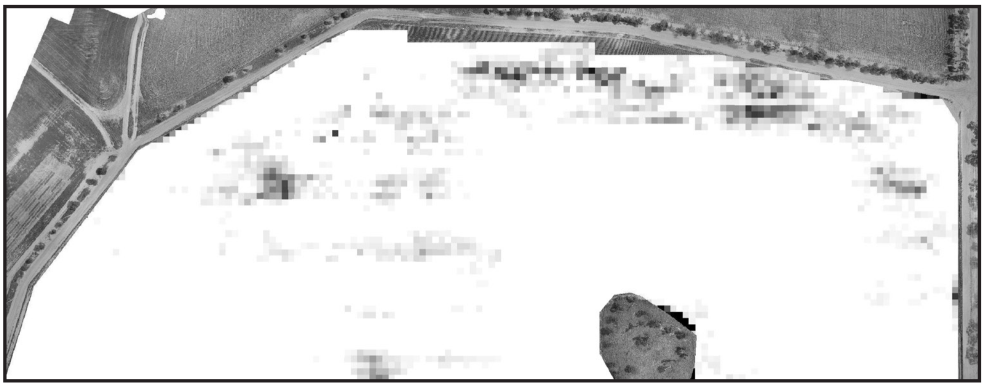


Figure 14. MAC S4 paddock barley grass weed density map 2019 (Landscape view).

In 2018 and 2019 the UAV flights captured data over a smaller area at 40 m height to provide a higher resolution strip to compare to 120 m lower resolution analysis of the paddock. The 40 m higher resolution data capture provided greater detail and more accurate barley grass weed densities compared to the 120 m medium resolution.

The capture of barley grass weed density was easier within legume break crops than cereal crops. The escape barley grass weeds were highly visible in the legume crops in late spring, however were still hard to identify in 40 m resolution image without knowledge of the paddock and where heavier weed infestations were.

The MAC S4 paddock has shown resistance to Group A herbicides and had large areas of barley grass weed patches survive herbicide applications in 2018 in a vetch crop. These resistant barley grass weed patches were able to be detected in similar areas in 2019, but at a lower density. This analysis could be converted to spray mapping information to target these areas in future seasons.

Acknowledgements

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Thank you to Bruce Heddle and Wilkins families for having the research and monitoring on their property.

Assessment of the rate of weed seed decay in chaff-lining systems of South Australia

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Key messages

- **Investigation of weed seedbank decline in nine chaff-lining systems of South Australia demonstrated that growers are achieving high concentration of weed seeds and crop residue at harvest.**
- **Assessment of the viable weed seed fraction after crop harvest suggests that large residual annual ryegrass, brome grass and Indian hedge mustard seedbanks have been established in cropping field because these species did not decay over the summer-autumn period in chaff-lines.**
- **Evaluation of chaff-tramlining systems showed that annual ryegrass seedbank decline is independent of chaff-line configuration and chaff density.**
- **The stability in the weed seedbanks in chaff-lines were consistent with the dry conditions over the summer-autumn period.**
- **Growers should be cautious of the magnitude of viable weed seeds in chaff-lines before the cropping season and expect variability in the effectiveness of this tactic between seasons.**

Why do the research?

Failure to control annual weed species that persist through cropping phases facilitates replenishment/establishment of weed seedbanks. Consequently, this maintains weed interference in subsequent years of crop production. Harvest weed seed control (HWSC) has been widely adopted in Australia since its inception over three decades ago to prevent redistribution of weed seeds across cropping fields during commercial harvesting operations (Walsh *et al*. 2017). Implementation of HWSC obstructs fresh seedbank inputs by subjecting the weed seed bearing chaff fraction to a treatment, such as combustion (narrow windrow burning), mechanical pulverisation (impact mills), decomposition (chaff-lining) and removal (chaff cart). Chaff-lining has been readily adopted by growers because of the low cost of modifying a harvester to confine the chaff fraction into a narrow row between stubble, or onto dedicated wheel tracks in controlled traffic farming systems (chaff-tramlining). There is a paucity of literature examining seedbank decline of important Australian weed species in chaff-lines, however a common conjecture is that a mulching effect is created by a combination of physical and chemical influences (Walsh *et al*. 2018). Field observations suggest that in the absence of seed decay, control failures of annual weed species and volunteer crop plants may be exacerbated. Therefore, growers urgently need information that substantiates the implications of chaff-lining to weed seedbanks.

How was it done?

Field sites were established at nine different locations with varying rainfall in SA (Figure 1). Sites were selected on the premise of dense annual ryegrass or brome grass infestations. Random sampling was performed at each site across four chaff-lines along a horizontal transect in areas of uniform weed density. Sub-samples were made at 0.5 m intervals so that 1.5 m of the chaff-line was collected. A vacuum was used to ensure complete capture of all weed seeds on the soil surface. In systems with a chaff-deck configuration, both chaff rows were sampled to alleviate distribution bias of the chaff fraction. Sub-samples were bulked and stored in an air-conditioned laboratory. Data on harvest height, and chaff-line depth and width was also obtained. This sampling strategy was repeated at random intervals from December to April.

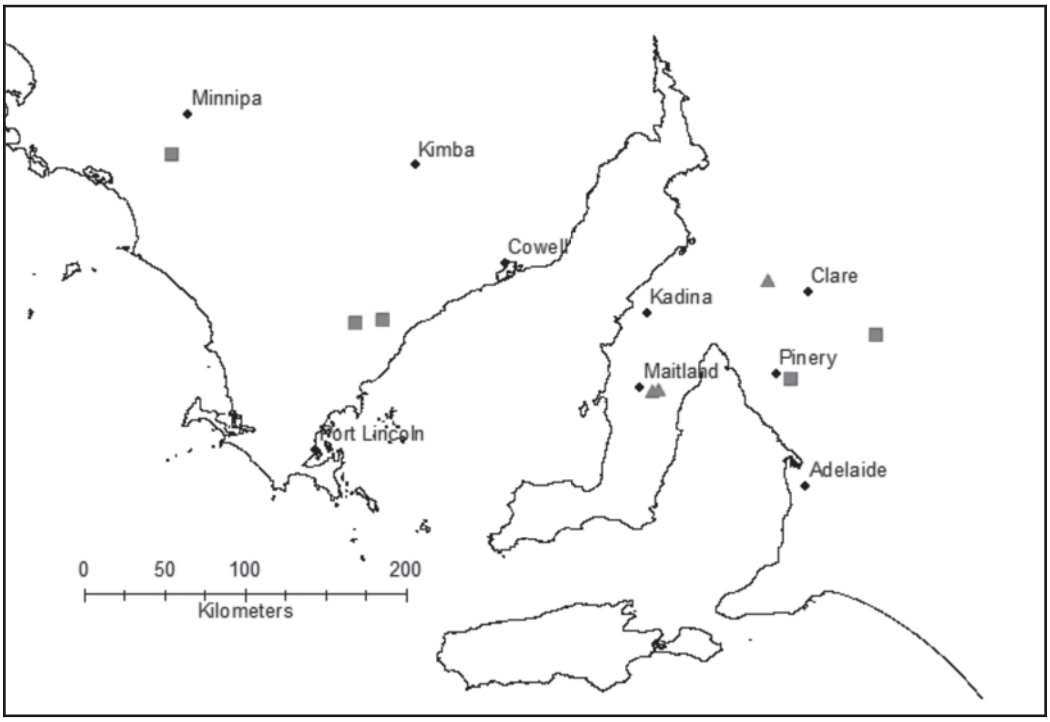

Figure 1. The geographical distribution of six chaff-lining (■) and three chaff-tramlining (▲) sites across the three rainfall zones of the major cropping regions of South Australia, which include: the Yorke Peninsula (high); Mid-North (medium) and Eyre Peninsula (low).

Table 1. Temporal changes in the brome grass seedbank concentrated in wheat chaff-lines at three different sites in South Australia, at Pinery (sites 3 and 4) and Wharminda (site 9).

Time of sampling	Mean brome grass density (seeds/m^2)		
	Site		
	3	4	9
1	14410	240	2363
2	18803	191	2072
3	26049	646	1963
4	23612	219	*

** not sampled*

Chaff was separated from the soil using a sieve and both components were weighed. A 25% sub-sample by mass was taken from each of the components and bulked together. The chaff-line material was spread between a 20 mm base and top layer of potting mix (coco-peat) in germination trays in the first week of May. The trays were then watered close to field capacity. Supplementary irrigation was supplied to trays if there was ten consecutive days without rainfall to ensure the potting mix was moist. Weed seedlings were routinely counted and removed to determine weed seed decay over the summer-autumn period. The data collection ceased in mid-September when no new seedlings emerged after two consecutive counts.

Seed decay in chaff-lines

Collection of wheat chaff-line samples from distinct rainfall zones (Figure 1) enabled quantification of weed seedbank decline under varying climatic and edaphic conditions. The importance of intervention to minimise seedbank replenishment was clearly shown in this study through the level of infestation of chaff-lines with annual ryegrass, brome grass and Indian hedge mustard seed (Table 1, Table 2, Figure 2). Brome grass density was high at site 3 (14410-26049 seeds/m^2), modest at site 9 (1963-2363 seeds/m^2) and low at site 4 (191-646 seeds/m^2). These fluctuations in the brome grass density at each site reflects the spatial variability in the distribution of this weed species (Table 1). A repeated measures ANOVA confirmed that there was no evidence that chaff-lining in wheat causes a decline in the brome grass seedbank ($P=0.158$).

Table 2. Tolerance of the annual ryegrass seedbank to chaff-lining in wheat at nine different sites across the major cropping regions of South Australia; Yorke Peninsula (sites 1-2), Mid-North (sites 3-6) and the Eyre Peninsula (sites 7-9).

Time of Sampling	**Mean Annual ryegrass density (seeds/m^2)**								
	Site								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1	93	5325	1343	3301	22678	8444	25287	513	7134
2	450	11176	982	5467	16969	11464	29831	2399	5443
3	597	7503	1409	7718	26686	12177	29244	1352	4657
4	*	*	1301	4829	18492	8657	*	2143	*

** not sampled*

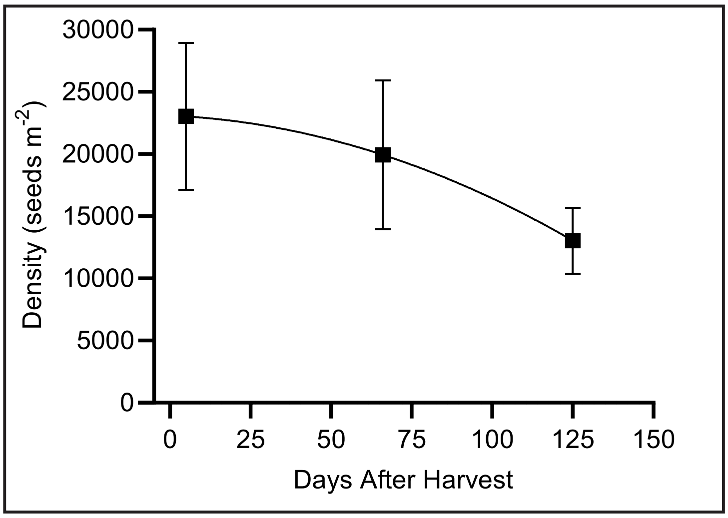

Figure 2. The temporal decline in the Indian hedge mustard seedbank in wheat chaff-lines after crop harvest at Minnipa, South Australia. Each point is the mean of four replicates and vertical bars are the standard error of the mean.

There were no consistent trends that demonstrated the susceptibility of annual ryegrass to decay in chaff-lines (Table 2). There was a reduction in annual ryegrass seedbank at three sites (3, 5 and 9), but a repeated measures ANOVA showed these were non-significant (P=0.361) and associated with the natural variability that exists at these sites. Large variation in the annual ryegrass and brome grass seedbank was identified between sites (P<0.001), but these seedbanks behaved similarly in wheat chaff-lines of different agro-ecological zones. The magnitude of annual ryegrass and brome grass seed capture (93-29831 seeds/m^2) demonstrates that HWSC tactics could have an important role in reducing weed seedbanks (Table 1, Table 2). Further research is needed to determine the implications that the large residual annual ryegrass (597-18492 seeds/m^2) and brome grass (219-23612 seeds/m^2) seedbank in chaff-lines will have to crop production.

Indian hedge mustard control failures at site 7 (Minnipa, South Australia) enabled investigation of the fate of its seeds in wheat chaff-lines. There was a 43% reduction in the Indian hedge mustard seedbank 125 days after harvest. However, there was no difference (P=0.322) between the initial and final Indian Hedge mustard seedbank (Figure 2). Our previous work in GRDC project UA00156 has shown that Indian hedge mustard has a low level of innate dormancy and readily germinates under favourable soil moisture conditions. The high organic carbon levels of chaff are likely to support microbial biomass, which has been associated with seed decay in statice (Kleemann and Gill 2018). While fatal germination, seedling recruitment and seed decay may contribute to some degradation of the Indian hedge mustard seedbank, spatial variability of this species within the field appears most important to the observed declining trend in the seedbank.

Chaff density

Chaff-density was calculated by assessing the chaff-line dimensions during sampling and processing. Similar patterns of seedbank decline were observed across the nine different sites in response to chaff density. Variability in the annual ryegrass and brome grass seedbank was not associated with increasing density of chaff-lines at sites across the Yorke Peninsula, Mid-North and Eyre Peninsula (Figure 3). Despite visual differences in chaff-deposition onto dedicated tramlines, a two-sample t-test showed that these were non-significant (P=0.448) and did not contribute to weed seed decay (Figure 3A). The levels of seed decay documented in the present study are consistent with findings in northern Australia by Ruttledge et al. (2018) in GRDC project UQ00084. While weed seed fate was not effected by chaff density, Ruttledge *et al*. (2018) reported suppression (15-35%) of annual ryegrass emergence in response to burial in chaff-lines under glasshouse conditions.

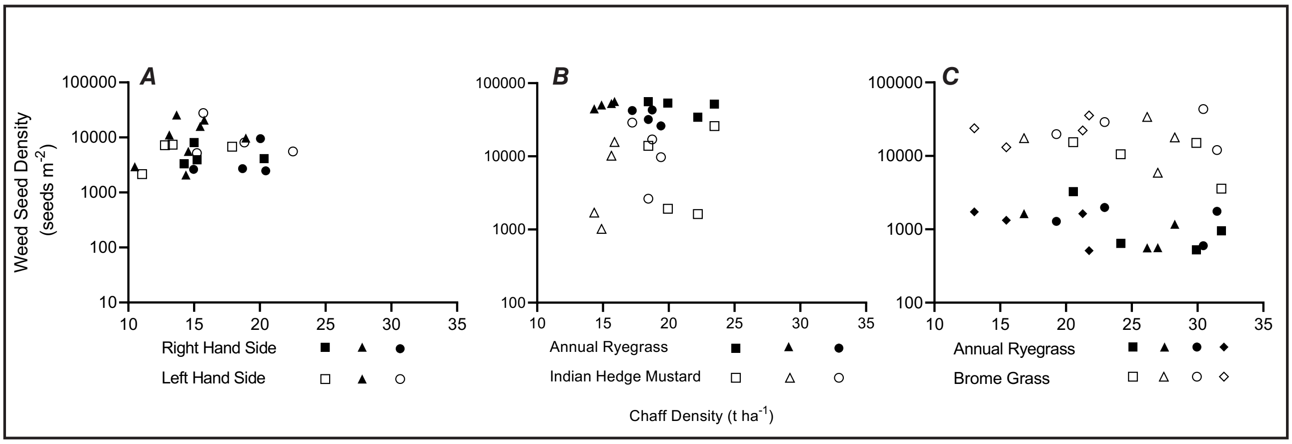

Figure 3.The relationship between seed fate and chaff density for different weed species under chaff-tramlining (A) and chaff-lining systems (B and C) at Maitland, Minnipa and Pinery, South Australia, respectively. Samples were collected at regular intervals over the summer-autumn period: T1 ■; T2 ▲; T3●; and T4 ◆.

Climatic implications

Exhaustion of weed seedbanks in chaff-lines occurs through seedling recruitment, seed decay, or a combination of these two factors. Climatic factors are intrinsically linked to regulating the germination behaviour of weed species, while sensitivity of soil microorganisms to temperature and moisture gradients determines rates of substrate depletion.

A HOBO® logger was placed at the bottom of chaff-lines at each site to collect data at hourly intervals on relative humidity, temperature and the number of dew events. The median temperature of chaff-lines ranged from 15.3-28.7°C (Figure 4), while there were no differences detected between sites (P=0.056). Despite the low C: N ratio of wheat residues, the concentration of organic matter in a chaff-line is likely to promote microbial activity. Extracellular enzymes that are secreted by soil microorganisms are known to have an important role in mediating weed seed decay; furthermore, their kinetics are influenced by temperature changes. The temperatures recorded in this study are likely to have positively shifted V_{max} towards an optimum that promotes decay of weed seeds. The stability of the annual ryegrass and brome grass seedbank in chaff-lines demonstrates that low soil moisture may have restricted soil microorganism populations. Even though the median number of dew events at Maitland (11) was more (P=0.011) than other sites (Figure 4), there was no reduction in the annual ryegrass seedbank (Table 2).

Rainfall data was sourced over the duration of the study from the nearest Bureau of Meteorology automatic weather station for all sites. Rainfall across the different regions was well-below average and represented 20-23% of the long-term mean (Figure 5). Intermittent, full hydration of annual ryegrass seeds associated with the summer-autumn rain is known to accelerate dormancy release by altering the seed composition of abscisic acid and gibberellins (Goggin *et al*. 2012). Rainfall deficiencies over the summer-autumn period may provide some explanation for weed seedbank stability in chaff-lines. Instead, the small rainfall events that were reported (Figure 5) are likely to have initiated transient hydration, which is known to reduce the time between imbibition and germination in annual ryegrass (Goggin *et al*. 2012). The temperature of the maternal environment in the year of annual ryegrass seed development has also been found to strongly influence seed dormancy (Steadman *et al*. 2004).

Brome grass seeds are photosensitive and preferentially germinate with burial, but populations in South Australia have been shown to exhibit a vernalisation requirement to release dormancy (Kleemann and Gill 2013). It is possible that the seed water content of annual ryegrass and brome grass varied in response to changes in relative humidity across the different sites (Figure 4). However, a previous Australian study showed dormancy release rates in annual ryegrass were not modified by natural fluctuations in humidity (Steadman *et al*. 2004). The proportion of the annual ryegrass and brome grass seedbank that is depleted in chaff-lines by fatal germination or seedling recruitment is difficult to predict because of their complex seed dormancy characteristics.

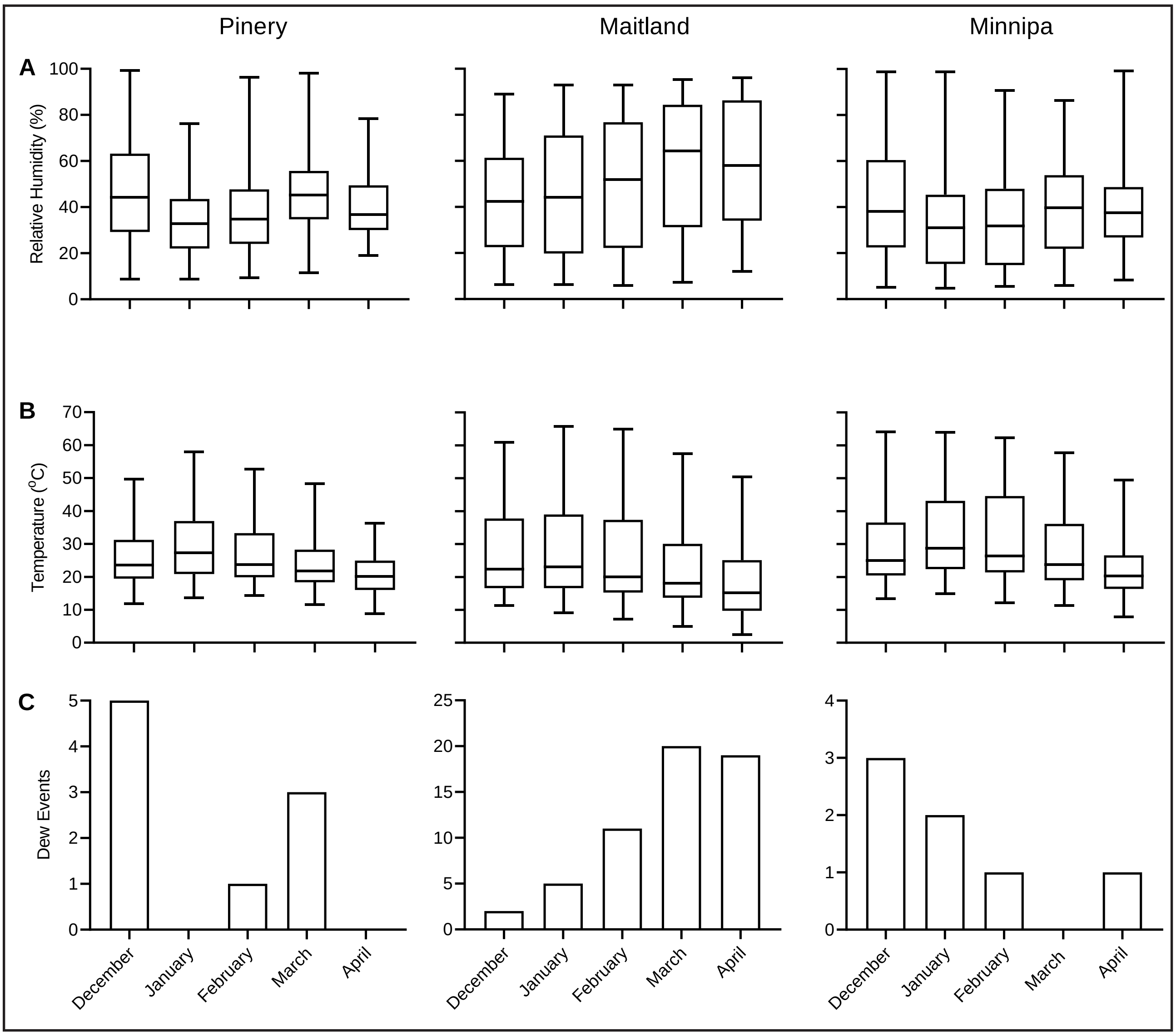

Figure 4. Observations from the Yorke Peninsula (Maitland), Mid-North (Pinery) and Eyre Peninsula (Minnipa) on relative humidity (A), temperature (B) and the number of dew events (C) over the sampling period. This data was collected at hourly intervals using a HOBO® logger that was placed on the soil surface beneath the chaff-line.

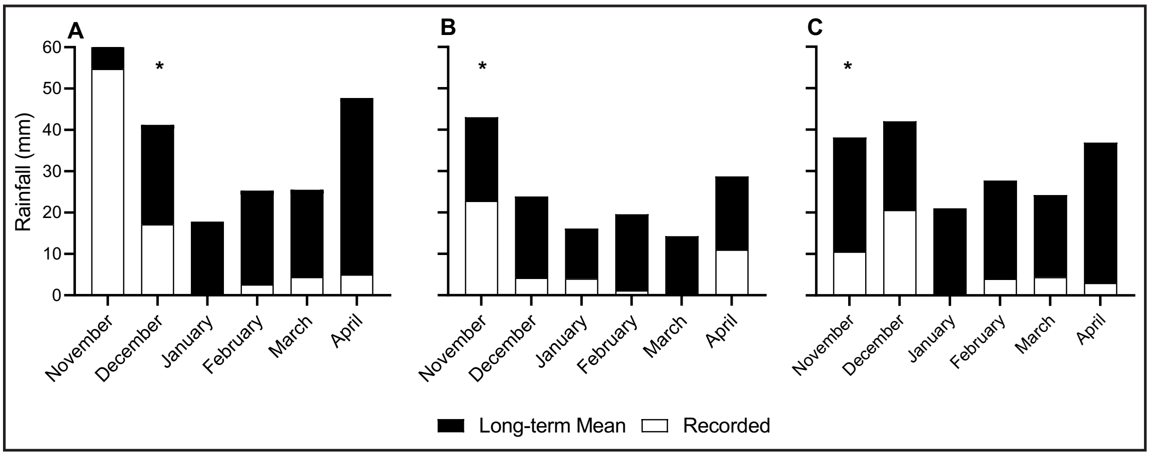

Figure 5. The long-term mean and recorded monthly rainfall for the chaff-lining field sites at Maitland (A), Pinery (B) and Minnipa (C), South Australia, following harvest (*).

Investigation of weed seedbank decline in nine chaff-lining systems of South Australia demonstrated that growers are achieving high concentration of weed seeds and crop residue at harvest. Assessment of the viable weed seed fraction after crop harvest suggests that large residual annual ryegrass, brome grass and Indian hedge mustard seedbanks have been established in cropping fields because these species did not decay over the summer-autumn period in chaff-lines. Evaluation of chaff-tramlining systems showed that annual ryegrass seedbank decline is independent of chaff-line configuration and chaff density. The stability in the weed seedbanks in chaff-lines were consistent with the dry conditions over the summer-autumn period; however, infrequent rainfall over this period is not unusual in South Australia. Therefore, growers should be cautious of the magnitude of viable weed seeds in chaff-lines before the cropping season and expect variability in the effectiveness of this tactic between seasons. Implementation of targeted control of these chaff-lines may be necessary to mitigate seedbank replenishment; however, care should be taken to prevent lateral dispersal of weed seeds by vectors, such as livestock and machinery.

Acknowledgments

The research undertaken as part of this project is made possible by the significant contributions of the growers through both trial cooperation, Jerel Fromm, Ian Noble and Ed Hunt on EP, and the support of the GRDC in project UA00156. Thank you to Ian Richter, Katrina Brands, Bradley Hutchings and Steve Jeffs (SARDI) for their technical input to the EP samplings.

References

Goggin DE, Powles SB, Steadman KJ (2012) Understanding Lolium rigidum seeds: the key to managing a problem weed? Agronomy 2 (3):222-239

Kleemann SGL, Gill GS (2013) Seed dormancy and seedling emergence in ripgut brome (Bromus diandrus) populations in southern Australia. Weed science 61 (2):222-229

Steadman KJ, Ellery AJ, Chapman R, Moore A, Turner NC (2004) Maturation temperature and rainfall influence seed dormancy characteristics of annual ryegrass (Lolium rigidum). Australian Journal of Agricultural Research 55 (10):1047-1057

Walsh M, Ouzman J, Newman P, Powles S, Llewellyn R (2017) High levels of adoption indicate that harvest weed seed control is now an established weed control practice in Australian cropping. Weed Technology 31 (3):341-347

Walsh MJ, Broster JC, Schwartz Lazaro LM, Norsworthy JK, Davis AS, Tidemann BD, Beckie HJ, Lyon DJ, Soni N, Neve P (2018) Opportunities and challenges for harvest weed seed control in global cropping systems. Pest management science 74 (10):2235-2245

Effect of sowing time x seed rate x herbicides on ryegrass management in barley

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Location
McEvoy Road, paddock N20
Rainfall
Av. Annual: 282 mm
Av. GSR: 202 mm
2019 Total: 235 mm
2019 GSR: 216 mm
Paddock history
2019: Self-regenerating medic pasture, barley in trial
2018: Mace wheat
2017: Self-regenerating medic pasture
2016: Mace wheat
Yield limiting factors
Annual Ryegrass

Key messages

- **There were large weed control benefits of delayed sowing of barley at Minnipa. However, when a highly effective pre-emergent herbicide was applied the benefit of delayed sowing was negligible.**
- **In barley a three week delay in sowing time did not significantly reduce grain yield as it did in the previous year in wheat. Lower yield penalty in barley from delayed sowing may be related to its earlier maturity and more competitive nature compared to wheat.**

Why do the trial?

Change in sowing time can have multiple effects on crop-weed competition. Delayed sowing can provide opportunities to kill greater proportion of weed seedbank before seeding the crop, but weeds that establish in late sown crops can be more competitive on a per plant basis. This is one of reasons why farmers who have adopted early seeding have reported excellent results in crop yield and weed suppression. Therefore, it is important to investigate sowing time in combination with other practices across different rainfall zones. The review of Widderick *et al*. (2015) also recommended research on sowing time in many crops. Delayed sowing can also reduce crop yield so the gains made in weed control may be completely nullified by the yield penalty.

There has been some research already on crop seed rate on weed suppression but none of these studies have investigated the benefits of higher crop density in factorial combinations with sowing time and herbicide treatments. Crop seed rate is an easy tactic for the growers to adopt provided they are convinced of its benefits to weed management and profitability. Furthermore, growers in the low rainfall areas tend to be reluctant to increase their seed rate due to concerns about the negative impact of high seed rate on grain screenings.

This field trial at Minnipa was undertaken to investigate factorial combinations of sowing time, seed rate and herbicides on the management of annual ryegrass in barley.

How was it done?

This field trial investigated combinations of the management tactics in Table 1.

All data collected during the growing season was analysed using the Analysis of Variance function in GenStat version 19.0.

In 2019, annual rainfall received at Minnipa was 17% below the long-term average but the growing season rainfall was 7% above the long-term average. The rainfall received in May, June and September was greater than the long-term average with all other months being well below the long-term average (Table 2).

What happened?

Barley plant density

There was a significant interaction between sowing time and wheat seed rate (Figure 1). As a general trend seedling establishment efficiency reduced as seed rate increased. Only in the high seeding rate, barley establishment differed significantly between TOS 1 and TOS 2.

Annual ryegrass plant density and seedbank

The average seedbank of annual ryegrass (ARG) at the site was 4168 ± 411 seeds/m^2. ARG plant density was significantly influenced by the time of sowing (P=0.002), herbicide treatment (P<0.001) and the interaction between the time of sowing and herbicide (P=0.001).

There was a large impact of the 3 week delay in seeding barley on ARG plant density (Figure 2). This was particularly evident in the untreated control in which ARG density decreased from 676 plants/m^2 in TOS 1 to 379 plants/m^2 in TOS 2 (44% reduction).

Table 1. Key management operations undertaken at Minnipa trial site in 2019.

Operation	Details
Location	Minnipa, SA
Seedbank soil cores	11 April
Plot size	1.5 m x 10 m
Seeding date	TOS 1: 4 May TOS 2: 24 May
Fertiliser	At sowing – DAP (18:20:0:0) @ 60 kg/ha
Variety	Compass barley
Seeding rate	100 seeds/m^2 150 seeds/m^2 200 seeds/m^2
Herbicides	4 May and 24 May (applied just before seeding) Boxer Gold 2.5 L/ha IBS Trifluralin 1.5 L/ha IBS Control (knockdown treatment only)
Trial design	split plot design with three replicates
Measurements	pre-sowing weed seedbank, crop density, weed density, ARG spike density, ARG seed production, wheat grain yield

Table 2. Rainfall received at Minnipa in 2019 and the long-term average for the site.

Month	Rainfall (mm)	
	2019	Long-term rainfall
Jan	4.0	11.2
Feb	1.2	13.2
Mar	0.2	18.9
Apr	11.0	15.5
May	57.2	28.2
Jun	56.4	37.1
Jul	15.6	35.0
Aug	19.2	38.7
Sep	53.6	27.5
Oct	3.4	19.9
Nov	7.0	16.9
Dec	6.4	18.9
Annual total	235.2	282.3
GSR total	216.4	201.9

This large response of ARG density to delayed sowing is most likely related to rainfall events in May, which would have caused weed emergence (Figure 2). The reduction in ARG plant density due to delayed seeding was also apparent in the herbicide treatments (Figure 2) with both herbicide treatments providing greater efficacy in TOS 2. However in the most effective herbicide treatment (Boxer Gold), high level of ARG control was also achieved in TOS 1, making any benefits from delayed sowing redundant.

Annual ryegrass spike density and seed production

ARG spike density was significantly influenced by the time of sowing ($P=0.019$), herbicide treatment ($P<0.001$) as well as the interaction between the TOS and herbicide treatment ($P=0.006$). However, there was no effect of barley seed rate on ARG spike density ($P=0.237$). When averaged across the seed rates and herbicide treatments, the three week delay in seeding at Minnipa reduced ARG spike density from 194 spikes/m^2 to 123 spikes/m^2 (37% reduction). Herbicide treatments were also more effective in TOS 2, with Boxer Gold treatment resulting in the production of only 27 ARG spikes/m^2 (Figure 3). These results clearly highlight the ability of Boxer Gold to manage moderate levels of ARG seedbank under adequate soil moisture conditions, reducing ARG seed production (spikes/m^2) by 83% and 87% for TOS 1 and TOS 2, respectively.

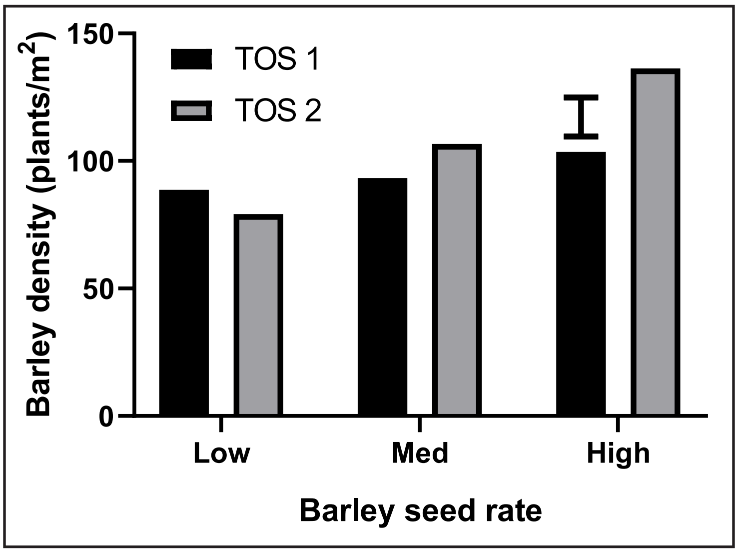

Figure 1. The effect of seed rate on barley plant density in time of sowing 1 (TOS 1) and time of sowing 2 (TOS 2). The vertical bar represents the LSD (P=0.05).

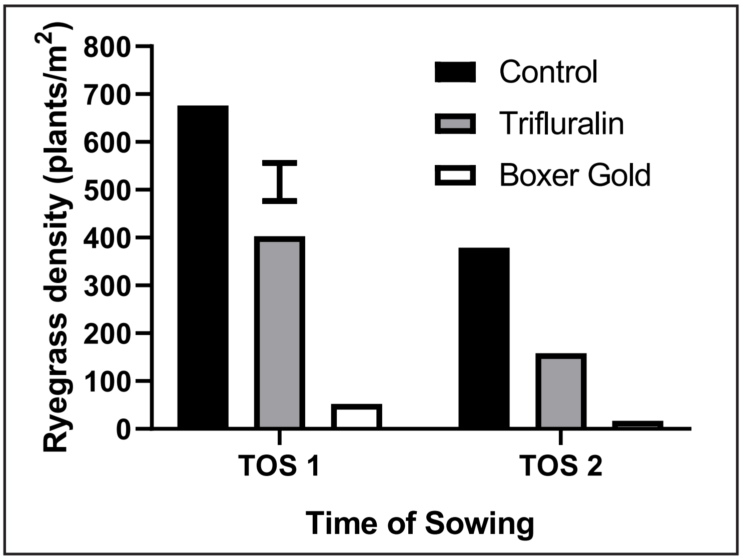

Figure 2. The interaction between the time of sowing and herbicide treatments (P=0.001). The vertical bar represents the LSD (P=0.05).

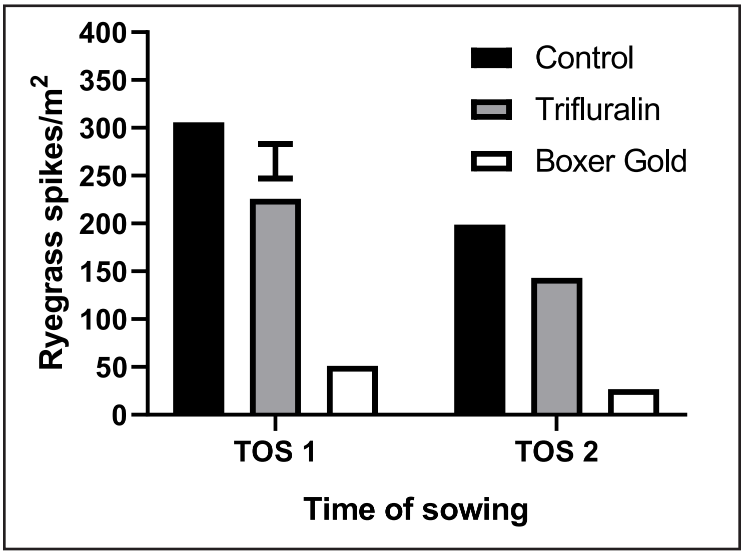

Figure 3. The effect of interaction between the time of sowing and herbicide treatments (P=0.006) on ARG spike density. The vertical bar represents the LSD (P=0.05).

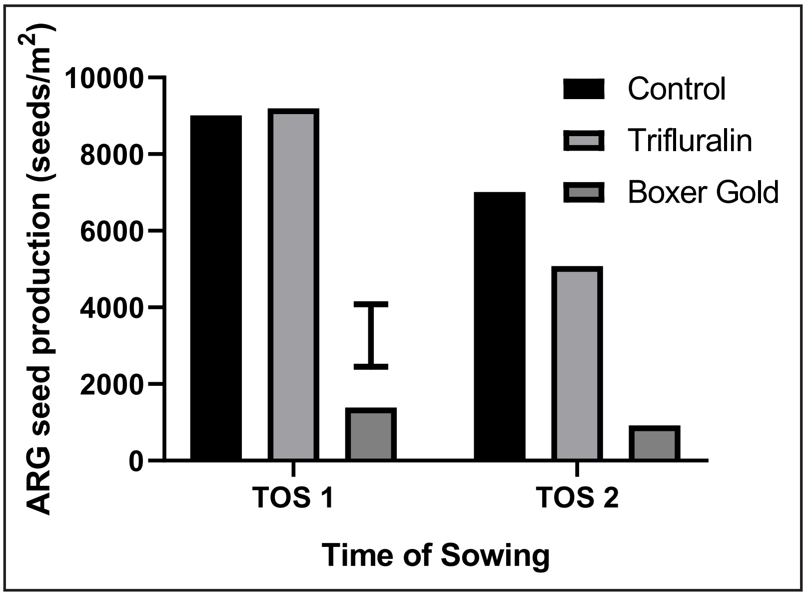

Figure 4. The effect of interaction between the time of sowing and herbicide treatments (P=0.021) on ARG seed production. The vertical bar represents the LSD (P=0.05).

Barley grain yield

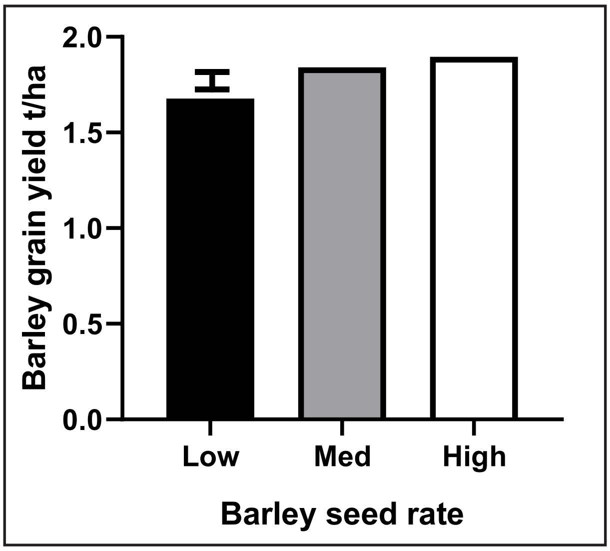

Figure 5. The effect of barley seed rate treatments (P<0.001) on barley grain yield. The vertical bar represents the LSD (P=0.05).

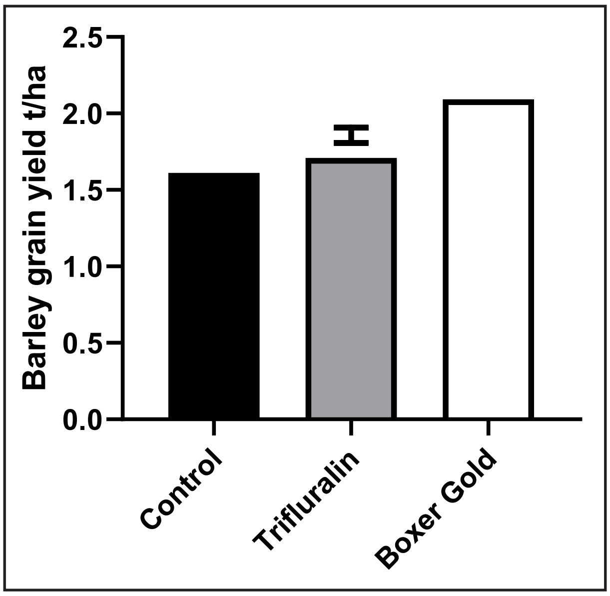

Figure 6. The effect of herbicide treatments (P<0.001) on barley grain yield. The vertical bar represents the LSD (P=0.05).

Barley grain yield at Minnipa was not significantly influenced by the time of sowing (P=0.644). However, crop seed rate (P<0.001), and herbicide treatment (P<0.001) had a significant effect on grain yield. Averaged across all treatments barley produced a grain yield of 1.81 t/ha (site mean yield). Barley yield increased as seed rate increased from low (1.68 t/ha), to medium (1.84 t/ha) and high (1.90 t/ha) (Figure 5). Even though the increase in barley yield as seed rate increased from low to high was only 13%, it was statistically significant. This increase in barley grain yield with increased seed rate was identical to the trend seen in wheat in 2018. Increased seed rate had no influence on percentage of barley screenings, however percentage of barley screenings reduced with increased control of annual ryegrass with herbicides.

Herbicide treatment had a significant effect on barley grain yield with Trifluralin (1.71 t/ha) increasing grain yield by 6% and Boxer Gold (2.09 t/ha) by 30% compared to the control (1.61 t/ha) (Figure 6). These yield gains equate to approximately a 2:1 return on the cost of trifuralin and a 3.75:1 return on Boxer Gold.

What does this mean?

Consistent with the trends observed for ARG spike density, ARG seed production was also significantly influenced by the time of sowing (P=0.023), herbicide treatments (P<0.001) and the interaction between the TOS and the herbicide treatments (P=0.021). Pre-emergence herbicides performed better in TOS 2 where the density of ARG plants had been reduced by the delay in seeding (Figure 4). The Trifluralin treatment produced 9192 ARG seeds/m^2 for TOS 1 and 5078 ARG seeds/m^2 for TOS 2. However in the most effective herbicide treatment (Boxer Gold), high level of ARG control was also achieved in TOS 1, making any benefits from delayed sowing redundant. While these Boxer Gold treatments all set less seed than the 2019 ARG soil seed bank, a substantial ARG infestation would be expected in 2020. In contrast to ARG plant density and spike density, trifluralin in TOS 1 produced a similar amount of ARG seeds to the untreated control. This means that the plants that survived the trifluralin tillered well and adequately compensated for the reduced plant density.

The three week delay in sowing barley did not significantly reduce its grain yield (P=0.64). This is in complete contrast to a similar wheat trial in 2018 where a 6 week delay in sowing reduced wheat grain yield by 36%. This could partially be explained by the longer sowing delay due to drier May and June in 2018. However, this lack of impact on barley yield from this delay in sowing was most likely related to the greater early vigour of barley and its earlier maturity than wheat. This is also evident by how much an effective herbicide improved grain yield with the most effective herbicide improving wheat yield in 2018 by up to 44% and 30% for barley in 2019 despite much heavier weed pressure.

These results give some confidence in using a short delay in sowing barley to achieve ARG control compared to wheat, however the cost of that delay would be dependent on seasonal conditions and the variety of barley grown. Compass barley grown in this trial is quite weed competitive and well adapted to a shorter growing season. If a long season barley like Planet or less competitive barley like Spartacus was grown the cost from the delay in seeding could be larger.

Acknowledgement

The authors thank Bruce and Kathryn Heddle for hosting the site. Malinee Thongmee and Hue Thi Dang (University of Adelaide), Fiona Tomney, Steve Jeffs, Bradley Hutchings and Katrina Brands (SARDI) for their technical input to the trial. We also acknowledge the investment from GRDC for the research into 'Cultural management for weed control and maintenance of crop yield' (9175134).

The effect of combinations of crop row spacing, seedbed utilisation and pre-emergence herbicides on ryegrass management in barley

Ben Fleet[1], Gurjeet Gill[1], Amanda Cook[2], Ian Richter[2] and Neil King[2]

[1]University of Adelaide, School of Agriculture, Food and Wine; [2]SARDI, Minnipa Agricultural Centre

Location
McEvoy Road, paddock N20
Rainfall
Av. Annual: 282 mm
Av. GSR: 202 mm
2019 Total: 235 mm
2019 GSR: 216 mm
Paddock history
2019: Self-regenerating medic pasture, barley in trial
2018: Mace wheat
2017: Self-regenerating medic pasture
2016: Mace wheat
Yield limiting factors
Annual Ryegrass

Key messages

- **The herbicide treatment had a significant effect on annual ryegrass (ARG) plant density. Trifluralin only reduced ARG spike density by 20% compared to the untreated control, whereas Boxer Gold caused a 73% reduction in ARG spike density.**
- **Barley sown on 25 cm row spacing resulted in a 38% less ARG seed production compared to the 37.5 cm row spacing treatment.**
- **Barley sown using the splitter seed boot treatment had 32% lower ARG seed production than the narrow seed boot treatment.**
- **It was still profitable to control ARG with effective herbicide treatments. Based on cash grain price of feed barley of $250/t in 2019, Trifluralin would be expected to increase the gross margin by $32/ha as compared $71/ha increase for Boxer Gold.**

Why do the trial?

As a general principle, large inter-row space tends to encourage weed invasion in field crops. At the start of the trend towards no-till, many growers adopted wider row spacing of crops as a way of achieving stubble retention. There is large variation in the row spacing used by growers for seeding wheat crops across the southern region. In wider row configurations, crop canopy closure is either delayed or not achieved, which allows weeds to compete with crops and set large amounts of seed. In a review of research gaps by Widderick *et al*. (2015), crop row spacing was identified as a priority area of research for the southern region. Seedbed utilisation (SBU) as a concept has been used by Australian agronomists to achieve safer use of fertilisers at crop sowing. Greater SBU reduces the concentration of fertiliser close to crop seed which improves safety. The same concept has relevance for increasing the inter-row space occupied by crop plants, which has the potential to improve crop's competitive ability with weeds. Greater SBU by crops can be achieved by altering seed boots that provide greater lateral spread of crop seed. Some growers have been using 'Ribbon seeders' such as Concord or retro-fitting splitter boots to increase SBU and resource utilisation by their crops.

How was it done?

This field trial investigated combinations of the following management tactics listed in Table 1.

All data collected during the growing season was analysed using the Analysis of Variance function in GenStat version 19.0.

In 2019, annual rainfall received at Minnipa was 17% below the long-term average but the growing season rainfall was 7% above the long-term average. The rainfall received in May, June and September was greater than the long-term average with all other months being well below the long-term average. Additional information on rainfall pattern for 2019 can be found in the report for the time of sowing x wheat seed rate x herbicide trial undertaken in the same paddock.

What happened?

Barley plant density

Even though the same seed rate was used in the normal (25 cm) and wide row (37.5 cm) treatments, barley plant density was greater (17%) in the normal row spacing (P<0.001). Barley plant density was significantly affected by the seedbed utilisation (SBU) treatment (P<0.001), with higher crop establishment in the splitter boot treatment (13%). Herbicide treatments, while having significantly different effects on barley plant density, did not differ significantly from the untreated control. The average barley plant density in the trial was 131 plants/m^2, which is highly suitable for this agro-ecological environment.

Table 1. Key management operations undertaken at Minnipa trial site in 2019.

Operation	Details
Location	Minnipa, SA
Seedbank soil cores	11 April
Plot size	1.5 m x 10 m
Seeding date	20 May
Fertiliser	At sowing – DAP (18:20:0:0) @ 60 kg/ha
Variety	Compass barley
Seeding rate	180 seeds/m^2
Herbicides	20 May (applied just before seeding) Trifluralin 1.5 L/ha IBS Boxer Gold 2.5 L/ha IBS Control (knockdown treatment only)
Trial design	split plot design with 4 replicates
Measurements	pre-sowing weed seedbank, crop density, weed density, ARG spike density, ARG seed production, wheat grain yield

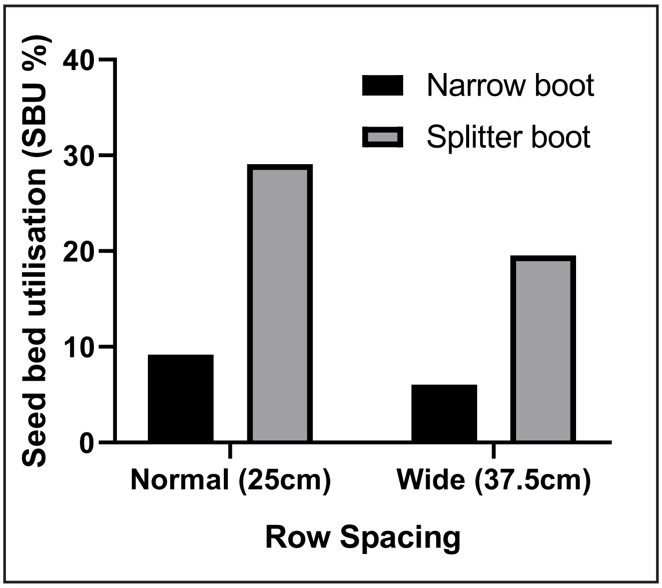

Figure 1. The effect of row spacing and seed boot treatments on seed bed utilisation (%). The LSD (P=0.05) is 0.93% SBU.

Seedbed utilisation (SBU)

SBU was significantly influenced by the crop row spacing (P<0.001), seed boot treatment (P<0.001), and there was a significant interaction between row spacing and seed boot treatments (P<0.001). The SBU percentage ranged from 6% for wide row spacing with narrow seed boot to 29% for the normal row spacing with the splitter seed boot (Figure 1).

Annual ryegrass seedbank and plant density

Assessment of soil cores for ARG seedbank showed that the average seedbank at the trial site was 2680 ± 263 seeds/m^2. This level of ARG seedbank would be regarded as a moderate to heavy infestation. There was a significant variation in ARG seedbank identified across the replicates, where replicate 4 was significantly higher than replicates 1 and 2. The blocking of the replicates at the site was able take account of this variation in ARG seedbank and it didn't have any adverse effect on the results.

The herbicide treatment had a significant effect on ARG density (P<0.001). There was also an interaction between herbicide and row spacing treatments (P=0.026) (Figure 2). Averaged across the row spacing and seed boot treatments, Trifluralin (210 ARG plants/m^2) and Boxer Gold (26 ARG plants/m^2) reduced ARG plant density by 20% and 90%, respectively compared to the untreated control (262 ARG plants/m^2).

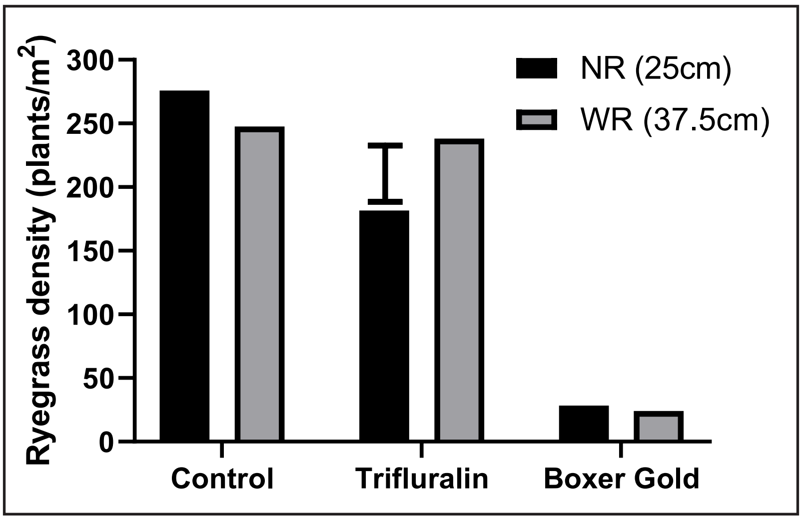

Figure 2. The effect of herbicide treatments and row spacing on ryegrass plant density. The vertical bar represents the LSD (P=0.05).

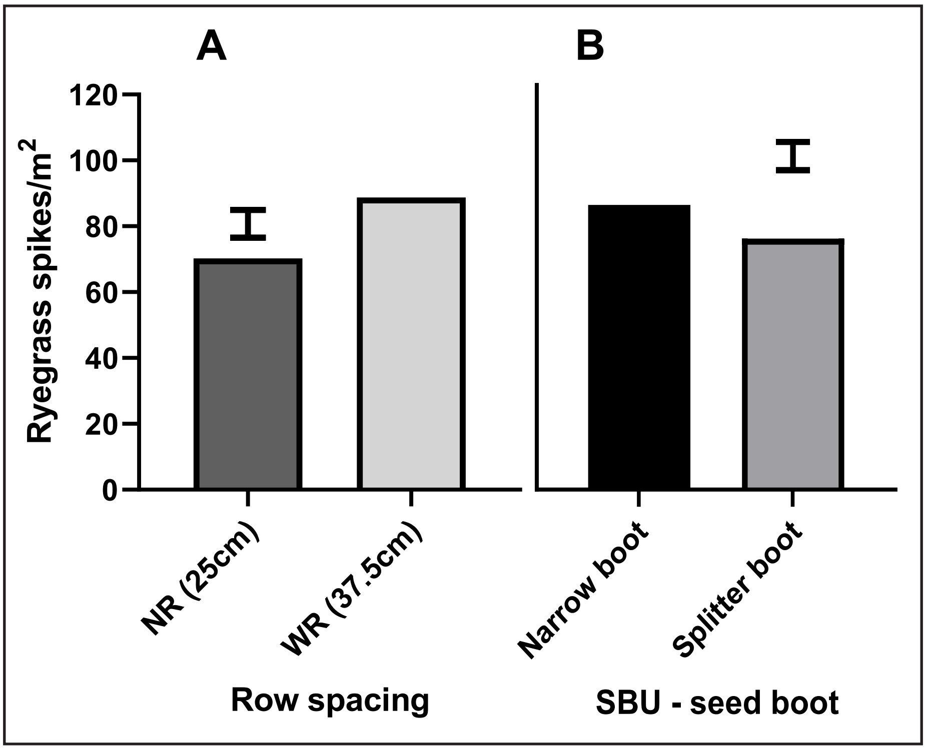

Figure 3. The effect of A – row spacing and B – seed boot treatments on ryegrass spike density. The vertical bar represents the LSD (P=0.05).

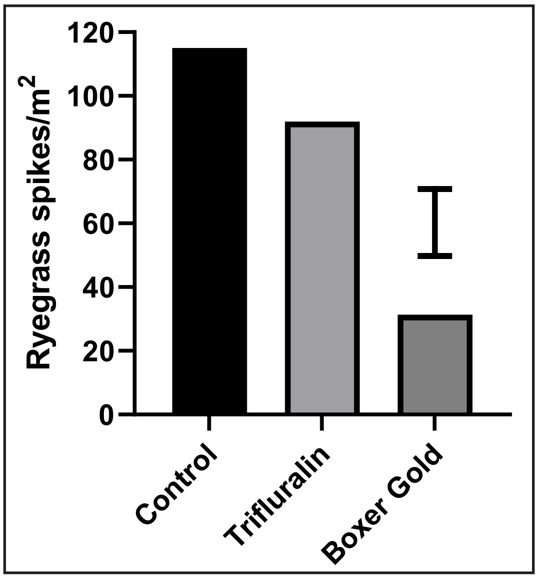

Figure 4. The effect of herbicide treatments on ryegrass spike density. The vertical bar represents the LSD (P=0.05).

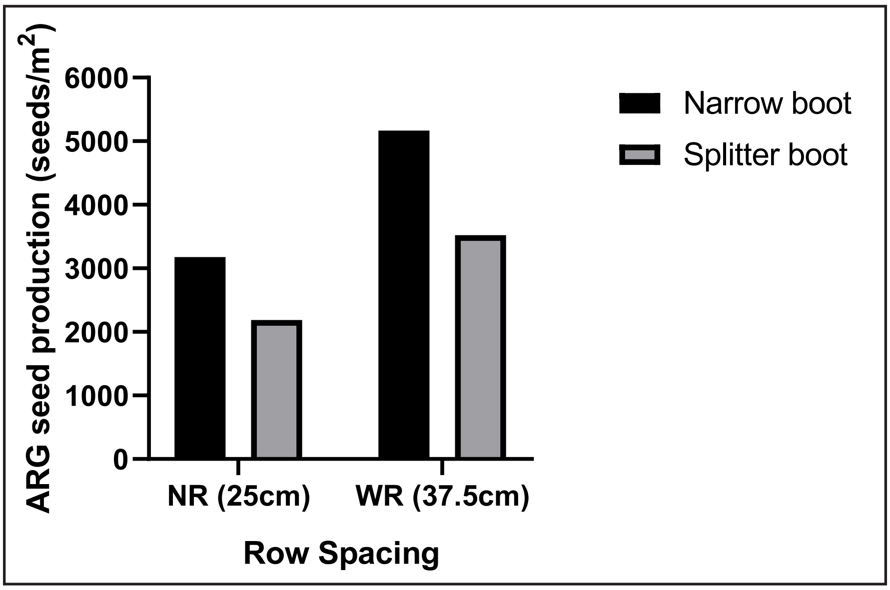

Figure 5. The effect of row spacing and seed boot treatments on ryegrass seed production across all herbicide treatments, columns are mean values (ARG seeds/m²).

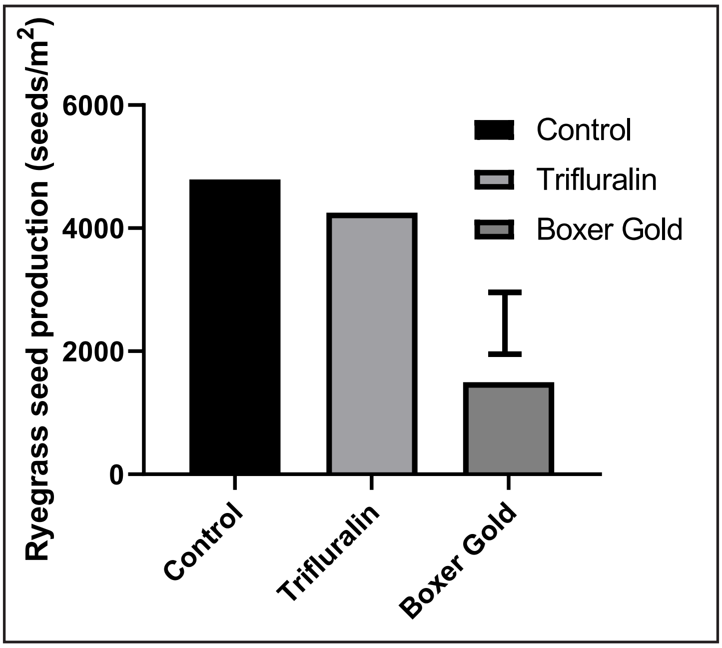

Figure 6. The effect of herbicide treatments on the density of ryegrass seed production. The vertical bar represents the LSD (P=0.05).

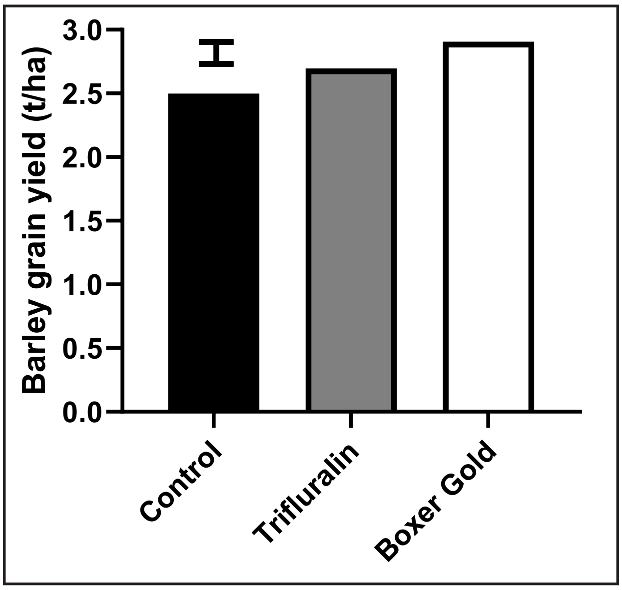

Figure 7. The effect of herbicide treatments on barley grain yield. The vertical bar represents the LSD (P=0.05).

Annual ryegrass spike density and seed production

The density of ARG spikes was significantly influenced by row spacing ($P<0.001$), seed boot treatment ($P=0.027$), and the herbicide treatment ($P<0.001$). However, there was no interaction between these management factors. The 25 cm row spacing had 20% lower ARG spike density than the 37.5 cm row spacing treatment (Figure 3). The splitter seed boot treatment had 12% lower ARG spike density than the narrow seed boot treatment (Figure 3). Trifluralin reduced ARG spike density by only 20% compared to the untreated control, whereas Boxer Gold caused a 73% reduction in ARG spike density (Figure 4).

Consistent with the spike density data, row spacing treatment ($P=0.003$), seed boot treatment ($P=0.01$), and the herbicide treatment ($P<0.001$) had a significant effect on ARG seed production. The normal row spacing set 38% less seed than the wide row spacing. The splitter seed boot treatment also had 32% lower ARG seed set compared to the narrow seed boot. These main effects were consistent for seed boot within row spacing treatments and vice versa, and can provide an additive effect when combined. The best performing treatment of normal row spacing and splitter boots set 2186 seeds/m^2, compared to the wide row spacing with narrow seed boot treatments that produced 5166 seeds/m^2 (Figure 5). This is a 2.4 fold difference in weed seed set between these treatments. ARG produced 4792 seeds/m^2 in the untreated control, which was reduced by 11% by Trifluralin and 69% by Boxer Gold (Figure 6).

Barley grain yield increased significantly in response to ARG control with Trifluralin or Boxer Gold (Figure 7). Only the Boxer Gold herbicide treatment produced significantly lower ryegrass seed than the untreated control. The poor performance of trifluralin suggests presence of a level of trifluralin resistance at this site. Seed collected from this site will be tested in 2020 to assess resistance to trifluralin. These results also highlight the difficulty of eliminating ARG through the use of pre-emergence herbicides alone.

What does this mean?

The herbicide treatment had a significant effect on ARG density ($P<0.001$). There was also an interaction between herbicide and row spacing treatments ($P=0.026$) (Figure 2). Averaged across the row spacing and seed boot treatments, Trifluralin (210 ARG plants/m2) and Boxer Gold (26 ARG plants/m^2) reduced ARG plant density by 20% and 90%, respectively compared to the untreated control (262 ARG plants/m2). The interaction between row spacing and herbicide treatments shown in Figure 2 indicate that row spacing only had a significant influence on trifluralin where significantly higher ARG control (24%) was achieved in the normal row spacing compared to the wide row spacing treatment. This is likely due to increased soil disturbance in the normal row spacing resulting in better incorporation of trifluralin in the soil. Trifluralin relies on effective soil incorporation to reduce herbicide losses from volatility and photodegradation. Though not significant, other treatments trended towards slightly higher ARG plant density in the normal row spacing treatments, this is also likely to be due to increased soil disturbance favouring ARG establishment.

Even in the most expensive and effective treatment of Boxer Gold (>$30/ha), ARG was able to produce 1495 seeds/m^2. This moderate level of ARG seed production would be more than adequate to allow problematic weed establishment in crops grown next year. Therefore, growers need to consider integration of harvest weed seed control or other management tactics such as narrower row spacing and splitter boots to further reduce injection of ARG seeds into the seedbank.

The results highlight the point that ARG is not highly competitive in barley. The presence of ARG at 262 plants/m^2 in the untreated control, only reduced grain yield by 8% compared to Trifluralin or 16% compared to Boxer Gold. However, it was still profitable to control ARG with herbicide treatments. Based on cash grain price of feed barley of ~$250/t in 2019, Trifluralin would be expected to increase the gross margin by $32/ha as compared $65/ha increase for Boxer Gold.

Acknowledgement

The authors thank Bruce and Kathryn Heddle for hosting the site. Malinee Thongmee and Hue Thi Dang (University of Adelaide), Fiona Tomney, Steve Jeffs, Bradley Hutchings and Katrina Brands (SARDI) for their technical input to the trial. We also acknowledge the investment from GRDC for the research into ‘Cultural management for weed control and maintenance of crop yield’ (9175134).

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Section Editor:
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Natural Resources Eyre Peninsula

Section 7

Pastures

Dryland Legume Pasture Systems: Small plot species adaptation trial

Fiona Tomney[1], Ross Ballard[2], David Peck[2], Jeff Hill[2], Ian Richter[1] and Naomi Scholz[1]
[1]SARDI, Minnipa Agricultural Centre; [2]SARDI, Waite

Location
Minnipa Agricultural Cenre, paddock S8
Rainfall
Av. Annual: 324 mm
Av. GSR: 241 mm
2019 Total: 254 mm
2019 GSR: 234 mm
Paddock history
2018: Medic pasture
2017: Scepter wheat
2016: Medic pasture
Soil type
Red sandy loam
Soil test
$pH_{(H2)}$ (0-10 cm) 8.4
Plot size
5 m 1.5 m x 3 reps x 25.5 cm row spacing

Key messages

- **This is a component of a five year Rural Research and Development for Profit funded project supported by GRDC, MLA and AWI; and involving Murdoch University, CSIRO, SARDI, Department of Primary Industries and Regional Development; Charles Sturt University and grower groups.**
- **This trial aims to assess a diverse range of annual pasture legumes in order to determine whether there are more productive and persistent options for the drier areas (<400 mm) of the mixed farming zone of southern Australia.**
- **The annual medics were the most productive pasture legume producing > 2 t/ha DM and setting > 500 kg/ha of seed. A new Tetraploid Barrel medic was the most productive.**
- **Astragalus was the most promising alternative legume and warrants further evaluation.**

Why do the trial?

Legume pastures have been pivotal to sustainable agricultural development in southern Australia. They provide highly nutritious feed for livestock, act as a disease break for many cereal root pathogens, improve fertility through nitrogen (N) fixation and mixed farming reduces economic risk. Despite these benefits, pasture renovation rates remain low and there is opportunity to improve the quality of the pasture base on many low to medium rainfall mixed farms across southern Australia. A diverse range of pasture legume cultivars are currently available to growers and new material is being developed. Some of these legumes, such as the annual medics, are well adapted to alkaline soils and have high levels of hard seed, which allow them to self-regenerate from soil seed reserves after cropping (ley farming system). Other legume cultivars and species are available and being developed that offer improved seed harvestability, are claimed to be better suited to establishment when dry sown and/or provide better nutrition for livestock. Regional evaluation is being undertaken to determine if they are productive and able to persist in drier areas (<400 mm annual rainfall) and on Mallee soil types common to the mixed farming zone of southern Australia.

How was it done?

The trial at Minnipa in paddock S8 was arranged in a fully randomised block design with three replications.

Nine legume entries were sown comprising two new tetraploid (double chromosome number) barrel medics; the new French serradella cultivar Frano, developed by Murdoch University; Ioman astragalus along with a new rhizobia strain; diffuse clover and Cefalu arrowleaf clover. Strand medic line PM-250 and barrel medic cultivar Sultan-SU were included as the controls for comparison.

The trial was sown on 16 May 2019 into moist soil. Plant emergence counts were completed on 18 June. Plots were scored for vigour on 6 August. Ioman astragalus and Frano French Serradella were sampled to determine if nodulation was satisfactory on 2 September. Early dry matter (DM) cuts were completed on 13 September. These samples will be used to determine nutritive value, however the results are not yet available. Plots were sampled to estimate seed production on 4 November 2019.

What happened?

The season opened in May with 44 mm of rainfall, enabling the trial to be sown into moist soil and over a month earlier than in 2018. Although Minnipa received less overall rainfall in 2019, the majority of the rain fell in the growing season, with an early September rainfall providing a valuable boost. This may have allowed some of the later maturing legumes to perform better than they might have in a more typical season.

All legume lines emerged 3 weeks post-sowing, however it was apparent that some lines had uneven or poor emergence, especially the two clover species. This was likely due to their smaller seed size resulting in them being sown too deeply. At this time the best emerged plots were Frano serradella and Ioman astragalus.

All lines continued to grow with the annual medics consistently the most productive species, producing > 2 t/ha DM. The new Tetraploid Barrel medic 1-2 was the most productive line, producing 2.24 t/ha DM.

Ioman astragalus performed well throughout the trial with vigorous early growth and good DM production, over three times that of the accession grown in 2018, with 1.74 t/ha this season compared to only 0.50 t/ha in 2018. Ioman astragalus also appeared to be fixing nitrogen as active nodules were found on its roots.

Frano French serradella consistently displayed more vigorous growth and more biomass than Margurita French serradella (Table 1). Frano produced 0.36 t/ha DM, which was over twice that of Margurita's 0.12 t/ha, however towards the end of their growing season in mid-October, the two cultivars were difficult to tell apart, Margurita having caught up; however in general the performance of the serradellas was poor. From early July the two serradella cultivars began to display a yellowish leaf colour, possibly the result of poor nodulation (2 nodules per plant) which is a known problem for this legume on alkaline soils and observed previously at Minnipa. The discolouration persisted until late September when 46 mm rain freshened up the trial and the serradellas appeared to fully recover.

Cefalu Arrowleaf clover and diffuse clover also had strong responses to the September rainfall, with vigorous growth into early November when the other lines, especially the medics, had already senesced. This extra growth was unfortunately not quantified as the decision was made not to take extra DM cuts, in order to maximise seed set for regeneration. Visually the late biomass of diffuse clover appeared similar to Frano French serradella, despite its very low DM cut of 0.09 t/ha on 13 September.

All legume lines flowered and set seed (Table 2). Ioman astragalus had the highest seed production with 35,761 seeds/m^2 (1698 kg seed/ha). This is considerably more than the 12,643 seeds/m^2 generated by the astragalus accession grown in 2018, but is a reflection of a threefold increase in biomass for 2019. PM-250 Strand medic also produced considerably more seed in this trial with 17,888 seeds/m^2 (601 kg seed/ha) compared to the 2018 trial (6,181 seeds/m^2) as a result of increased biomass.

Table 1. Average plant density (plants/m^2), plot vigour score and dry matter (t/ha) at Minnipa, 2019.

Pasture legume species	Plant density (plants/m^2) 18 June	Average plot vigour score 6 Aug	Dry matter (t/ha) 13 Sept
Ioman Astragalus	152	7.7	1.74 a
Frano French Serradella	116	6.7	0.36 b
Margurita French Serradella	64	5.3	0.12 b
Cefalu Arrowleaf Clover	107	6.5	0.43 b
Diffuse Clover	47	4.8	0.09 b
Tetraploid Barrel medic 1-2	89	7.3	2.24 a
Tetraploid Barrel medic 2-1	112	7.5	2.11 a
Sultan-SU Barrel Medic	120	7.5	2.16 a
PM-250 Strand Medic	75	7.8	2.14 a
LSD (P=0.05)			*0.70*

Table 2. Seed assessment measurements at Minnipa, 4 November 2019.

Pasture legume species	Average No. of seed pods/m^2	Average No. of seeds/pod	Average No. of seeds/m^2	Average seed yield (kg/ha)
Ioman Astragalus	1698	21	35761	1698
Frano French Serradella	500	3	1465	29
Margurita French Serradella	423	3	1145	20
Cefalu Arrowleaf Clover	383	79	30542	318
Diffuse Clover	372	82	30545	338
Tetraploid Barrel Medic 1-2	2172	6	13781	530
Tetraploid Barrel Medic 2-1	2220	7	14575	575
Sultan-SU Barrel Medic	1857	7	13030	563
PM-250 Strand Medic	3005	6	17888	601

The seed production of the serradellas was the least and may be insufficient for adequate regeneration. Margurita's seed set was only 1,145 seeds/m^2 (20 kg seed/ha). This was probably due to its flowering period through mid-September and October, which coincided with some extremely hot temperatures. Cefalu Arrowleaf clover and diffuse clover had even later flowering periods, from mid-October into November. Although both lines still set very large amounts of seed with >30,000 seeds/m^2, this may not have occurred in the absence of the September rainfall.

What does this mean?

Despite another challenging season with less annual rainfall than in 2018, all of the pasture legume lines established, flowered and set seed, although the amount set by the serradellas may be insufficient for regeneration. The annual medics were the most productive pasture legume in terms of both dry matter and seed set. They continue to be the best pasture option for neutral to alkaline soils on the upper EP.

In the 2018 and 2019 Dryland Legume Pasture Systems Legume Adaptation trials, astragalus was the best adapted alternative legume species. This 2019 trial included the cultivar Ioman that grew vigorously, set large amounts of seed and appeared to be actively fixing nitrogen; it can also have seed harvested by a grain harvester. Astragalus merits further investigation in the Minnipa environment, however seed is not commercially available.

The clovers and serradellas showed the ability to respond to spring rain when the medics had already set seed and begun to senesce, however their overall production was poor and the seed set of the serradellas was penalised by its late flowering time. Whilst the clovers still managed to set a considerable amount of seed despite an even later flowering window, which fell through some extremely hot temperatures, their productivity and ability to set seed has not yet been assessed in the Minnipa environment in a season with average spring rainfall.

In 2020 the trial will be sown to wheat, with pasture legume regeneration following the cropping phase measured in 2021. Their regeneration after the cereal phase, which is the recommended practice for some pasture legumes following their establishment year, will be a function of the amount of seed set and suitability of their hard seed level to the Minnipa environment.

Acknowledgements

This project is supported by funding from the Australian Government Department of Agriculture as part of its Rural R&D for Profit program; the Grains Research and Development Corporation, Meat and Livestock Australia; and Australian Wool Innovation. The research partners include the South Australian Research and Development Institute, Murdoch University, the Commonwealth Scientific and Industrial Research Organisation, the WA Department of Primary Industries and Regional Development, and Charles Sturt University, as well as 10 grower groups. Project code: RnD4Profit-16-03-010.

Commercial annual legume cultivars are produced by a range of companies and we appreciate them making their cultivars available for this work.

Dryland Legume Pasture Systems: Legume adaptation trial 2019 regeneration

Fiona Tomney[1], Ross Ballard[2], David Peck[2], Jeff Hill[2], Ian Richter[1] and Naomi Scholz[1]

[1]SARDI, Minnipa Agricultural Centre; [2]SARDI, Waite

Location
Minnipa Agricultural Centre, paddock S8
Rainfall
Av. Annual: 324 mm
Av. GSR: 241 mm
2019 Total: 254 mm
2019 GSR: 234 mm
Paddock history
2018: Legume adaptation trial sown and established
2017: Scepter wheat
2016: Medic pasture
Soil type
Red sandy loam
Soil test
$pH_{(H20)}$ (0-10 cm) 8.4
Plot size
5 m x 1.5 m x 4 reps

Key messages

- **This is a component of a new five year Rural Research and Development for Profit funded project supported by GRDC, MLA and AWI; and involving Murdoch University, CSIRO, SARDI, Department of Primary Industries and Regional Development; Charles Sturt University and grower groups.**
- **This trial aims to assess a diverse range of annual pasture legumes in order to determine whether there are more productive and persistent options for the drier areas (<400 mm) of the mixed farming zone of southern Australia.**
- **Annual medics continue to be the best pasture option for neutral/alkaline soils on the upper Eyre Peninsula. Common vetch is an alternative option where a sown legume ley of one year duration is preferred.**
- **Building up a seed bank is critical to the longer term performance of the pasture. The aim in the pasture establishment year should be to maximise seed set.**
- **Levels of hard seed affect regeneration. Legumes with high hard seed levels should be cropped in the year following establishment.**

Why do the trial?

Legume pastures have been pivotal to sustainable agricultural development in southern Australia. They provide highly nutritious feed for livestock, act as a disease break for many cereal root pathogens, and improve fertility through nitrogen (N) fixation. Despite these benefits pasture renovation rates remain low and there is opportunity to improve the quality of the pasture base on many low to medium rainfall mixed farms across southern Australia. A diverse range of pasture legume cultivars are currently available to growers and new material is being developed. Some of these legumes, such as the annual medics, are well adapted to alkaline soils and have high levels of hard seed, which allow them to self-regenerate from soil seed reserves after cropping (ley farming system). Other legume cultivars and species are available and being developed that offer improved seed harvestability, are claimed to be better suited to establishment when dry sown and/or provide better nutrition for livestock. Regional evaluation is needed to determine if they are productive and able to persist in drier areas (<400 mm annual rainfall) and on Mallee soil types common to the mixed farming zone of southern Australia.

The Dryland Legume Pasture Systems project will both develop and evaluate a range of pasture legumes together with innovative establishment techniques, measure their downstream benefits to animal and crop production and promote their adoption on mixed farms.

This trial was established in 2018 to assess a diverse range of annual pasture legumes in order to determine whether there are more productive and persistent options for the drier areas (< 400 mm) of the mixed farming zone of southern Australia. In 2019 the trial was allowed to regenerate to determine which legumes regenerated and how their performance differed from the establishment year.

How was it done?

The trial sown in 2018 at Minnipa in paddock S8 was arranged in a fully randomised block design, with four replications. Similar trials were established at Loxton (SA), Piangil (Vic), Kikoira (NSW) and Condobolin (NSW). Data was analysed using Analysis of Variance in GENSTAT version 19. The least significant differences were based on F probability=0.05.

Table 1. Annual pasture legume species sown in the legume adaptation trial at Minnipa in 2018.

Pasture species	Notes
Harbinger Strand medic	Old cultivar; West Coast ecotype
Herald Strand medic	Old cultivar; aphid resistant
Jaguar Strand medic	Pod and leaf holding medic from Pristine Forage Technologies
PM-250 Strand medic	Powdery mildew resistant; tolerant of sulfonylurea (SU) herbicide residues; specifically developed for SA dryland Mallee farming systems
Pildappa Strand medic	West Coast ecotype, previously considered for release
Caliph Barrel medic	Old cultivar
Cheetah Barrel medic	Pod-holding medic from Pristine Forage technologies
Sultan-SU Barrel medic	Tolerant of SU residues; Boron tolerant; good aphid resistance
Boron Burr medic	Boron tolerant; spineless
Scimitar Burr medic	Old cultivar; spineless
Toreador Disc medic	Developed for sandy soils
Minima medic	Widely naturalised in dry areas; spineless
SARDI Rose Clover	Developed in upper mid-north; not widely sown in Mallee but reports of good performance
Rose Clover Early 35623	Experimental; early flowering and aerial seeded
Bartolo Bladder Clover	WA cultivar; aerial seeded, limited testing in the southern region
Prima Gland Clover	WA cultivar
Zulu Arrowleaf Clover	WA cultivar; earliest flowering line
Tammin Subterranean Clover	New cultivar; high level of hard-seed and tolerant of Red-legged Earth Mite
Balansa Clover X nigrescens clover	Experimental; an aerial seeded hybrid
Volga Common Vetch	Old cultivar
Studenica Common Vetch	New vetch specifically developed for drier areas
Capello Woolly Pod Vetch	Old cultivar
Casbah Biserrula	WA cultivar; with limited testing in the southern region
Margurita French Serradella	WA cultivar suited to acid soils
Santorini Yellow Serradella	WA cultivar; hard-seeded suited to acid soils with limited testing in the southern region
Trigonella balansae 5045	New species, aerial seeded.
Trigonella balansae Early 37928	New species, early line; aerial seeded
Astragalus	Experimental Australian Pasture Genebank selection; new rhizobia
Lotus arenarius	Experimental Australian Pasture Genebank selection
Lotus ornithopodiodies	Experimental Australian Pasture Genebank selection

Thirty different pasture legume species (Table 1) were sown to provide a broad range of legume species and attributes. The chosen species are a mixture of old varieties, new varieties, pre-releases, legumes with new traits, and pasture gene-bank selections based on their likely adaptation to rainfall and soil type. Some legume cultivars developed in Western Australia have also been included. These have performed well in WA and more recently in NSW, on their acid-dominant soils, but have had limited evaluation in South Australia where neutral to alkaline soils prevail.

The trial was sown on 27 June 2018 under relatively dry conditions, having received 22 mm of rain in the three weeks prior to seeding. All seed was inoculated with the best available strain of rhizobia and lime pelleted before sowing.

In 2019 the trial was allowed to regenerate. The growth of pasture lines that successfully regenerated were monitored to determine how their performance differed from the establishment year.

The seed of all species was reassessed in the field on 26 March 2019, with seed still present in all plots. On 29 April all plots were raked, to improve seed to soil contact and knock taller lines such as the Zulu Arrowleaf clover, to the ground. Plant emergence counts were completed on 20 May 2019. On 29 July all plots were given a visual score for plot vigour in terms of regeneration and biomass. A Green Seeker was then run over all plots.

Early dry matter (DM) cuts were completed on 31 July 2019 on selected lines. Plots were then mowed to simulate a grazing in late August. No further measurements were taken on the trial during the 2019 season.

What happened?

All lines showed some regeneration apart from the vetches, which have been selected to have <5% hard seed to prevent them becoming a weed in the following cereal crop. The regeneration of the biserrula and serradellas was poor, averaging 5 or less plants/m2, despite the biserrula producing reasonable seed levels in 2018. This is due to their high hard seed level (> 90%) and is consistent with the recommendation that biserrula be cropped the year following its establishment, to enable some breakdown of hard seed. The regeneration of Astragalus, the best adapted alternative legume species in the 2018 trial, was also poor with an average plot score of only 3.0. This was also probably due to high hard seed levels.

Once emerged, the regenerated pasture species continued to grow well thanks to favourable seasonal conditions. Toreador Disc medic consistently appeared to be the pasture legume with the best regeneration in terms of visual biomass, followed by Scimitar Burr medic.

The annual medics developed for alkaline soils, had the highest DM production. After a slower start, PM-250 Strand medic produced the most early (winter) DM (1.27 t/ha), although one of the Toreador plots still appeared to be the best plot in the trial from a visual perspective. Caliph Barrel medic, which produced the most biomass last year (along with Studenica Common vetch) with 1.3 t/ha, was slower to regenerate than the other medic lines, probably due to having harder seeds (>90%), however it still produced above average growth with 1.14 t/ha. The WA bred legumes (bladder clover, serradella and biserrula) developed for acidic sands, produced less DM; the result of poor regeneration and sub-optimal adaptation to soil type (Table 2).

Table 2. Average plot score, early DM and 2018 late DM for selected pasture legume species.

Legume species	Average plot score	Average early DM 31/7/19 (t/ha)	Average late DM 26/9/18 (t/ha)
PM-250 Strand Medic	8.8	1.27	0.72
Toreador Disc Medic	8.8	1.22	0.88
Bartolo Bladder Clover	2.0	0.001	0.18
Trigonella 5045	8.5	0.72	0.31
Casbah Biserrula	2.0	0.002	0.12
Margurita French Serradella	1.4	0.003	0.08
Scimitar Burr Medic	8.0	1.13	0.68
EP Harbinger Strand Medic	8.8	1.10	0.93
SARDI Rose Clover	2.5	0.04	0.23
Caliph Barrel Medic	8.1	1.14	1.30
Jaguar Strand Medic	8.1	0.92	0.65

What does this mean?

Pasture legume production, regeneration and persistence is determined by multiple factors including adaptation to soil type (texture and pH) capacity to set seed (early flowering is desirable in low rainfall areas) and hard seed levels that allow regeneration and persistence through the cropping sequence.

On the alkaline sandy loam and low rainfall conditions at the Minnipa Agricultural Centre, annual medics continue to provide the best option where a self-regenerating legume is preferred. If seed set is maximised in the establishment year the resultant seed bank may be 25 times what is initially sown, and will support pasture regeneration for many years. Common vetch may be a better option where a sown legume ley of one year is preferred, because of its ability to provide early production and options for late weed control. The new vetch cultivar Studenica, which equalled the DM of the most productive annual medic (Caliph barrel) in 2018, is scheduled for commercial release in 2021.

In 2020 the trial will be sown to wheat, with pasture legume regeneration following the cropping phase measured in 2021.

Acknowledgements

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mla
MEAT & LIVESTOCK AUSTRALIA

Australian Government

Charles Sturt University

australian wool innovation limited

CSIRO

Dryland Legume Pasture Systems: Medic nodulation and nitrogen fixation

Ross Ballard[1], Fiona Tomney[2], David Peck[1], Jeff Hill[1], Ian Richter[2] and Naomi Scholz[2]

[1]SARDI, Waite; [2]SARDI, Minnipa Agricultural Centre

Location
Minnipa Agricultural Centre, paddock S8
Rainfall
Av. Annual: 324 mm
Av. GSR: 241 mm
2019 Total: 254 mm
2019 GSR: 234 mm
Paddock history
2018: Strand medic or trigonella
2017: Scepter wheat
Soil type
Red sandy loam
Soil test
$pH_{(H20)}$ (0-10 cm) 8.3
Plot size
5 m x 1.5 m x 4 reps x 25.5 cm row spacing

Key messages

- **The nodulation of strand medic was below potential, but was not increased by inoculation.**
- **Trigonella formed more nodules than medic, but in the end PM-250 strand medic was more productive and fixed the most N.**
- **Legume inoculation (2018) increased wheat grain protein (2019). The increase could not be attributed to any measure of legume performance.**

Why do the trial?

There are reports of low grain protein levels in wheat following medic pastures and many observations of poor medic nodulation. Previous work has shown that rhizobial inoculation can improve the nodulation of medics in the SA and Victorian Mallee, and that more generally about 50% of the populations of medic rhizobia in soils are sub-optimal in their nitrogen (N) fixation capacity.

This trial aimed to:

- Determine if inoculation can improve medic nodulation at Minnipa,
- Quantify the amount of N fixed by different legumes,
- Assess impacts on the following wheat crop.

How was it done?

The trial commenced in 2018 at Minnipa in paddock S8. It was a factorial experiment (inoculation × legume) arranged in a fully randomized block design, with four replications.

There were three inoculation treatments (no rhizobia applied, or standard and high rates of inoculation) and four legumes. The legumes were Herald strand medic, representing an 'old' medic, PM-250 strand medic, representing a 'new' medic, Z-2447 medic, a medic with potential improvements in N-fixation capacity, and trigonella, a new aerial seeded legume that is also nodulated by medic rhizobia. The high rate of inoculation was applied as a double rate of recommended label rates of peat inoculant on seed and supplemented with inoculated glass micro-beads also inoculated at double rate and sown at 10 kg/ha with the seed. Standard and high rates of inoculation delivered on average 10,000 and >30,000 rhizobia per seed, respectively. Nodulation, root and shoot dry-matter (DM) production and N-fixation were measured.

In 2019, the plots were over-sown with wheat (cv. Scepter). Wheat grain yield and grain protein were measured.

What happened?

In the pasture year (2018) significant differences in nodulation and N-fixation were measured amongst the legume species (Table 1). However, inoculation even at the high rate, did not improve legume nodulation, N-fixation or DM production (data not shown).

Trigonella had about 4 times the number of nodules (17 per plant), compared to the three medics whose nodulation was similar (≤ 5 nodules per plant). Among the 540 medic plants assessed, 76 plants (14%) had no nodules and 21 plants had ≥15 nodules. Medic nodulation was not increased by inoculation.

Although trigonella had the most nodules and was the most efficient legume for N-fixation (65% N-fixation and 27 kg fixed N/t shoot DM), it did not fix more nitrogen overall because it was less productive. PM-250 and Herald strand medics fixed most N (9.8 and 7.5 N kg/ha respectively), not accounting for root contributions (+8% DM).

Table 1. Nodulation, herbage production, total shoot N and N-fixation of four legumes sown at Minnipa, 2018.

Legume	Nodulation (No./plant)	Production (kg/ha)	Total N (kg/ha)	N-fixation (%)	N-fixed (kg N/t shoot DM)	N-fixed (kg/ha)
Herald medic	5.0	326	13.0	56	22.4	7.5
PM-250 medic	4.4	408	16.0	61	24.1	9.8
Trigonella	17.0	171	7.4	65	27.4	4.8
Z-2447 medic	4.4	252	10.0	49	19.8	5.0
LSD (P=0.05)	*0.7*	*58*	*2.4*	*3*	*1.6*	*1.6*

Table 2. Effect of legume inoculation treatment (2018) on the yield and protein content of Scepter wheat in 2019.

Inoculation rate	Grain yield (t/ha)	Grain protein (%)
Not inoculated	3.02	12.7
Standard inoculation	2.74	13.1
High inoculation	2.60	13.3
LSD (P=0.05)	*ns*	*0.4*

In the wheat (2019), responses were due to inoculation rate (Table 2) rather than legume type (data not shown). Wheat grain protein was significantly greater (13.3%) in the high inoculation rate treatment, compared to no inoculation (12.7%). Wheat grain yield was not significantly affected by treatment, however showed a trend of decreasing yield (–14%, P=0.099) as inoculation rate increased.

What does this mean?

Legume DM production, nodulation and N-fixation

The results demonstrate the importance of legume DM production to the total amount of N fixed. Although legume production was low in 2018 due to late establishment (27 June) and low growing season rainfall (150 mm), it was still a strong determinant of the amount of N-fixed. PM-250 produced most DM (408 kg/ha) and fixed the most N (9.8 N kg/ha). Trigonella was the least productive legume and fixed the least N.

Medic nodulation was low, but not improved by inoculation. Similarly, other measures of legume N-fixation were not improved by inoculation. This is consistent with the current understanding that at Minnipa and in similar environments where soil pH_{CaCl} is >7 (alkaline) and where large backgrounds of annual medic persist, the likelihood of an inoculation response is low.

Although strand medic forms fewer nodules than many other legume species, nodule number (mean of 4.5 nodules/plant) was below potential. Numerous plants had no nodules. Other plants had 20 nodules, providing an indication of what is possible. The lack of inoculation response points to factors other than rhizobial deficiency as the cause of poor nodulation. SU-herbicide residues were unlikely to be the cause since PM-250 is tolerant. A possible explanation lies in the level of available soil N at the site (61 mg/kg soil N, 0-10 cm), since medic nodulation is known to be sensitive to moderate levels of available soil N.

Neither of the new legumes (trigonella or Z-2447) provided an advantage over the PM-250 and Herald. Breeder's line Z-2447 was neither well nodulated or productive. Other medic lines selected for improved N-fixation capacity combined with agronomic performance are being tested.

Wheat crop impact

Wheat grain protein level was greater and yield trended lower, following legume inoculation. This result suggests there was an unmeasured impact of legume inoculation in the previous year.

A negative relationship between grain yield and grain protein is well established and generally thought to be a consequence of extra carbohydrate (yield) in the grain diluting the protein content and vice versa. Since there was no evidence of increased legume growth with inoculation, neither excessive available soil N or water use seem likely to have limited grain yield, although they were not measured. Further, if available soil N or water were implicated, significant effects of legume type should also have occurred, since differences in legume production were substantial. The high rate of inoculation may have affected some aspect of the soil microflora.

Whilst the relative economic benefit of grain yield and protein will depend on grain prices and grade premiums, the trend of reduced grain yield and inability to measure an inoculation response in the legumes, leads us to conclude that inoculation of medic provides no value at Minnipa. The fact that inoculation responses have been measured on Mallee soils in the SA/Vic Mallee may be the result of their lower pH. Further investigation is needed to understand the basis of low nodulation in medic.

Acknowledgements

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Dryland Legume Pasture Systems: Boron tolerant annual medics

David Peck[1], Fiona Tomney[2], Jeff Hill[1], Ian Richter[2], Ross Ballard[1]

[1]SARDI, Waite; [2]SARDI Minnipa Agricultural Centre

Location
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Rainfall
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2016: Medic pasture
Soil type
Red sandy loam
Soil test
pH$_{(H20)}$ (0-10 cm) 8.4
Plot size
5 m x 1.5 m x 4 reps

Key messages

- **Annual medics are widely grown on neutral to alkaline soils that commonly contain high levels of boron in the subsoil that reduce plant growth.**
- **Boron tolerant barrel, strand and disc medic cultivars exist, but all spineless burr medic cultivars are intolerant of high boron levels.**
- **A cohort of boron tolerant spineless burr medics have been developed and entered field evaluation trials at Minnipa and Roseworthy in 2019.**

Why do the trial?

Annual medics are widely grown as ley pastures on neutral to alkaline soils and provide many benefits to mixed farms including providing high quality feed to livestock, fixing nitrogen; and reducing cereal disease levels. Mixed farms have reduced economic risk compared to livestock or cropping farms. High levels of boron in the subsoils is a widespread constraint in neutral to alkaline soils which can restrict dry matter production and seed set. Tolerant barrel, strand and disc medic cultivars exist, but this information is not always known by farmers and their advisors. All spineless burr medic cultivars are susceptible to high boron levels which may have restricted their adoption. We have developed a cohort of boron tolerant spineless burr medics and field evaluation was begun at Minnipa and Roseworthy in 2019.

How was it done?

Part 1: Medic cultivars were grown in soil with high boron levels in a glasshouse, leaf damage symptoms recorded and cultivars allocated to different tolerance groups (Howie 2012).

Part 2: The above identified that all spineless burr medic cultivars are susceptible to high boron levels. Screening wild accessions (supplied by the Australian Pasture Genebank) identified a burr medic accession with boron tolerance and vigorous growth. The boron tolerant accession was crossed with current spineless burr medic cultivars Scimitar and Cavalier. F2 plants with high early vigour were selected and a molecular marker used to identify homozygous boron tolerant plants. A single seed descent breeding method using speed breeding was used to obtain uniform lines. Lines were seed increased at Waite in 2018 and lines with the highest agronomic performance selected for 2019 field evaluation trials.

A cohort of 16 boron tolerant lines along with their parents and barrel medic cultivars that differ in boron tolerance, were sown at Roseworthy and Minnipa. The trials were managed as best practice first year annual medics to maximise dry matter and seed production. Best practice consists of a high sowing rate (10 kg/ha), controlling broadleaf and grass weeds, monitoring and controlling insects and no grazing. Dry matter production was assessed and pods collected. Seed yield will be determined by April 2020.

What happened?

Boron tolerance rating of annual medic cultivars is provided in Table 1. Tolerant cultivars exist for barrel, disc and strand medic but all spineless burr medic cultivars were found to be susceptible. Several cultivars have been released since this work was done which have not specifically had their boron tolerance tested, but they were developed by backcross breeding programs and likely to behave similar to their recurrent parents. Pristine Forage Technologies have developed the pod holding cultivars Jaguar (strand), Cheetah (barrel) and Lynx (barrel) which share close pedigrees with Herald, Caliph and Mogul respectively. Sultan-SU was bred to be tolerant of SU herbicide residues with its recurrent parent being Caliph and Sultan-SU carries the boron molecular marker of Caliph.

Table 1. Boron tolerance rating for annual medic cultivars (from Howie 2012).

Cultivar	Species	Boron response
Caliph	Barrel	Tolerant
Jester		Moderately susceptible
Mogul		Very susceptible
Parabinga		Moderately susceptible
Paraggio		Tolerant
Sephi		Tolerant
Toreador	Disc	Tolerant
Tornafield		Susceptible
Cavalier	Spineless burr	Susceptible
Circle Valley		Susceptible
Santiago		Susceptible
Scimitar		Susceptible
Serena		Susceptible
Angel	Strand	Tolerant
Harbinger		Tolerant
Herald		Tolerant

Evaluation of the boron tolerant spineless burr medic cohort is at an early stage, with more observations required before short-listing a line for release as a cultivar. However, the boron tolerant lines have so far produced dry matter similar to or better than cultivars Scimitar and Cavalier. Seed yields are yet to be determined and hence we have not determined the best performing lines in the establishment year. Hardseed studies and the performance of regenerating pastures is required before we can shortlist the superior lines.

What does this mean?

High levels of boron in sub soils is a widespread constraint to plant production in neutral to alkaline soils. Significant yield losses have been documented for cereals, pulses and pastures. Paull *et al* (1992) found medic shoot production under high boron solution culture was reduced by 27% (most tolerant) to 67% (most susceptible). Farmers and their advisors can take boron tolerance status into account when deciding on which cultivar to plant. High levels of boron can vary with topography, with high boron being more likely in the swales and less likely in the dunes. Burr medics are better adapted to loams and clays that occur in the swales and why we consider developing boron tolerant spineless burr medic cultivar is important.

Boron tolerance was not a breeding aim of any of the boron tolerant cultivars listed in Table 1. However, the fact that we have passively selected several boron tolerant cultivars suggest that high levels of boron was often a constraint in field evaluation and that boron tolerance enabled them to have higher yields. Many boron tolerant cereal and pulse cultivars exist and their performance may provide a useful guide to the significance of boron on individual farms. Benefits from boron tolerance will vary from season to season with tolerance more likely to provide benefit in dry years when subsoil water is more important. Climate change predictions are for a more variable climate with more dry years and it is likely that boron tolerance will become a more valued trait.

The breeding aim of the boron tolerant cohort is to combine the new trait of boron tolerance with improved agronomic performance. In 2019, field evaluation of the boron tolerant cohort was begun. While it is too early to tell if we have superior lines, most lines produced high dry matter in 2019. Seed yields, hardseed breakdown studies (December 2019 to April 2020) and regeneration performance in 2020 is required before we can short list lines.

High levels of boron in the subsoil are often associated with high salt levels. High salt levels can restrict plant growth including boron tolerant genotypes. The spineless burr medic cultivars Scimitar and Cavalier have useful salt tolerance. The lines that perform the best in the field in 2019 and 2020 will be screened for salt tolerance (and boron tolerance) and the final shortlist made. The final line chosen for cultivar release will have high agronomic performance combined with boron tolerance and possibly useful salt tolerance. Research is expected to be completed in 2022 which will be followed by a minimum of three years of seed build up and hence commercial seed is expected to be first available in 2025.

Acknowledgments

This project is supported by funding from the Australian Government Department of Agriculture as part of its Rural R&D for Profit program, the Grains Research and Development Corporation, Meat and Livestock Australia; and Australian Wool Innovation. The research partners include the South Australian Research and Development Institute, Murdoch University, the Commonwealth Scientific and Industrial Research Organisation, the WA Department of Primary Industries and Regional Development, and Charles Sturt University, as well as 10 grower groups. Project code: RnD4Profit-16-03-010. The trial at Roseworthy is located on a University of Adelaide research farm. Development of boron tolerant marker and speed breeding method was funded by Meat and Livestock Australia.

Reference

Bogacki P, Peck DM, Nair RM, Howie J, Oldach KH. 2103 Genetic analysis of tolerance to Boron toxicity in the legume *Medicago truncatula*. BMC Plant Biology 2013, 13:54

Howie JH 2012 Boron tolerance in annual medic (*Medicago spp.*) Crop and Pasture science 2012, 63, 886-892.

Paull JG, Nable RO, Lake AWH, Materne MA, Rathjen AJ 1992, Response of Annual Medics (*Medicago spp*.) and Field Peas (*Pisum sativum*) to High Concentration of Boron: Genetic Variation and the Mechanism of Tolerance. Australian Journal of Agricultural Research 42, 203-213

Dryland Legume Pasture Systems: Grazing trial

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Location
Minnipa Agricultural Centre,
paddock S8
Rainfall
Av. Annual: 324 mm
Av. GSR: 241 mm
2019 Total: 254 mm
2019 GSR: 234 mm
Paddock history
2018: Various legume species or Scepter wheat
2017: Scepter wheat
2016: Medic pasture
Soil type
Red sandy loam
Soil test
$pH_{(H20)}$ (0-10 cm) 8.4
Plot size
2 hs x 3 reps

Key messages

- **Pasture legumes sown in 2018 were allowed to regenerate in 2019 and were grazed with ewe hoggets.**
- **Sheep live-weight increased on average by 13.8 kg (+26%, ~180 g/day) and was similar for all legume treatments, but differences between the sown legumes may have been masked by volunteer pasture species in the plots.**
- **Sown legume intake ranged from 401 kg/ha (*Trigonella balansae*) to 1461 kg/ha (Harbinger medic). Sheep showed some grazing preference for medic over trigonella.**
- **The site will be sown with wheat in 2020. Crop growth, grain yield and quality will be measured. Stubbles will be grazed. It will return to pasture in 2021.**

Why do the trial?

In southern Australian mixed farming systems, there are many opportunities for pasture improvement. The Dryland Legume Pasture Systems (DLPS) project aims to boost profit and reduce risk in medium and low rainfall areas by developing pasture legumes that benefit animal and crop production systems. A component of the DLPS project aims to quantify the impacts of different pasture legume species on livestock production and health. Included are widely grown legumes (strand medics and vetch) and legumes with reasonable prospects of commercialisation (trigonella).

A five-year grazing system trial was established at the Minnipa Agricultural Centre (MAC) in 2018. It is the main livestock field site for the DLPS program in southern Australia.

How was it done?

The large-scale (36 ha) grazing system experiment was established in paddock South 8 at MAC in July 2018. The trial, which consists of six treatments, is arranged in a randomised block design with three replications. The treatments are: Scepter wheat (Control 1; wheat measurements not until 2020); Volga vetch (Control 2), locally sourced harbinger strand medic; PM-250 strand medic with powdery mildew resistance and SU herbicide tolerance; SARDI rose clover; and *Trigonella balansae*, a new aerial-seeded legume closely related to medic. Each 'plot' is 2 ha in size, to allow grazing during pasture phases and on stubbles after harvest in cropping years. Four set sampling points are located within each plot to facilitate consistent pasture measurement over time. Because poor seasonal conditions limited legume growth and the priority was to optimise legume seed set, the plots were not grazed in 2018. Legume dry-matter (DM) production, seed set, nitrogen (N)-fixation and nutritive value (at maximum biomass) were measured.

The pasture treatments were allowed to regenerate in 2019. The trial was rolled with a light steel roller a week after a 10 mm rainfall event on 30 April 2019 to ensure sufficient seed to soil contact, which was followed up by 15.8 mm in the 24 hours following rolling. The vetch and cereal treatments were re-sown on 4 and 16 May respectively, in line with the planned rotation sequence below:

- 2018 pasture establishment year (aim to maximise seed set)
- 2019 pasture allowed to regenerate (monitor regeneration, graze, measure livestock production)
- 2020 wheat (measure crop yield and quality, graze stubbles)
- 2021 pasture allowed to regenerate (monitor regeneration, graze, measure livestock production)
- 2022 assessment of pasture regeneration.

Soil sampling for water content, basic nutrition, nitrogen and soil borne disease tests was completed on 4 May.

Total rainfall received for April at Minnipa was 11 mm, with May recording 57 mm and June 56 mm, providing a good start to the 2019 season. Plant emergence counts were completed between 21 and 29 May 2019.

On 29 July, eight 1-year-old ewe hoggets (equivalent to current district practice of 7 DSE/ha) were introduced into each treatment paddock after weighing and condition scoring. Four grazing exclusion cages (1 m x 1 m) were placed in each 2 ha plot (treatment) area. Pasture biomass cuts were taken within and outside the cages to enable the estimation of feed on offer (FOO), pasture DM production and composition (sown legume content and volunteer species, the latter comprising mostly naturalised medic). Pasture intake by the sheep was calculated as the difference in DM within and outside the exclusion cages. Livestock weights and pasture production were measured when the sheep were introduced (29 July) and then on 26-27 August and 3 October. Legume samples are still being processed to determine nutritive value, N-fixation level and seed production for 2019.

What happened?

2018

Legume production, N-fixation and nutritional results for the 2018 season are shown in Table 1. Vetch was the most productive legume. It produced double the DM of PM-250 medic and SARDI rose clover. Rose clover fixed the least N (10%) and had the lowest DMD and crude protein. Vetch had the highest N-fixation percentage (72%) and fixed most shoot N (21 kg/ha).

Despite a late start to the season and below average rainfall (150 mm GSR), each of the pasture species set a large number of seed/m^2 in the absence of grazing (Table 1).

The legume treatments did not significantly affect volumetric soil water content at the end of the season. Soil N results are pending.

2019

The pasture legumes differed in their regeneration density (295 to 757 plants/m^2), but were generally satisfactory (>500 plants/m^2) (Table 2). Vetch density was lower, but adequate for this larger seeded legume.

No significant differences were measured for FOO, pasture production or intake. At the commencement of grazing, FOO ranged between 1963 kg DM/ha (PM-250 medic treatment) and 1086 kg DM/ha (rose clover treatment) with volunteer pasture components (mainly naturalised medic) comprising on average 24% of the total DM (data not shown). All legume treatments had flowered by mid-August, with growth noticeably slowing due to low rainfall in that month (19 mm). Total pasture production to 3 October ranged between (3153 kg/ha, 73% vetch) and (1920 kg DM/ha, 95% Harbinger medic) (Table 2). Intake of the sown legume component ranged between 1461 kg DM/ha (Harbinger medic) and 401 kg DM/ha (*Trigonella balansae*).

No significant (P=0.3) treatment differences in livestock performance were measured. Sheep weight increased by between 26% and 30% (Table 2) and condition scores remained stable (data not shown).

Table 1. Pasture herbage and seed production, N-fixation, nutritive value for five legumes grown at Minnipa in 2018.

Legume	DM Prod'n (kg/ha)	Seed Prod'n (#/m^2)	Nitrogen fixation (%)	Nitrogen fixed (kg/ha)	DMD (%)	Crude protein (%)
Volga vetch	1297	9	72	21	68	14
Trigonella balansae	744	8208	49	11	67	19
SARDI Rose clover	541	6621	10	1	63	14
Harbinger medic	822	7639	45	9	66	18
PM-250 medic	514	4177	54	8	69	20
LSD (P=0.05)	*134*	*237*	*12*	*2*	*1.3*	*1.1*

Table 2. Legume regeneration density, total and sown legume DM production, total and sown legume intake and sheep live-weight, for five legume treatments at Minnipa in 2019.

Treatment	Sown legume density (plants/m^2)	Total production (kg/ha)	Sown legume production (kg/ha)	Total Intake (kg/ha)	Sown legume intake (kg/ha)	Sheep weight 29 July (kg)	Sheep weight 10 Oct. (kg)	Weight change kg (% gain)
Volga vetch	95	3153	2315	2014	1295	50.4	65.0	14.6 (30)
Trigonella balansae	551	2375	1572	941	401	51.5	66.0	14.5 (29)
SARDI Rose clover	295	2584	1466	1917	1116	50.3	63.3	13.0 (26)
Harbinger medic	635	1920	1902	1474	1461	49.3	63.2	13.8 (28)
PM-250 medic	757	2065	1721	1469	1398	50.4	63.5	13.1 (27)
LSD (P=0.05)	*93*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*

What does this mean?

Sheep weight increased in all treatments, with an average gain of 14 kg/head at the end of the 73 day grazing period. A good quantity and quality of feed supported rapid growth as the animals matured as hoggets. No adverse effects of the different legume treatments on sheep performance were measured or observed. Vetch was the most productive legume in both years and fixed most N in 2018. It is the best option where a sown legume of one year duration is preferred, but comes with a higher input cost as it needs to be sown each season, whereas ley pasture species self-regenerate.

Observation of the standing feed in late September indicated limited grazing of trigonella after flowering and overall the intake of this species was least (401 kg/ha) and final FOO highest (1434 kg/ha) compared to the other legumes. However, this was not reflected in sheep performance, probably because volunteer pasture species, mainly naturalised medics, contributed significantly to total pasture production (34% of DM in the trigonella treatment) and provided the sheep with an alternative feed source. The avoidance of mature trigonella by sheep may allow it to achieve higher seed yields under grazing, but in a pure sward this aspect may equally limit sheep production.

A benefit of medic PM-250, which is scheduled for commercial release in 2021, is its powdery mildew tolerance. Powdery mildew was not observed in 2019. Reports suggest that where susceptible medics are affected by powdery mildew, grazing by sheep is reduced. In the presence of powdery mildew, the production of PM-250 has previously been found to be up to 49% greater, compared to susceptible medics. PM-250 is also expected to be more palatable to sheep in years where conditions are conducive to the development of powdery mildew. PM-250 is also tolerant of SU and Intervix herbicide residues whereas the other legume cultivars are not.

The site will be cropped with wheat in 2020. If differences in N-fixation measured in 2018 were similar in 2019 (results pending), then effects on crop performance are anticipated. The site will be allowed to regenerate to pasture in 2021. This will provide critical information on the persistence of the sown legumes through the cereal crop and provide the opportunity for further grazing studies.

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Dryland Legume Pasture Systems: Evaluating pasture establishment methods for Mallee mixed farms

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Location
Waikerie
Schmidt Family
Rainfall
Av. Annual: 253 mm
Av. GSR: 164 mm
2019 Total: 161 mm
2019 GSR: 119 mm
Yield
Potential: Medic, 2 t/ha based on 20 kg/ha/mm from French (1981) for annual legume pastures
Actual: 0.7 t/ha
Soil type
Sandy loam
Soil test
pH CaCl2 7.8 0-10 cm, 7.7 70-100 cm
Nitrate N 0 -10 cm 18 mg/kg
Colwell P 0 -10 cm 13 mg/kg
S KCL 0-10 cm 6.9 mg/kg, 70-100 cm 6.5 mg/kg
OC 0-10 cm 0.42%, 70-100 cm 0.43%
Salinity Ec 1:5 0-10 cm 0.11 dS/m, 70-100 cm 0.11 dS/m
Plot size
1.68 m x 32 m x 4 reps
Trial design
Fully randomised block with time of sowing as main plots and pasture species as the sub plots
Yield limiting factors
Drought, weeds

Key messages

- **Field experiments located near Waikerie and Piangil are evaluating establishment methods (summer, twin and autumn sowing).**
- **Although the alternative pasture species established adequate plant numbers under the establishment methods, they may be less productive than medic.**
- **Serradella, Rose clover and Bladder clover performed well under summer sowing, however under twin sowing, establishment and production for all the legume species was poor at Waikerie.**
- **Further investigation is required to define the conditions where summer and twin-sowing practices are reliable.**

Why do the trial?

A significant obstacle to the adoption of pasture species is difficulty in successfully establishing high seed cost pastures, particularly in low-medium rainfall areas. The optimal establishment time for pastures in autumn is a compromise between early enough for sufficient rooting depth and biomass production, but late enough that the risk of a false break is low and high soil temperatures do not limit germination and seedling growth (Puckridge and French, 1983). Unfortunately, this sowing window coincides with the optimal sowing window for the main cropping program on mixed farms (Flohr *et al*., 2017).

Together with improved pasture cultivar options, systems need to be developed to help mixed farmers overcome logistic and economic issues surrounding pasture establishment. In Western Australia, summer and twin sowing methods have shown promise but these alternative establishment methods have had limited evaluation in south-eastern Australia (Revell *et al*., 2012). A feature of some of the legumes under investigation is their aerial seeded habit and retention of seed, allowing seed to be farmer harvested and re-sown. This project is examining the potential of different pasture legume species to be established more efficiently, to provide growers with greater flexibility in moving between crop and pasture phases by avoiding clashes with peak crop sowing times, reduce establishment costs and increase early season feed.

How was it done?

Three establishment methods were evaluated at Waikerie (SA) and Piangil (Vic) in 2019 using legume pasture species/cultivars that have not been traditionally grown in the Mallee region (Table 1). Growing season rainfall in Waikerie in 2019 was 119 mm (long-term average 164 mm) and in Piangil 100 mm (long-term average 220 mm).

Establishment methods evaluated were:

- Twin-sown, where “hard” pasture seed/pod was sown with wheat seed in 2018 for 2019 pasture establishment.
- Summer-sown, where “hard” seed/pod was sown in summer and softened to establish on the autumn break.
- Autumn-sown (control treatment), where “soft” seed was sown on the break of the season.

In Waikerie twin-sown treatments were sown on 5 June 2018, summer-sown treatments were sown on 14 February 2019, and autumn-sown treatments on 23 May 2019. In Piangil twin-sown treatments were sown 28 June 2018, summer-sown treatments were sown on 7 February 2019, and autumn-sown treatments on 13 May 2019. Indicative sowing rates are in Table 1, and all pastures were sown with a base level of either 45 kg/ha of MAP in Waikerie or 50 kg/ha of MAP in Piangil.

At each site plant number/m^2 was recorded in June, and two measures of biomass production were recorded.

The experiment was a general treatment structure in randomised blocks with sowing method and cultivar as treatment factors with four replications, and designed and analysed using Genstat.

What happened?

Establishment

In Waikerie the seasonal break (> 15 mm) occurred on 9 May with 20 mm rainfall. Summed rainfall prior to 9 May 2019 was 22 mm. In Piangil, the seasonal break occurred on 2 May with 19 mm rainfall, with summed rainfall prior to 2 May of 17 mm. At both sites all establishment treatments emerged within 2 weeks of each other. Sowing method had a significant effect on plant density at both sites (Figure 1). The targeted population for sown pastures is typically 150-200 plants/m^2.

Production

Treatment differences in dry matter production were measured at Waikerie, despite production being limited by rainfall (Figure 2). Production was greatest for summer and autumn-sown PM-250 medic. Although Serradella and Rose clover produced more dry matter when summer sown, the overall production was lower. Dry matter was lowest in twin-sown treatments, consistent with lower plant numbers.

Table 1. Indicative sowing rates of pod or seed (kg/ha) and equivalent amount (kg/ha) of viable hard seed sown in twin and summer sown treatments; and sown rate of germinable seed (kg/ha) in the autumn sown treatment.

Legume	Twin and summer sown treatments (kg/ha)	Autumn sown treatment (kg/ha)
PM-250 medic	30 pod, 8 viable hard seed	8
Trigonella balansae	11 seed, 5 viable hard seed	5
Bladder clover	18 seed, 16 viable hard seed	8
Rose clover	74 seed, 11 viable hard seed	8
Biserrula	9 seed, 5 viable hard seed	4
French serradella	30 pod, 8 viable hard seed	8
Gland clover	Not measured	4

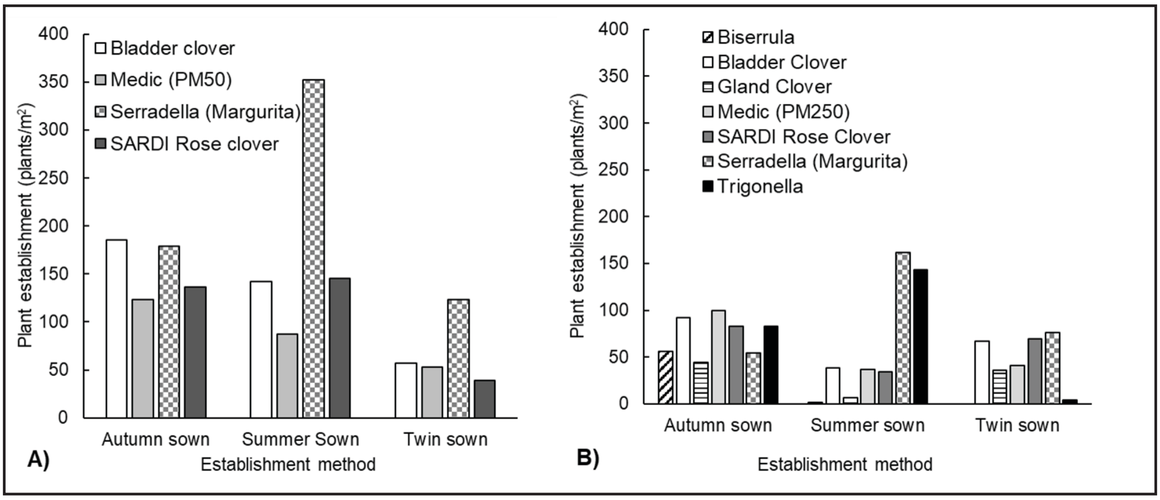

Figure 1. Plant establishment resulting from different establishment methods at a) Waikerie on 25 June 2019, vertical line is LSD (5%)=41, P <0.001 and b) Piangil on 5 June 2019, vertical line is LSD (5%)=27, P <0.001.

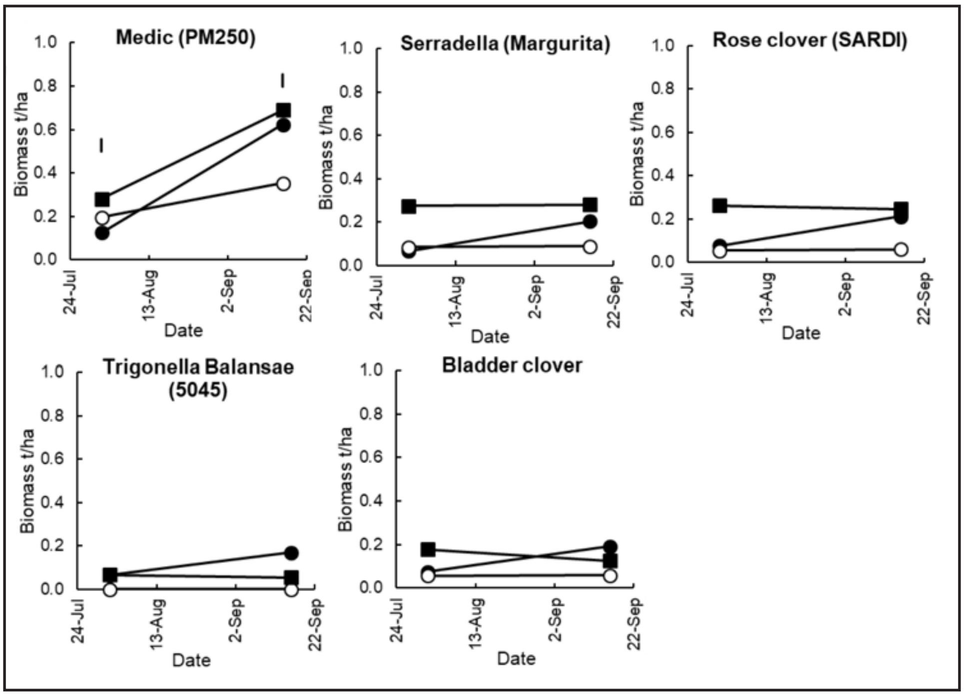

Figure 2. Biomass production (t/ha) in 2019 at Waikerie in the establishment treatments autumn sowing (●), twin-sowing (○) and summer-sowing (■), vertical line is LSD (5%) = 0.1, P<0.001.

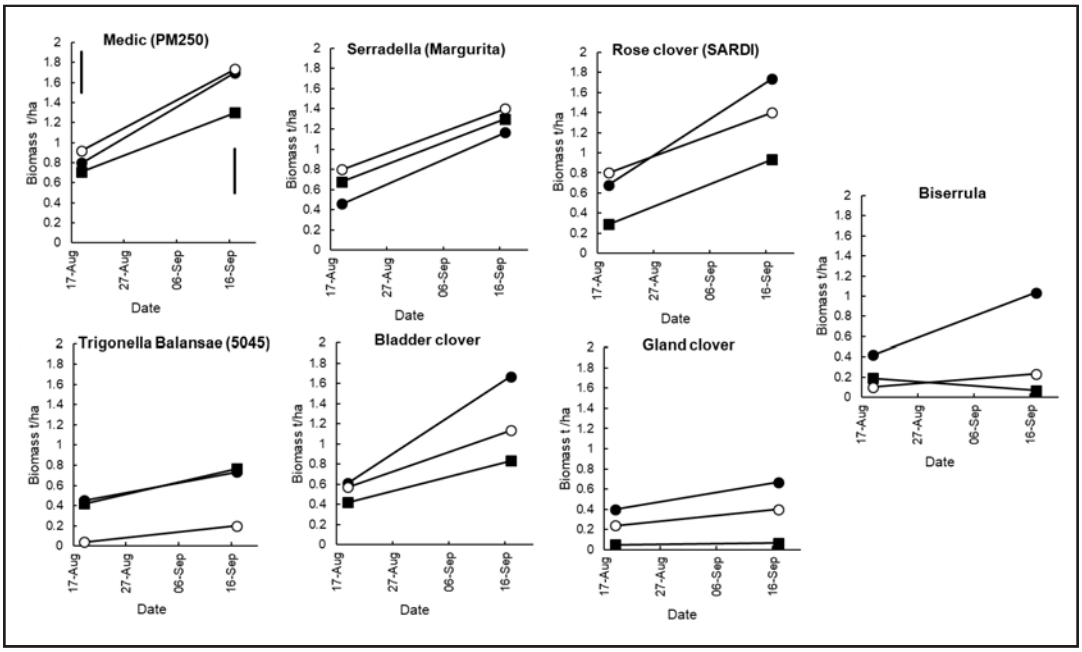

Figure 3. Biomass production (t/ha) in 2019 at Piangil in the establishment treatments autumn sowing (●), twin-sowing (○) and summer-sowing (■), vertical line is LSD (5%) = 0.41, 0.44 respectively, P<0.05.

While establishment counts were higher for summer and autumn sowing at Waikerie, biomass production tended to be higher at Piangil (Figure 3). The twin sown treatments at Piangil had establishment counts similar to the other sowing techniques, however plant density did not necessarily directly relate to biomass production. For example, there was higher plant density in summer-sown Serradella, but twin-sown treatments produced similar biomass. Medic produced similar biomass in the autumn- and twin-sowing treatments. Production of Trigonella and Gland clover was generally low, indicating they are not as well adapted to the soil type.

Results from 2019 indicate that twin and summer-sowing may be viable establishment methods for the Mallee region, however they might not be suitable for all legume species. In both environments, Margurita Serradella gained the greatest advantage from the alternative establishment methods.

Results for PM-250 medic were inconsistent, with twin-sowing inferior at Waikerie and summer-sowing inferior at Piangil. Given that all treatments emerged on similar dates, and there was very little summer rainfall in 2019, further exploration of the methods are required under a range of growing seasons such that risks and/or benefits associated with earlier seasonal or false breaks can be evaluated. This experiment will be repeated in Lameroo, SA in 2020.

Weed management

An important consideration with twin- and summer-sowing is weed control. At Waikerie, there were significantly more broad-leaved weeds in the twin- and summer-sown plots compared to autumn-sown plots (data not shown). On 1 August weed dry-matter was 3.6 vs. 44 vs. 50 g/m^2 for autumn, summer and twin treatments respectively ($P<.001$). Autumn-sown plots received a knock down spray at sowing, while twin and summer sown plots did not. Twin- and summer- sowing methods should only be considered for paddocks with low weed levels.

Seasonal analysis

To understand the likely suitability of summer and twin-sowing to Mallee environments, historic climate records (1970-2018) were analysed to reveal the distribution of when the seasonal break occurred. Using the APSIM model (version 7.10) and historic weather records, the mean break of a season was predicted (7-day period where rainfall exceeds evaporation, Unkovich 2010). The analysis revealed that Lameroo has the earliest median break and a higher probability of a break occurring before 25 April, while Piangil and Waikerie typically have a later seasonal break. In environments with a greater probability of an early seasonal break, summer-sowing will likely be more beneficial as a longer growing season can be exploited more often (Figure 4). In environments where the seasonal break is often later, there is greater risk of seed losses or burial, rhizobia death and exposure to pathogens.

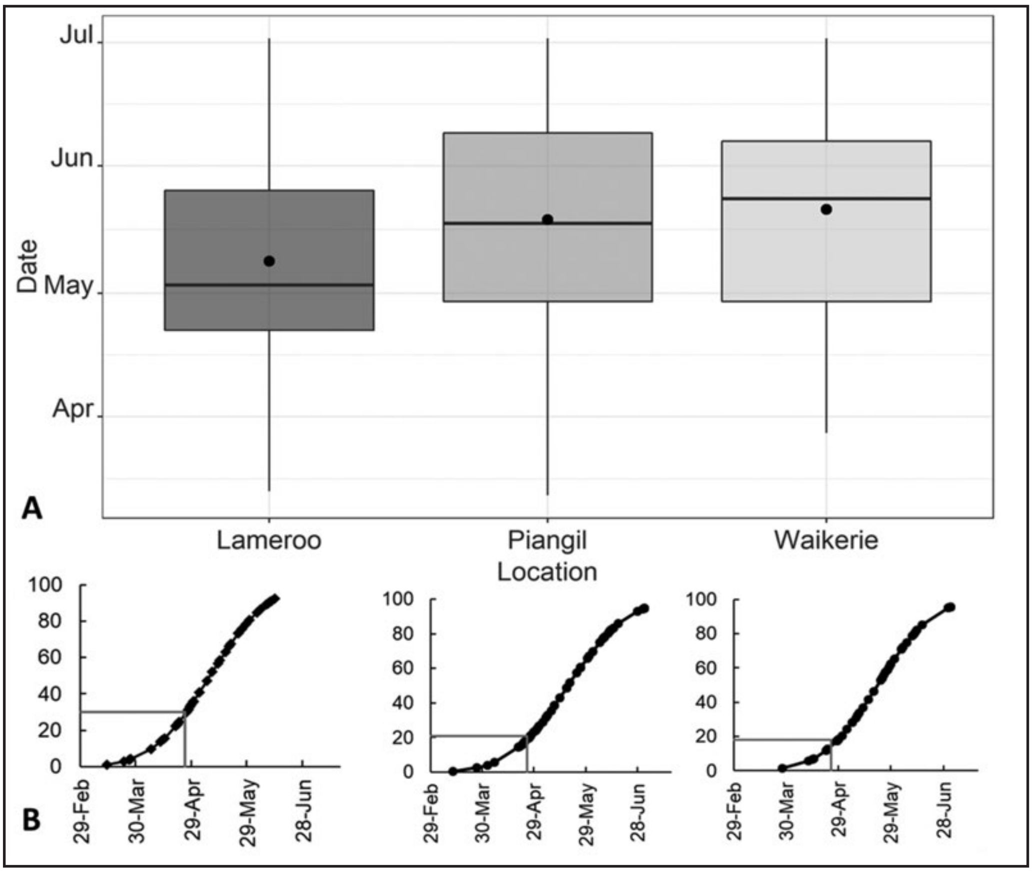

Figure 4. a) Box and whisker plots showing 25th-75th percentiles of when the autumn break occurred in the historic data set 1970-2018 using the Unkovich (2010) rule, b) the probability of the seasonal break occurring on 25 April.

What does this mean?

Alternative establishment methods have demonstrated potential in the Mallee, however they are not suitable for all legume species. The alternative legume species Serradella, Rose clover and Bladder clover have demonstrated potential for summer sowing, however establishment and production under twin sowing was low at Waikerie. While PM-250 medic was the highest biomass legume, it is not yet clear which establishment technique will consistently give the best results. This is worthy of further investigation given the potential to provide growers with greater sowing flexibility and reduced seed costs.

Acknowledgements

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References

Flohr, B.M., Hunt, J.R., Kirkegaard, J.A., and Evans, J.R. (2017). Water and temperature stress define the optimal flowering period for wheat in south-eastern Australia. Field Crops Research 209, 108-119.

Puckridge, D.W., and French, R.J. (1983). The annual legume pasture in cereal ley farming systems of southern Australia- a review. Agriculture Ecosystems & Environment 9, 229-267.

Revell, C.K., Ewing, M.A., and Nutt, B.J. (2012). Breeding and farming system opportunities for pasture legumes facing increasing climate variability in the south-west of Western Australia J Crop and Pasture Science 63, 840-847.

Unkovich, M. (2010). “A simple, self adjusting rule for identifying seasonal breaks for crop models”, in: Proceedings of the 15th ASA Conference ‘Food Security from Sustainable Agriculture’. (Lincoln, New Zealand).

French, R.J., 1981. Red-brown earths of Australia: management under low rainfall (South Australia) In: J.M. Oades and D.G. Lewis (Editors), Red-Brown Earths of Australia. Monograph. Waite Agricultural Research Institute, pp. 97-115.

Vsn International (2013). GenStat for Windows 18th Edition [Online]. Hemel Hempstead, UK: VSN International. Available: GenStat.co.uk [Accessed].

Dryland Legume Pasture Systems: Development of new pasture systems in NW Victoria

Roy Latta and Michael Moodie

Frontier Farming

Location
Piangil, Victoria Mallee
Rodney Haydon
Rainfall
Av. Annual: 330 mm
Av. GSR: 220 mm
2019 Total: 142 mm
2019 GSR: 100 mm
Yield
Potential: Pasture @ 45kg biomass/mm PAW (85 mm estimated) = 4 t DM/ha
Actual: Treatment 2 t DM/ha, Vetch 3.2 t DM/ha
Paddock history
2018: Wheat
Soil type
Alkaline red loamy sand
Soil test
pH $CaCl_2$ 7.4 0-10 cm, 8.4 70-100 cm
Nitrate N 0-10 cm 5.8 mg/kg
Colwell P 0-10 cm 11 mg/kg
S KcL 0-10 cm 6.5 mg/kg, 70-100 cm 9.6 dS/m
OC 0-10 cm 0.53%, 70-100 cm 0.19%
Salinity Ec 1:5 0-10 cm 0.11 dS/m, 70-100 cm 0.38 dS/m
Plot size
1.85 m x 20 m x 4 reps
Trial design
Fully randomised block with time of sowing as main plots and pastures species as the sub
Yield limiting factors
An early finish, a total 25 mm rainfall for August, September and October

Key messages

- **Legume pasture species that have not traditionally been grown in the Victorian Mallee established, largely successfully, in 2019 from hard but germinable seed sown in June 2018 (Twin sown) and February 2019 (Summer sown).**
- **They produced up to 2 t/ha of biomass and 400 kg/ha of seed in a season of only 40% of average growing season and annual rainfall.**

Why do the trial?

The trial aims to identify the application and system benefits of novel legume pasture species that have not traditionally been grown in the target region (Victorian Mallee). Recent research (Moodie *et al*., 2017) found that legumes grown in sequence with cereals increased wheat yields by 0.5–1.5 t/ha and improved annual profits by up to $100/ha in the low rainfall mixed farming regions.

Vetch is the most commonly grown pasture legume in the region. However, there are alternative pasture legumes which have the potential to increase production on certain soil types unsuited to vetch. They also have hard seed characteristics that may allow them to regenerate after a cropping phase, similar to annual medic. Pastures regenerating at high populations will increase early biomass production and livestock forage, with associated N fixation and weed competition benefits for the following cereal. The hard seed characteristic may also allow the pasture seed or pod to be sown in the cereal crop or during the summer preceding the pasture phase.

How was it done?

The trial included three establishment methods; Twin sowing (28 June 2018) with a companion crop of wheat, summer sowing (7 February 2019) and autumn sowing (13 May 2019). To protect against a false break, the twin and summer sown seed was “hard”, but assessed to be germinable by the autumn seasonal break at a species specific level. The seeding rates (Table 1) were calculated on the basis of providing each species with similar numbers of germinable seeds in autumn 2019, taking into account species specific “soft” seed percentages. The autumn sown seed was commercially prepared scarified seed with approximately 80% “soft” seed. The vetch and barley were autumn sown only with commercial seed.

Chemicals applied pre-sowing were 2 L/ha glyphosate as a site application on 5 February 2019, trifluralin and glyphosate @ 1 L/ha to the barley treatment and Diuron and Simazine each at 200 g/ha to the vetch treatment. No pre-sowing chemicals were applied to pasture legume treatments due to the prior times of sowing. At all times of sowing, 50 kg of Granulock Z MAP was applied and the legume seed was inoculated with the dry granular species specific Group rhizobia.

Herbicides applied in-crop to the twin and summer sowing were Bromoxynil @ 1 L/ha to the Biserrula on 21 June 2019 and Select @ 500 mL/ha and Verdict @ 30 mL/ha to all the legumes on 26 June. No in-crop herbicides were applied to the autumn sowing.

Table 1. Alternative pasture legume common names, species and cultivars, and seed (kg/ha) sown at the twin, summer and autumn time of sowing and vetch and barley sown at the autumn sowing.

Treatment		Cultivar	Twin	Summer	Autumn
			Sowing rate (kg/ha)		
Biserrula	(*Biserrula pelecinus*)	Casbah	5.7	5.7	4.5
Bladder clover	(*Trifolium spumosum*)	Bartolo	14.7	14.7	6.8
Gland clover	(*Trifolium glanduliferum*)	Prima	Not determined		4.6
Annual medic	(*Medicago littoralis*)	PM-250	7.2	7.2	6.8
Rose clover	(*Trifolium hirtum*)	SARDI	9.8	12.5	6.8
Serradella	(*Ornithopus sativus*)	Margurita	7.4	7.4	6.8
Trigonella	(*Trigonella balansae*)	5045	4.9	4.9	4.5
Vetch	(*Vicia sativa*)	Studenica	-	-	25
Barley	(*Hordeum vulgare L.*)	Compass	-	-	50

The 2019 measurements included soil chemical analysis and soil water content immediately prior to establishing the summer sown treatments from 2 cores to 1 m in depth within each plot. Plant measurements of the novel pasture legumes included emergence on 5 June from 8 x 0.1m^2 quadrants, pasture biomass on 19 August, 17 September and 16 October, seed yield on 5 December 2019 all from 5 x 0.1m^2 quadrants. The vetch was chemically fallowed on 5 September with 3.2 t DM/ha. The barley continued on to harvest, yielding 2.7 t/ha. The 5 June plant emergence and 19 August biomass measurements are presented as comparisons to the novel pastures.

Statistical analysis with GenStat of plant density, biomass production and seed yield was carried out by a general analysis of variance with time of sowing as the main plots and pasture species as the sub plots. The barley and vetch measurements were not included in the analyses.

What happened?

A key trial impact was the rainfall, 100 and 142 mm, growing season and annual rainfall respectively, approximately 40% of the long-term average for the location.

The mean plant density of all 7 pasture legumes (Table 2) had less established plants on 5 June 2019 from twin sowing (June 2018) than summer (February 2019) and autumn (May 2019) sowing treatments. The biomass and seed production were similar for all establishment methods at each time of measurement.

The means of the three establishment methods (Table 3) found Biserrula and Gland clover had lower plant numbers, biomass and seed yield, and Trigonella lower biomass, than other entries. Bladder clover produced more seed and annual medic similar or more biomass than all other entries.

In comparison to autumn sowing, Biserrula (Table 4) established less plants and was less productive from twin and summer sowing. Bladder clover was similarly productive from all times of sowing irrespective of less plants from summer sowing. Summer sown gland clover failed. Annual medic established less plants from twin and summer sowing but had similar biomass and seed production across all establishment treatments. Rose clover had less plants and biomass production from summer sowing. Serradella established more plants from summer sowing and more biomass in August from twin sowing. Trigonella twin sown established less plants and was less productive.

Vetch and barley established at greater than optimum plant densities, more than 50 and 150 plants/m^2 respectively. Vetch produced similar biomass by August to the total annual biomass of annual medic, the next best.

Table 2. Mean 2019 plant establishment (plants/m^2), biomass production (t DM/ha) and seed yield (kg/ha) for the three establishment methods.

	5 June	19 Aug	17 Sept	16 Oct	5 Dec
	(plants/m^2)	(t DM/ha)			(kg/ha)
Twin Sowing	34	0.57	1.10	1.15	174
Summer Sowing	48	0.39	0.92	0.90	183
Autumn Sowing	58	0.55	1.25	1.45	240
LSD P=0.05	*13.9*	*ns*	*ns*	*ns*	*ns*

What does this mean?

The new project "Dryland Legume Pasture Systems" (DLPS) aims to discover resilient low-cost pasture legumes with appropriate management packages to provide livestock and cropping benefits to the low-medium rainfall mixed farming regions of Australia. There are two main components of novel pasture systems studied through this project.

1. New legume pasture species/cultivars that have not traditionally been grown in the target region. Each species may provide benefits such as increased production on certain soils types; improved value to livestock; the ability for seed to be retained; hard seed characteristics that provides a viable pasture after many cropping phases.

Established near Piangil in the Victorian Mallee the trial did not measure any production benefits from the novel pasture systems in comparison to vetch in 2019, the initial pasture establishment year. Vetch is well adapted to the alkaline loamy sand soil type of the trial site and by August had produced similar biomass to the best novel pasture legumes total October 2019 production. However, it should be noted that vetch established at near optimum plant density, 77 plants/m^2, compared to only approximately 25% of optimum densities for the pasture legumes.

The ability for seed to be harvested and retained by the farmer was considered possible with the seed pods, apart from the annual medic, remaining largely attached to the vines in December. This would allow some seed to be collected by mechanical harvester, however lack of plant height due to low plant populations and rainfall would limit potential yields in 2019. The hard seed characteristics that allow the novel pastures to produce a viable pasture after a cropping phase will not become evident until 2021, following the 2020 cropping phase.

2. Alternative pasture establishment systems aimed at reducing the cost of pasture establishment and potentially improved productivity from greater water use efficiency.

The second trial component based on alternative systems targeting opportunities to reduce the cost of pasture establishment and potentially improved productivity provided useful outputs. Sowing "hard" pasture seed/pod with a crop (twin sown) or late in the summer with no companion crop (summer sown) was partially successful. While there was generally less plants established from the twin and summer sowings than the autumn sowing control, the production differences were minimal except in the cases where virtually no plants established. This included Biserrula following both the twin and summer sowing and Trigonella following the twin sowing. There is some anecdotal evidence, based on biomass production figures, that more plants established after the 5 June plant counts from both the Biserrula and Trigonella twin sowings. The reasons for this are open to conjecture, but it is unlikely that seed softening continued through until June and more seed became available to germinate. Seed depth and the seasonal rainfall pattern may have been factors. However, in the case of Serradella and Trigonella, more plants established from the summer sowing than the autumn sowing, suggesting a greater level of "soft" seed than calculated.

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Table 3. Plant establishment (plants/m^2), biomass production (t DM/ha) and seed yield (kg/ha) of pasture legumes as a mean of the 3 times of sowing.

	5 June	19 Aug	16 Oct	5 Dec
	(plants/m^2)	(t DM/ha)		(kg/ha)
Biserrula	15	0.3	0.5	62
Bladder clover	53	0.5	1.4	440
Gland clover	23	0.2	0.5	69
Annual medic	47	0.8	1.8	255
Rose clover	50	0.6	1.6	192
Serradella	78	0.7	1.5	150*
Trigonella	61	0.3	1.0	225
LSD (P=0.05)	*15.4*	*0.21*	*0.25*	*76*

**Serradella pod weight not seed*

Table 4. Plant establishment (plants/m^2), biomass production (t DM/ha) and seed yield (kg/ha) of 7 pasture legumes at 3 times of sowing (TOS).

		5 June	19 Aug	16 Oct	5 Dec
	TOS	**(plants/m^2)**	**(t DM/ha)**		**(kg/ha)**
Biserrula	Twin	<1	0.01	0.21	31
	Summer	1	0.08	0.09	20
	Autumn	45	0.42	1.08	135
Bladder clover	Twin	54	0.57	1.37	401
	Summer	31	0.42	1.28	432
	Autumn	74	0.61	1.61	487
Gland clover	Twin	28	0.24	0.62	41
	Summer	5	0.05	0.12	19
	Autumn	35	0.4	0.81	148
Annual medic	Twin	33	0.92	1.81	249
	Summer	29	0.71	1.64	239
	Autumn	80	0.8	2.01	277
Rose clover	Twin	56	0.8	1.91	185
	Summer	28	0.29	1.13	153
	Autumn	66	0.68	1.86	237
Serradella	Twin	61	1.06	1.44	119
	Summer	130	0.68	1.33	163
	Autumn	44	0.46	1.56	169
Trigonella	Twin	4	0.04	0.72	191
	Summer	115	0.42	0.93	257
	Autumn	66	0.45	1.24	227
LSD (P=0.05)		*26.7*	*0.41*	*0.44*	*102.9*
Barley	Autumn	156	3.2		
Vetch	Autumn	77	2.3		

Reference

Moodie M, Wilhelm N, Telfer P and McDonald T (2017). Broadleaf break crops improve the profitability of low rainfall crop sequences. In: Doing More with Less. GJ O'Leary, RD Armstrong and L Hafner Eds. Proceedings of the 18th Australian Society of Agronomy Conference, 24 – 28 September 2017, Ballarat, VIC, Australia © 2017. (http://www.agronomyaustraliaproceedings.org/).

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Section 8

Livestock

Value of standing crops for lamb production and soil protection

Alison Frischke[1], Genevieve Clarke[1] and San Jolly[2]
[1]Birchip Cropping Group; [2]Productive Nutrition

Location
Karyrie
Rainfall
2019 Total: 418 mm
2019 GSR: 197 mm
Paddock history
2018: Fallow
2017: Lentil
Soil type
Clay loam

Key messages

- **A standing cereal crop is a low risk option for feed; it is a familiar crop grown on winter rainfall, with lower grain handling efforts and its end-of-season result can be flexible with seasonal and market conditions.**
- **With a protein supplement, lambs can be finished faster and turned off earlier, leaving more groundcover for soil protection than other pasture paddocks. Background**
- **Have you considered using a standing crop for grazing in spring or summer? Feeding sheep over the late spring feed gap when pastures are unproductive and before stubbles are ready or during summer months once stubbles are exhausted and you could be taking a break, is time consuming and requires extra resources and double handling of feed.**
- **A 'standing crop' is a crop that has been held as a fodder bank for grazing later in the year once it becomes reproductive, from head formation in the boot to full grain maturity. The standing crop can be a cereal, or a combination of a cereal with a pasture legume or grain supplement to satisfy higher protein demands of growing lambs.**
- **A standing crop can offer improved nutrition and groundcover compared to other annual pasture paddocks at these times. Systems growing autumn/winter drop lambs with genetic potential for growth rates >300 g/day, need to be maintaining high growth rates to achieve target sale weights for marketing. The standing crop can be a useful way to help finish these lambs faster at three to six months of age, enabling you to sell earlier and take stocking pressure off your farm.**
- **A standing crop can also be useful for ewes to regain condition pre-joining, during pregnancy and lambing.**

Why do the trial?

To demonstrate the value of standing crops for sheep production and soil protection.

How did we do it?

Single plots of cereal varieties (wheat, barley, oats, Table 1) were sown using knife points, press wheels and 30 cm row spacing as a demonstration on 17 May 2019, targeting a plant density of 130 plants/m^2. Assessments included GS30 biomass, GS65 (anthesis) biomass, grain yield and quality (harvested 5 December 2019). Feed tests were conducted on GS30 and GS65 biomass and grain for selected varieties in Table 2.

Granulock® Supreme Z fertiliser + Flutriafol (200 mL/100 kg) fungicide @ 60 kg/ha was applied at sowing, and urea was top-dressed on 24 June @ 100 kg/ha, 25 July @ 100 kg/ha, and 26 August @ 100 kg/ha.

Weeds, pests and disease were controlled according to best management practice.

Table 1. Sowing rate (kg/ha) to achieve 130 plants/m², GS30 and GS65 biomass (t/ha) and grain yield (t/ha) for standing cereal crops, Karyrie 2019.*

Cereal type	Variety	Sowing rate (kg/ha)	GS30 biomass (t/ha)	GS65 biomass (t/ha)	Grain yield (t/ha)
Oats	Wintaroo	47	0.8	13.8	2.9
	Mulgara	64	1.1	11.3	1.4
	Yallara	50	0.9	10.4	2.6
	Mitika	53	0.8	8.9	2.9
	Bannister	41	0.7	9.3	4.5
	Outback	40	0.8	9.7	0.7
Mulgara	Moby	47	1.6	9.9	0.1
	Rosalind	62	1.2	10.7	5.0
	Spartacus CL	67	1.4	10.8	4.9
	Scope CL	66	1.2	9.2	3.5
	Compass	73	1.1	11.0	1.8
	Fathom	54	1.6	10.0	2.6
	RGT Planet	81	1.6	12.1	5.5
Yallara	Scepter	76	1.1	12.7	5.3
	Trojan	64	0.8	10.6	5.6
	Longsword	40	0.7	11.5	3.9
	Wedgetail	59	0.9	11.5	4.9
	DS Bennett	49	1.1	12.1	5.3

**Demonstration data only*

What happened?

Feed production

Early biomass measured at GS30 indicated 0.7-1.1 t DM/ha for oats, 1.1-1.6 t DM/ha for barley and 0.7-1.1 t DM/ha for wheat (Table 1).

If left ungrazed until GS65, biomass results showed oats produced 8.9-13.8 t DM/ha, barley 9.2-12.1 t DM/ha and wheat 10.6-12.7 t DM/ha (Table 1).

The demonstration indicated that if sheep were able to graze the grain of mature crops in 2019, they would have had access to 1.4-4.5 t/ha oats, 1.8-5.5 t/ha barley and 3.9-5.6 t/ha of wheat grain (Table 1).

The site experienced strong winds on 21 November, resulting in lodging of Wintaroo and Mulgara. It also caused head loss in Moby which had very few remaining attached at harvest. This impacted on final yield, however the grain is easily grazed off the ground by sheep.

Feed value

When GS30 was reached, all crops tested had high digestibility, protein and metabolisable energy (ME) levels (Table 2).

By anthesis (GS65) and milky dough stage, nutritional values begin to vary so a feed test is recommended to better understand the crop value. In this trial, crude protein and metabolisable energy dropped towards dry ewe maintenance values (8% protein, 8 MJ ME/kg DM), so supplements are needed for production.

Grain quality

Samples were analysed externally using NIR. Feed quality of grain is stated in Table 2. Note the range of values, reinforcing the need to feed test to understand how crop type, variety, location and season has influenced its value. Oats are generally lower in protein, but higher in fibre than wheat and barley.

On-farm profitability

Extensive head loss occurred in some barley varieties this season. The following example can be used to calculate feed value of lost heads (Table 3).

The example valued the grain at $245/t and used a grazing wastage loss of 20% - an estimate of trampling and burying that could vary between 15 and 40%. Therefore, for a 1.26 t/ha crop, there will be about 1 t/ha grain available for sheep production.

What does this mean?

Based on current barley, wool and lamb prices, converting 1 t of standing crop grain into sheep production produces a gross margin for grazing higher than the gross value of the grain before production costs have been deducted (Table 3). This suggests that grazing a standing cereal crop offers a great conversion of grain value and can be a more profitable alternative than harvesting.

If the standing crop is a two-year option, the wastage factor can be discounted as any grain trampled or buried in year one will be eaten as regenerated cereal in year two.

Commercial practice

The advantage of grazing a standing crop to finish lambs is that it is a low cost, low risk proven practice that can be either planned or opportunistic. There is no need to learn new skills, it just involves using the crop for a different purpose.

Table 2. Feed value of standing cereal crops.

Crop variety	Plant growth stage	Crude protein (%)	Metabolisable energy (MJ/kg DM)	Neutral detergent fibre (%)	Digestibility (DMD) (%)
Mulgara oats	GS30	30.3	12.5	38.0	82.3
	GS65	8.3	9.2	53.5	62.7
	Grain	16.8	12.6	30.3	74.5
Yallara oats	GS30	28.6	12.5	39.4	81.8
	GS65	7.6	10.2	43.4	68.5
	Grain	14.0	12.1	32.0	71.4
Moby barley	GS30	28.1	12.2	44.5	80.4
	GS65	10.6	9.4	56.6	63.9
	Grain	13.0	13.0	17.1	84.9
Fathom barley	GS30	28.8	12.3	44.3	81.2
	GS65	9.0	8.4	61.6	58.2
	Grain	13.5	13.2	15.4	87.1
Scepter wheat	GS30	32.5	12.1	42.3	79.8
	GS65	7.2	8.9	53.1	61.1
	Grain	15.6	14.4	10.0	95.9

Table 3. Estimating grazing value of a standing crop of barley ($/ha).

Grain yield (t/ha)	Gross grain value ($/ha)	DSE grazing days*	Gross margin Prime lamb/Merino ewe enterprise Grazing value ($/ha)**
1	245	1500	288
2	490	3000	575

**DSE grazing days = (DM (kg/ha) – wastage) x feed test ME (we used 12 MJ)/ 8 MJ (1 DSE requires 8 MJ/day)*
***Gross margin grazing value = DSE grazing days x (GM/DSE/365)*
2020 Prime lamb/Merino ewe GM/DSE = $70, pers. comms. Barry Mudge, PIRSA Farm Gross Margin and Enterprise Planning Guide

The standing crop is sown and grown as a winter crop would be managed for harvest. In spring, the crop can be assessed for its best end-use/return opportunity, and a responsive decision made according to market and seasonal conditions. If the decision is made to graze a standing crop, grain handling and labour costs over spring and summer are lower because any supplementary feeding will be for a shorter time.

What cereals should I grow for grazing as a standing crop?

The first option is to use a cereal variety that is already on hand. It will be a variety that performs well in the local area that can easily be managed. By sowing and managing the paddock as for a normal crop, responsive decisions can be made to graze, cut for hay or harvest grain based on lamb and grain prices and seasonal conditions or events such as heat stress or frost that may have compromised grain production. Alternatively, choose a variety that is fit for purpose. Examples include:

- Winter grazing: early maturing Moby barley that has good early biomass.
- Spring/summer grazing: longer season Outback oats.
- Finishing lambs: grain varieties with good protein.
- Grass control: choose herbicide tolerance for ryegrass and silver grass control.

Does plant structure or growth stage affect sheep preference for grazing?

From grower experience, sheep will eat any cereal, regardless of whether it has awns, rough texture, is green or dry. They will preferentially graze varieties for palatability (mouth feel, sweetness and digestibility) if they are given a choice, but when there is only one variety available they will eventually consume it.

During milky dough stage, crops can become unpalatable but sheep will graze if there is no alternative. If sheep are put in earlier, the crop will ripen at different stages as it is grazed, so there will be something good to eat somewhere in the paddock. Supplement with protein during this time, especially if weaning lambs.

Supplements

Sheep protein requirements range from 8% for a dry ewe to 18-20% for lambs growing at 200 g/day. If there has been a dry finish and the crop protein is 14-16%, wait until the crop heads have been eaten off before supplementing with more protein. In favourable seasons, protein can fall to 8-10% and a supplement of legume grain would be beneficial.

All cereal grains are low in calcium and sodium, so supplement with a limestone 80%: salt 20% loose mix. There is no need for magnesium supplementation on a mature crop. Provide supplements to sheep before they enter the standing crop, so they are used to it and ready to consume it when they enter.

Introducing animals to the standing crop

The standing crop can be used at any time but take care if introducing animals to the crop once grain has set. Barley and wheat contain high levels of readily digested starches and low levels of fibre so care must be taken to prevent grain poisoning or acidosis.

It is safe to introduce lambs during head emergence, milky dough stage of crop and early grain fill as it ensures that they are grazing the crop when it matures and grain develops, and rumen microbes can gradually adjust to the change in nutrition.

If grain has set, the usual rules when introducing sheep to grain apply:

- Check pulpy kidney vaccinations are up to date and vaccinate before entering the crop if necessary. Repeat after four weeks if trading lambs and vaccination history is unknown.
- Train sheep onto the grain gradually. Begin by trail feeding in their current paddock before introducing to the crop.
- During the introduction phase, feed grain daily. Start with 50 g per head on the first day, followed by increases of 50 g every day until a full ration is reached.
- Fibre stimulates saliva production, which contains the natural buffer bicarbonate. Provide fibre or a bicarbonate supplement if paddock feed is low while trail feeding. There will be adequate fibre once in the standing crop.
- Alternatively, move sheep in and out of the standing crop over 10 days of adjustment. To avoid gorging, introduce to the paddock late in the day with full bellies, and only leave on for a short time initially, then gradually increase the time each day.
- Providing vetch/legume hay during introduction to the crop is also an acidosis prevention strategy, supplying an alternative feed as well as protein.
- Lambs will initially be more hesitant to graze as they familiarise themselves with the standing crop and are less likely to gorge themselves than ewes with previous experience.
- Monitor the flock for signs of scouring, unhappiness, lethargy, disjointed gait or lameness which will indicate the amount of grain is being increased too soon.

Wheat and triticale have the highest risk of acidosis due to high starch and low fibre levels. Barley is not as dangerous, but has a huge range of nutrient values, so be familiar with the grain analysis. Oats are safest due to their higher fibre levels and lower starch levels and sheep can go straight onto the crop. Scope barley and forage cereals (less grain) also have lower acidosis risk. At times sheep can be put onto rations quicker than the guidelines, at other times it might take longer.

Grazing behaviour of sheep in tall crops

Mow 1-2 header widths around the edge of the paddock to the trough, but not through the crop – they will make walking tracks and rut it out. Sheep will move across the standing crop paddock as they graze over time.

If the crop has been left to mature, first graze with lambs. They will eat approximately 75% of the grain and 25% leaves. Once heads have been knocked to the ground, Merino lambs are reluctant to eat them, but British or crossbred lambs will eagerly continue grazing. Start topping up lambs with legume grain to finish or shift to another paddock. Once upright heads have gone, turn in the ewes to graze the remainder.

Standing crop paddock management

Ideally leave 1-1.5 t/ha residue to provide adequate groundcover, protecting the soil from wind and water erosion and reducing evaporation of stored water over summer. Because the bulk of biomass provided by the standing crop is much larger than a finished pasture or stubble, the standing crop will provide better paddock protection for longer over the summer months.

A system suggested for a standing crop paddock is to plan to graze the paddock for two years. Sow the standing crop in April and put lambs on it to graze from milky dough stage through grain maturity. Once lambs are finished and removed from the paddock, there will still be a lot of grain remaining the next autumn to germinate on early rains. The germinating cereal seed can be used for lambing, then sprayed out and sown to vetch for the second year – or the paddock can be cleaned up further with ewes or wethers to use more straw, then destocked to germinate the residual cereal seed for a second season of cereal pasture.

Sowing the standing cereal crop into a lucerne stand or a regenerating clover or medic-based pasture will provide added protein nutrition for lamb production and help the pasture legumes persist in the rotation.

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Section 9

Disease

Cereal variety disease guide summary of 2019 season and implications for 2020

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Season summary

2019 was a second successive year with generally low levels of foliar diseases, owing to low carryover of inoculum, relatively dry growing conditions in most areas, and many growers using fungicides as protectants. Large areas of SA are also now being sown to such a narrow range of wheat and barley varieties, that the predominant varieties are largely determining which diseases are most prevalent.

Net form net blotch

The major concern that came out of 2019 is the rapid spread of resistance to fungicides observed in net form net blotch and wheat powdery mildew. The large area sown to Spartacus CL and Compass in South Australia has seen virulence on these varieties increase in the past three years. This is particularly the case with Spartacus. Testing of specific samples collected from the Yorke Peninsula by SARDI in 2019 has shown that a proportion of the pathogen population is now highly virulent on this variety. This is reflected in the lower rating provided in this guide.

The growing of barley in infected barley stubbles from the same variety will have greatly sped up this natural evolutionary process. The use of fungicides may have helped protect barley crops up to this point but it is now apparent that the same evolutionary processes have led to the development of resistance to SDHI products, including Systiva®, and some DMI products including tebuconazole. A limited survey conducted across the Yorke Peninsula suggests that the SDHI resistance is currently focused on the mid to lower Yorke Peninsula whilst the DMI resistance is likely to be much more widespread across SA.

Rusts

The rusts were almost absent from South Australian crops. Just a smattering of barley leaf rust was observed in the most susceptible varieties in untreated trial plots on the Yorke Peninsula and in the South East. Stripe rust, although absent from SA this season, has changed in virulence once again with a new strain observed in Victoria and NSW. This new strain's most notable feature is increased virulence on almost all durum varieties. It also has significantly increased virulence on DS Bennett, Emu Rock and Trojan but decreased virulence on many varieties including Mace, Scepter, and Chief CL Plus.

Powdery mildew in wheat

This disease has become a regular problem in the northern part of the Yorke Peninsula, particularly around Bute. Close rotations with the very susceptible varieties, Scepter and Chief CL Plus are largely responsible for this problem. Frequent use of fungicides to manage this disease as well as preventative sprays for rusts and septoria have now resulted in resistance to strobilurins and some DMI products developing in the mildew population. A limited survey conducted in the area revealed a high level of resistance to both strobilurins and tebuconazole in several paddocks.

Rhizoctonia

In most parts of South Australia, Rhizoctonia has built up substantially over the last two seasons. This pathogen was helped by the dry winter and spring conditions experienced in both 2018 and 2019, while a dry summer in 2018/19 also ensured the soil-borne inoculum carried through to the next season. Rhizoctonia is hosted by a broad range of plants, however cereals and grassy weeds are preferred hosts and will increase inoculum greatly.

Unfortunately the run of bad seasons may put pressure on growers to plant repeated cereals and limit effective grassy weed control in pastures and break-crops, each of which is likely to favour Rhizoctonia.

Crown rot was a serious problem for cereal crops which had acceptable rainfall early in 2018 but had little rainfall during grain filling. Low rainfall at the start of the season in many areas meant that infection with crown rot was lower than expected in those crops and expression of crown rot was limited. The low rainfall in 2018 also meant that breakdown of infested cereal residues will have been very slow, with inoculum levels after non-cereals higher than expected in 2019. It will be particularly important to know the crown rot risk (using the PREDICTA®B service) prior to making the decision to sow very susceptible cereal crops such as durum wheat in 2019.

Eyespot was less of a problem in most crops in 2019 due to low rainfall. There were some exceptions to this where eyespot expression was much higher than would have been expected given the low rainfall. Crops affected in this way seem to have had higher loads of infested stubble from previous crops. This suggests that the infested stubble has been wetted up by small rainfall events which produced a very humid environment at the base of the new crop, allowing higher than expected levels of spore production and infection.

Explanation for resistance classification

R The disease will not multiply or cause any damage on this variety. This rating is only used where the variety also has seedling resistance.

MR The disease may be visible and multiply but no significant economic losses will occur. This rating signifies strong adult plant resistance.

MS The disease may cause damage but this is unlikely to be more than around 15% except in very severe situations.

S The disease can be severe on this variety and losses of up to 50% can occur.

VS Where a disease is a problem, this variety should not be grown. Losses greater than 50% are possible and the variety may create significant problems to other growers.

Where ‘-‘ is used then the rating is given as a range of scores that may be observed depending on which strain of the pathogen is present. This is currently only used for some barley and oat diseases where the pathogens are particularly variable and unpredictable. This classification based on yield loss is only a general guide and is less applicable for the minor diseases such as common root rot, or for the leaf diseases in lower rainfall areas, where yield losses are rarely as severe.

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Disease identification

A diagnostic service is available to farmers and industry for diseased plant specimens.

Send your samples to:

SARDI Diagnostics
Plant Research Centre,
Hartley Grove
Urrbrae SA 5064

Wheat	Rust			*Septoria tritici* blotch	CCN Resistance	Yellow leaf spot	Eyespot	Powdery mildew	Root lesion nematodes		Crown rot	Common root rot	Flag smut	Black point ‡	Quality in SA
	Stem	Stripe	Leaf						*P. neglectus*	*P. thornei*					
Arrow	S	S	SVS	S	MS	MRMS	S	SVS	MRMS	MS	S	MS	MS	MS	AH
Accroc	MS	R	S	MRMS	S	MR	S	MRMS	S	MSS	SVS	S	SVS	MRMS	Feed
Beckom	MRMS	MRMS	MSS	S	R	MSS	S	MSS	S	MSS	S	MSS	MR	MRMS	AH
Bennett	MRMS	S	S	MSS	S	MRMS	MSS	R	S	S	VS	S	SVS	S	ASW
Calabro	MS	RMR	MSS	MRMS	S	MR	–	MR	S	MS	SVS	MSS	RMR	MS	Feed
Catapult	MR	MRMS	S	MSS	R	MRMS	–	S	S	MS	S	MSS	MS	MSS	AH
Chief CL Plus	MR	S	MR	MSS	MS	MRMS	S	SVS	MRMS	MSS	MSS	MS	SVS	MS	APW
Cobalt	S	RMR	MS	S	MSS	MS	–	MSS	S	S	S	MSS	RMR	MRMS	APW
Cobra	MR ^	MSS	MR/S*	MSS	MS	MRMS	S	MSS	MSS	MSS	S	MSS	S	MSS	AH
Cutlass	R	MS	R	MSS	MR	MSS	S	MSS	MSS	MSS	S	MS	MS	MS	APW
Emu Rock	MS	MSS	SVS	SVS	S	MRMS	MSS	MSS	MSS	S	MSS	MSS	MS	MSS	AH
Forrest	RMR	RMR	S	MS	S	MRMS	MS	S	VS	SVS	SVS	MS	MR	MR	APW
Grenade CL Plus	MR	MRMS	S	S	R	S	S	MSS	MSS	S	S	MS	MR	MSS	AH
Havoc	S	MR	S	MSS	S	MRMS	–	S	S	MSS	S	MS	MS	MS	AH
Illabo	MRMS	MR	S	MSS	MRMS	MS	–	MRMS	S	S	S	MSS	R	MRMS	AH
Impala	MR	MR	SVS	VS	MSS	MSS	MSS	R	SVS	S	S	MSS	S	MS	Soft
Kittyhawk	MRMS/S*	RMR	MS	MRMS	S	MRMS	S	MS	S	S	SVS	S	RMR	MRMS	AH
Longsword	MR	RMR	MSS	MSS	MRMS	MRMS	S	MSS	MRMS	MR	S	MS	MRMS	MS	Feed
Mace	MRMS	SVS	MSS	S	MRMS	MRMS	S	MSS	MS	MS	S	MS	S	MRMS	AH
Manning	MR	RMR	MSS	MR	S	MRMS	MS	MS	MSS	S	VS	SVS	R	S	Feed
Nighthawk	RMR	RMR	MSS	MSS	MS	MS	–	S	S	MS	S	MSS	MSS	–	Feed
Orion	MR	MSS	R	MRMS	MS	MSS	S	SVS	MS	S	S	MSS	S	S	Soft / Hay
Pascal	MSS	RMR	MS	MSS	S	MRMS	MSS	R	S	S	S	MS	S	MS	APW
Razor CL Plus	MRMS	MS	S	SVS	MR	MSS	S	MSS	S	MRMS	S	MSS	RMR	MS	ASW
Revenue	RMR ^	R	VS	MSS	S	MRMS	MS	R	S	S	S	SVS	S	MS	Feed
Rockstar	MR	MRMS	S	MSS	MSS	MRMS	–	S	MRMS	MRMS	SVS	MS	VS	–	AH
Scepter	MRMS	MSS	MSS	S	MRMS	MRMS	S	SVS	S	MSS	S	MS	MSS	MS	AH
Sheriff CL Plus	MS	MSS	SVS	S	MS	MRMS	–	SVS	MRMS	MRMS	S	MSS	S	MRMS	APW
Trojan	MRMS	MSS	MR/MS*	MS	MS	MSS	MS	S	MSS	MSS	MS	MS	SVS	MS	APW
Vixen	MRMS	MRMS	SVS	S	MSS	MRMS	S	SVS	MRMS	MS	S	MSS	SVS	MSS	AH
Zanzibar	VS	RMR	SVS	S	MSS	MS	–	MR	S	MS	S	S	SVS	MS	Feed

‡ - Black point is not a disease but a response to certain humid conditions.

R = resistant, MR = moderately resistant, MS = moderately susceptible, S = susceptible, VS = very susceptible, ^ = some susceptible plants, /* = Reaction to less common strains

Tolerance levels are lower for durum receivals

Durum	**Rust**			***Septoria tritici* blotch**	**CCN Resistance**	**Yellow leaf spot**	**Eyespot**	**Powdery mildew**	**Root lesion nematodes**		**Crown rot**	**Common root rot**	**Flag smut**	**Black point ‡**	**Quality in SA**
	Stem	**Stripe**	**Leaf**						***P. neglectus***	***P. thornei***					
Artemis	MR^	MS	RMR	MRMS	MS	MRMS	–	MSS	MS	MR	VS	MS	R	MS	Durum
Aurora	RMR	MRMS	R	MRMS	MSS	MRMS	S	MSS	MRMS	RMR	VS	MSS	R	MSS	Durum
Bitallli	MR	MS	MR	MRMS	S	MRMS	–	S	MSS	RMR	SVS	MS	R	MRMS	Durum
Saintly	MR	MR	MRMS	S	MS	MRMS	MS	MSS	MRMS	MR	VS	MS	R	MS	Durum
Spes	R	MRMS-SVS	R	MRMS	MS	MRMS	–	MSS	S	RMR	VS	MSS	R	MS	Durum
Vittaroi	MR	MS	MR	MS	S	MRMS	–	MR	MS	MR	SVS	MSS	R	MSS	Durum
Westcourt	RMR	MR	RMR	MS	MSS	MRMS	–	MSS	MS	MR	VS	MS	R	-	Durum

Triticale	**Rust**			***Septoria tritici* blotch**	**CCN Resistance**	**Yellow leaf spot**	**Eyespot**	**Powdery mildew**	**Root lesion nematodes**		**Crown rot**	**Common root rot**	**Flag smut**	**Black point ‡**	**Quality in SA**
	Stem	**Stripe**	**Leaf**						***P. neglectus***	***P. thornei***					
Astute	RMR	RMR	RMR	R	R	MRMS	–	R	R	MS	MSS	MS	R	MR	Triticale
Fusion	R	RMR	RMR	R	R	MRMS	MS	R	RMR	MSS	MS	S	R	MSS	Triticale
Goanna	R	MR^	RMR	R	R	MR	–	R	MRMS	SVS	S	–	R	–	Triticale
KM10	R	RMR	MR	R	S	MR	–	R	MR	MS	MS	MRMS	R	MRMS	Triticale
Wonambi	R	MR^	R	RMR	MS	MR	–	R	MR	MS	MSS	–	R	–	Triticale
Joey	S	MR	MR	RMR	MRMS	MR	–	R	MRMS	MSS	MS	MRMS	–	–	Triticale

‡ - Black point is not a disease but a response to certain humid conditions.

R = resistant, MR = moderately resistant, MS = moderately susceptible, S = susceptible, VS = very susceptible, ^ = some susceptible plants, /* = Reaction to less common strains
Tolerance levels are lower for durum receivals

Barley	**Leaf rust***	**Net form net blotch***	**Spot form net blotch***	**Scald***	**CCN Resistance**	**Powdery mildew**	**Eyespot***	**Covered smut**	**Common root rot**	**Root lesion nematodes**		**Black point**
										P. neglectus	***P. thornei***	
Alestar	R-MS	MR-S	MSS	MS-SVS	R ^	RMR	–	R	MSS	MR	MR	MRMS
Banks	MR-S	R-MRMS	MRMS-S	R-SVS	S	MR-MS	–	MSS	MSS	MR	MR	MS
Commander	MS-S	MS-VS	MSS	MR-SVS	R	MRMS	–	RMR	MSS	MRMS	MRMS	MSS
Compass	SVS	MR-MSS	MRMS-MSS	MR-SVS	R	MRMS-S	MS	R	MS	MRMS	MR	MSS
Fathom	MRMS-S	MS-VS	RMR	R-S	R	MRMS	MRMS	MR	MSS	MRMS	MR	MSS
La Trobe	MRMS-S	MR-MSS	MSS	R-SVS	R	MR-SVS	MRMS-S	MS	S	MRMS	MRMS	MSS
Leabrook	MS-SVS	MR-MS	MR-MS	MS-SVS	MRMS	MR-MS	–	R	MS	MR	MR	MSS
Maximus	MS-S	MR-MRMS	MRMS-MS	R-MRMS	R	MR-S	–	MS	S	–	–	MSS
Oxford	R-MS	MR-VS	MS-S	MS-SVS	S	R	MRMS	MRMS	MSS	MR	MRMS	MR
Planet	MR-MS	MR-SVS	S-SVS	R-SVS	R	R	S	R	MSS	MRMS	RMR	MRMS
Rosalind	MR-MS	MR	MS-S	MR-S	R	MRMS-S	MS	MRMS	S	MR	MR	MSS
Scope	MS-SVS	MR	MS-S	MS-SVS	S	RMR	MS	MS	MS	MRMS	MRMS	MS
Spartacus CL	MR-S	MSS-SVS	S	R-VS	R	MR-SVS	MS	MS	MS	MRMS	MRMS	MSS
Westminster	R-MRMS	R-S	S	R-S	–	*R mlo*	–	MR	MSS	MRMS	MS	MRMS
WI4952	MS-SVS	MR-MRMS	MR-MS	R-VS	S	R-MS	–	R	MSS	MR	MR	MSS

R = Resistant, MR = Moderately Resistant, MS = Moderately Susceptible, S = Susceptible, VS = Very Susceptible, – = Uncertain

* Due to multiple strains of these pathogens, the table provides a range of reactions that may be observed. Different ratings are separated by a -

mlo - These varieties carry durable resistance

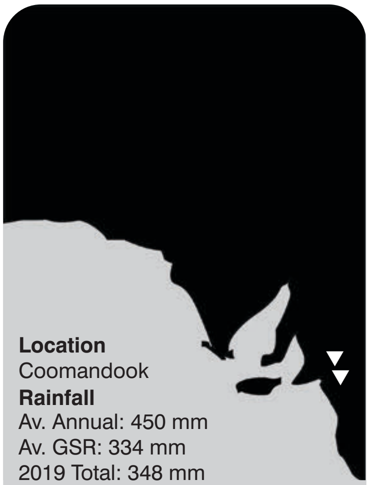
Oats	**Rust**		**CCN**		**Stem nematode**		**Bacterial blight**	**Red leather leaf**	**BYDV***	***Septoria avenae***	**End Use**
	Stem*	**Leaf***	**Resistance**	**Tolerance**	**Resistance**	**Tolerance**					
Bannister	MR-S	R	R	I	–	MI	MR-S	MS	MS	S	Grain
Bilby	S	R	S	–	–	–	S	MS	MR-MS	S	Grain
Brusher	MS-S	MS-S	R	MI	MS	I	MR-MS	MS	MS	MS	Hay
Durack	S	R-S	R	MI-MT	–	I	MR-S	MS	MS-S	S	Grain/Hay
Forester	R-S	MR-MS	MS	MI	S	I	MS-S	MR	MR-S	MR	Hay
Glider	MR-S	MS-S	MS	I	R	T	R	MR	MR-S	MR	Hay
Koorabup	R-S	MS-S	S	–	–	MI	MR-MSS	MS-VS	MS-S	MR	Hay
Kowari	MR-S	R	VS	–	–	I	MR-MSS	MS	S	S	Grain
Mitika	MR-S	MS-S	VS	I	S	I	MR-MSS	S	MS-S	S	Grain
Mulgara	MS	MR-MS	R	MT	R	MT	MR	MS-S	MS	MS	Hay
Tammar	MR-S	MR-MS	MR	MT	R	T	MR	MR-MS	MS	MR	Hay
Tungoo	MS-S	MS	R	MT	R	T	MR	MR	MR-MS	MR	Hay
Wallaroo	S	S	R	MT	MS	MI	S	MS	MS	S	Hay
Williams	MR-S	R	S	I	–	I	MR-MSS	MS	MR-MS	MR-MS	Grain/Hay
Wombat	MS-S	MS	R	T	MR	MT	MS-S	MS	MR	MS	Grain
Wintaroo	S	S	R	MT	MR	MT	MR-MS	MS	MR-MS	MR-MS	Hay
Yallara	S	MS	R	I	S	I	MR-MSS	MS	MS	MS	Grain/Hay

T = Tolerant, MT = Moderately Tolerant, MI = Moderately Intolerant, I = Intolerant, VI = Very Intolerant, – = Uncertain

* = Due to multiple strains of these pathogens, the table provides a range of reactions that may be observed. Different ratings are separated by a -

Improved crop nutrition for disease management and reduced fungicide dependency

Blake Gontar
SARDI Soil Biology & Molecular Diagnostics, Waite



Location
Coomandook
Rainfall
Av. Annual: 450 mm
Av. GSR: 334 mm
2019 Total: 348 mm
2019 GSR: 294 mm
Yield
Potential: 4.1 t/ha
Actual: 3.5 t/ha
Paddock history
2019: Wheat
2018: Lupin
2017: Barley
Soil type
Deep (>50 cm) coarse sand over clay
Plot size
2 m x 10 m x 5 reps
Trial design
Split-split-plot
Yield limiting factor
Nil

Location
Palmer
Rainfall
Av. Annual: 325 mm
Av. GSR: 235 mm
2019 Total: 131 mm
2019 GSR: 120 mm
Yield
Potential: 0.6 t/ha
Actual: 0.7 t/ha
Paddock history
2019: Wheat
2018: Pea
2017: Barley
Soil type
Clay loam
Plot size
2 m x 10 m x 4 reps
Trial design
Split-split-plot
Yield limiting factor
Drought, possible herbicide damage in furrow due to furrow collapse

Key messages

- **Foliar and root diseases reduced yield by 0-20% over four cereal trials conducted form 2018-2019.**
- **Improving crop nutrition did not reduce Rhizoctonia disease severity.**
- **• Sulfur reduced spot form net blotch severity on barley in 2018, but did not influence yield.**
- **Yield responses to P and Cu in barley were greater under high Rhizoctonia disease pressure in 2018, indicating correct nutrition may be more important under high disease pressure.**

Why do the trial?

Disease is a significant cost issue for South Australian growers, causing yield loss and increasing management inputs such as fungicides. At the same time, many crops grown on in SA also have nutrient deficiencies, particularly copper, zinc and potassium. Previous research has demonstrated that these nutrient deficiencies not only reduce growth and yield directly, but can also affect the capacity of plants to resist or tolerate disease.

While the benefits of addressing nutritional requirements are becoming better understood and adoption by growers has increased, most research is carried out under low disease ('controlled') conditions. It is possible that the yield response to improved crop nutrition will be greater under moderate disease conditions. Addressing an underlying nutrient problem may reduce the need for some fungicide applications. A two-year project scoping the disease management benefits of improving crop nutrition has been established with funding from South Australian Grains Industry Trust (SAGIT).

How was it done?

Four field trials were conducted over two years. Field experiments were established at Stokes and Wangary on the lower Eyre Peninsula in 2018 and at Coomandook (upper South East) and Palmer (Murray Mallee) in 2019. Details of the 2018 trials were published in the Eyre Peninsula Farming Systems Summary 2018 p78.

In 2019, the Coomandook site had low-marginal phosphorous (13-15 mg/kg) and marginal potassium (42-90 mg/kg), whilst the Palmer site had low phosphorous (10 mg/kg) and marginal copper (0.29 mg/kg). Both sites were sown to Planet barley, Palmer on 14 May and Coomandook on 21 May. At each site, six nutrient treatments were applied at seeding either with or without fungicide to manage disease. Treatments sown without fungicide were also artificially inoculated with Rhizoctonia to ensure an even and significant amount of this root disease. The experiments were of a randomised, complete block design with 5-6 replicates of each of the 12 treatment combinations (Table 1).

Table 1. Treatment details at Palmer and Coomandook in 2019.

Palmer			Coomandook		
P (kg/ha as DAP)	**K (kg/ha as MOP)**	**Disease**	**P (kg/ha as DAP)**	**Cu (kg/ha as CuSO4)**	**Disease**
0	0	Low	0	0	Low
10	40	High	10	5	High
20			20		

In 'low disease' plots, Uniform was applied to fertiliser and soil and Vibrance was applied to the seed and Prosaro applied to foliage from late tillering stage, all at the highest label rate, to achieve relatively low levels of disease. In the 'high disease' plots, soil was inoculated with Rhizoctonia and foliar disease was allowed to develop from naturally-infected stubble present in the paddock. Weed and nitrogen management throughout the year were representative of district practice.

Tissue tests were conducted on above-ground biomass ('whole tops') sampled at late tillering to confirm any response to nutrients. Approximately forty plants were collected from each plot, with tests conducted on a single sample per treatment, bulked across replicates.

Root disease (predominately Rhizoctonia due to inoculation) was assessed visually for all plots at 'late-tillering' and 'full head emergence'. Forty plants per plot were assessed by collecting four 10 cm lengths of row dug from both ends of each plot to a depth of 20 cm, the roots were washed and disease severity scored on a 0-5 scale (0=no disease, 5=all roots totally rotted). Foliar disease was assessed at 'booting' and 'early dough' growth stages by randomly sampling 20 leaves per plot and recording percentage leaf area affected.

Plots were harvested on 13 November at Palmer and 18 November at Coomandook. Data were analysed in R (Version 3.6.1) and the R package 'asreml' to estimate treatment variability and adjust for spatial trends in the trials.

What happened?

Both sites received acceptable early rainfall, allowing crop establishment in both trials in the preferred seeding window. However, follow up rainfall at Palmer was poor, with the trial remaining drought-affected throughout the season. Growing season rainfall at Coomandook was approximately 285 mm.

Tissue nutrient status

Tissue tests conducted on whole above-ground biomass at Coomandook suggested marginal phosphorous status in nil phosphorous treatments, whereas all other treatments had sufficient phosphorous. Differences in potassium confirmed a response to the applied potassium treatments, however all samples were above the critical threshold. At Palmer, phosphorous deficiency was evident in nil phosphorous treatments and a consistent response to both phosphorous and disease was evident. Copper was sufficient for all samples.

Root disease

As can be expected, disease level (inoculated vs. fungicide treated) had a highly significant effect on both seminal and crown root disease for all sites, at all timings of assessment. This demonstrates that the method was effective at setting up different levels of disease. Disease could not be completely minimised in the 'control' plots, meaning the two disease levels are better defined as 'low' and 'high'.

There were minor effects of nutrition on root disease at Coomandook. Nutrient treatments did not affect root disease score in seminal roots at the first assessment (late tiller stage). However, effects were observed in the crown roots, where differences were observed across phosphorus treatments (Table 2). The effect of phosphorous was different for low and high disease pressures. Under low disease pressure, only the 20 kg/ha rate of phosphorous reduced disease. Under high disease pressure 10 kg/ha of phosphorous reduced crown root disease score from 3.46 to 3.11, while the addition of 20 kg/ha phosphorous resulted in average crown root score of 3.33, intermediate between 0 and 10 kg/ha phosphorous and not different from either.

Table 2. Average crown root disease score at early assessment (late tiller stage) for Phosphorous and Disease level treatments at Coomandook in 2019.

Disease	Phosphorous (kg/ha)	Disease score (0=none, 5=all)
Low	0	0.87
	10	0.94
	20	0.62
High	0	3.46
	10	3.11
	20	3.33
LSD		*0.25*

Under low disease pressure the addition of 20 kg/ha reduced crown root disease score from 0.87 down to 0.62.

At the second assessment (head emergence timing), phosphorous had an overall effect on seminal root disease only, reducing seminal root disease score on average (across disease levels) from 2.7 down to 2.4 with the addition of either 10 or 20 kg/ha of phosphorous. This same effect was not observed on the crown roots.

At Palmer, neither phosphorous nor copper had an effect on seminal or crown root disease score under low or high disease pressure, at either sampling time.

Leaf disease

Leaf disease was not assessed at Palmer, due to low rainfall throughout the year limiting any development of leaf disease.

At Coomandook, spot form net blotch developed in high disease plots (13.3% leaf area) and was limited in 'low' disease plots (0.015%) leaf area. However, nutrition had no effect on leaf disease at the first assessment (mid-tiller stage). Disease continued to develop in high disease plots and was present at 33.0% leaf area at head emergence, while low disease plots remained controlled (0.02%). Again, nutrition did not have an effect.

Yield

At Coomandook, potassium did not influence yield. Both Phosphorous and Disease Level did affect yield (Table 4). Response to phosphorous and potassium was the same under low and high disease pressure. The addition of phosphorous increased yield by approximately 0.5 t/ha. There was no difference between the two levels of additional phosphorous (10 and 20 kg P/ha), suggesting the site was responsive to phosphorous but not highly so. High disease pressure reduced yield by 0.35 t/ha.

At Palmer, barley yielded approximately 0.7 t/ha. There was no response to disease level, indicating that the effect of Rhizoctonia was not limiting, likely due to the water limited (drought) conditions. There were no other effects.

What does this mean?

Disease, both root and foliar, was a significant limitation at Coomandook in 2019, reducing yield by around 10%. Yields at Palmer were unaffected by disease, despite root disease symptoms being more severe and the difference between low and high root disease symptoms being greater. These two sites demonstrate that the relationship between disease presence and yield loss is dependent on environmental factors i.e. rainfall or plant available water.

Nutrient inputs influenced yield at Coomandook, but not at Palmer. At Coomandook, increasing potassium did not improve yield under marginal soil potassium conditions, including in the diseased treatments where roots may have been expected to struggle to source potassium. This suggests that either the root systems can continue to function despite moderate-high damage, or that potassium was still sufficiently available at this site in this season.

Table 3. Average root disease scores (0=no disease, 5=all roots totally rotted) for low and high Rhizoctonia treatments on seminal and crown roots at late tillering and full head emergence stages at Coomandook and Palmer in 2019.

Site	Late tillering				Full head emergence			
	Seminal		Crown		Seminal		Crown	
	Low	High	Low	High	Low	High	Low	High
Coomandook	1.41	2.48	0.81	3.30	1.71	3.28	1.36	3.76
Palmer	1.85	2.74	1.24	3.90	1.94	3.50	1.45	4.60

Table 4. Yield at Coomandook considering Disease level and Phosphorous amount.

Phosphorous level (kg/ha)	Disease level	Yield (t/ha)
0	High	2.97^{a}
0	Low	3.25^{ab}
10	High	3.30^{ab}
10	Low	3.79^{c}
20	High	3.53^{bc}
20	Low	3.82^{c}

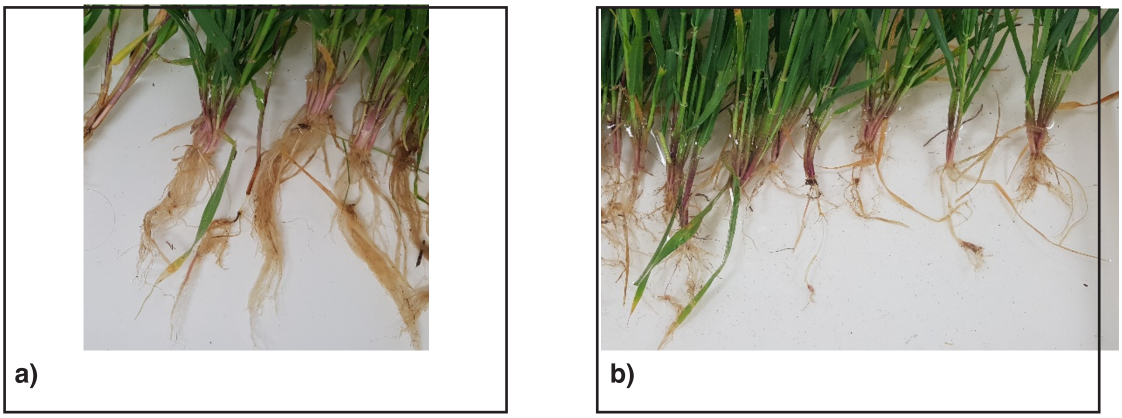


Figure 1. Palmer nutrition by disease trial 2019. a) low disease plots b) high disease plots. No yield differences were found between these treatments.

Phosphorous improved yield, but did so similarly in both low and high disease situations. Adding extra phosphorus (20 kg/ha) did not increase yield further (above the 10 kg/ha treatment), even in the treatments where roots were compromised by Rhizoctonia.

There were no clear benefits of nutrient inputs on actual root disease at either site. Root disease scores were high in inoculated plots, with generally all seminal and crown roots in all treatments at both sites displaying some disease. The responses did not show clear patterns i.e. the addition of 10 kg/ha phosphorous reduced disease score in crown roots under high disease pressure at Coomandook, whilst 20 kg/ha did not. Furthermore, the effects of phosphorous were visible in crown roots only at the early assessment, and seminal roots only at the second assessment. This may suggest subtle relationships between stage of root development, Rhizoctonia development and plant phosphorous requirement or it may simply be a chance effect.

It is important to note that no root disease response was particularly substantial. Small reductions in root or foliar disease, although statistically significant, are unlikely to influence yield or profit. Disease level treatment (low or high) had the greatest impact on root disease, which suggests established methods of managing Rhizoctonia (rotation to reduce inoculum, fungicides) are likely to have far greater impact on disease development than nutrient inputs.

Acknowledgments

Thank you to SAGIT for providing funding for this project (Project S818), Alan McKay and Nigel Wilhelm (SARDI, Waite) for assistance with trial planning and management, Helena Oakey (SAGI, Uni of Adelaide) for assistance with statistical design and analysis and to Graeme Charlton, John Richardson, Andrew Hansen and Steen Paech for providing field trial sites to conduct this research.

Section Editor:
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Section 10 Pests

Russian wheat aphid: FITE approach economically sound

Maarten van Helden[1,2], Thomas Heddle[1], Bonnie Wake[1], James Maino[3], Jess Lye[3] and Fiona Tomney[1]
[1]SARDI; [2]University of Adelaide; [3]cesar

Location
Minnipa Agricultural Centre, paddock S4
Rainfall
Av. Annual: 324 mm
Av. GSR: 241 mm
2019 Total: 254 mm
2019 GSR: 234 mm
Yield
Actual: Trial average yield: 2.24 t/ha (Scepter 2.16; Spartacus 2.55, Aurora 1.84 t/ha)
Paddock history
2018: Vetch
2017: Barley
2016: Wheat
Soil type
Sandy loam
Plot size
12 m x 1.8m (6 row) x 4 reps x 25.5 cm row spacing
Trial design
Randomised complete block design

Key messages

- **In the 2019 Minnipa field trials, natural infestation of RWA was extremely low. As such, prophylactic seed treatments were not warranted against this aphid for the 2019 season.**
- **After artificial inoculation, RWA numbers increased to levels above the United States (US) intervention threshold. In this trial up to 15% of tillers with aphids and >30% of tillers with symptoms were measured, but no significant effect on yield was observed.**
- **RWA should be managed using currently recommended intervention thresholds. The US threshold of 20% of plants with RWA before tillering, and 10% of tillers with aphids after GS35-40 seems sufficiently conservative to avoid any yield loss. Find further details in the GRDC RWA Tips and Tactics Guide, which can be downloaded online.**

Why do the trial?

Russian Wheat Aphid (RWA) was first reported in 2016 in South Australia (SA), and has since been detected widely throughout Victoria, and in New South Wales (NSW) as far north as Coonamble and as far east as Tamworth. It has not been detected in Queensland or Western Australia.

As part of the GRDC investment “Russian Wheat Aphid Risk Assessment and Regional Thresholds”, field trials were run at Minnipa for the second year through the Minnipa Agricultural Centre team. The purpose of these trials was to look into the level of natural infestation of cereal crops, and the effect of high RWA populations (obtained through artificial inoculation) on aphid and symptom dynamics and yield loss. This trial was one of a suite of trials undertaken in SA, Victoria, Tasmania, and NSW over 2018 and 2019, and contributes to a larger dataset.

The aim of the trial reported here was to determine the risk of RWA infestation in cereal crops in the Minnipa area in 2019 and observe the effect of high aphid numbers achieved through artificial inoculation on crop development and yield.

How was it done?

Two replicated trials were sown in paddock S4 at Minnipa Agricultural Centre on 15 May 2019, using seeding equipment with direct drill, press wheels and 25.5 cm row spacing, targeting a plant density of 150 plants/m².

Crop types sown were Scepter wheat, Spartacus barley, Aurora durum wheat and fertiliser, herbicides and fungicide were managed as per best practice. The trials were harvested on 8 November 2019.

The trials were set-up in two separate areas (one area inoculated, one area natural infestation) as a randomised complete block design. Seed-treated buffer zones were installed around and between trials.

Trial 1 Natural infestation trial

- 2 cereals (wheat, barley), 2 treatments, 4 replicates=16 plots
- untreated control (UTC)
- Imidacloprid seed-treated (1.2 kg/t Imidacloprid)

Trial 2 - Artificial inoculation trial

- inoculated with 50 RWA/m^2 at growth stage (GS) 20 on 26 June 2019
- 3 cereals, 3 treatments, 4 replicates=36 plots
- untreated control (UTC)
- Imidacloprid seed-treated (1.2 kg/t Imidacloprid)
- Chlorpyrifos (600 ml/ha; applied 19 August)

Aphids (all species), natural enemies and symptoms were scored every two weeks by observing 25 random tillers in each plot until harvest.

Plots were harvested on 8 November and total yield and quality parameters were recorded. Statistical analysis was done using R, more advanced analysis is still underway.

What happened?

Russian wheat aphid populations (Figure 1) were almost absent in the natural infestation areas during the whole trial (circles), except for a small increase (not visible in the graph) at the end of September when aphids start migrating. No Oat aphids (*Rhopalosiphum padi*) or Corn aphids (*R. maidis*) were observed in this site. In the inoculated area, RWA populations established on the UTC and Chlorpyrifos treatment immediately after inoculation. In the imidacloprid treated plots that were also inoculated, aphids could not establish (4 weeks after sowing), but a small peak can be observed at the last observation date (October) when aphids start migrating (mainly from the other inoculated plots) because plants are ripening off.

Initial populations in the UTC treatment were around 5 aphids per 100 tillers, increasing to around 100 aphids per 100 tillers at the end of September. In the chlorpyrifos treatment, aphid dynamics were nearly identical, but spraying on 19 August strongly reduced the population to < 10 RWA/100 tillers (Figure 1).

Since differences between commodities were not significant, results are not presented separately per commodity for aphids and symptoms.

The percentage of tillers with symptoms (Figure 2) shows a rapid build-up on the treatments with aphid populations, reaching around 30-40 % at the start of August. This then falls gradually during the rest of the observational period. Symptoms are less obvious in a maturing crop. Symptoms do not fluctuate as much as aphid dynamics, and persist when aphids are eliminated (chlorpyrifos treatment). Therefore, symptom expression was similar between the UTC and the chlorpyrifos treatment, despite the aphids being eliminated by spraying on 19 August (GS 35).

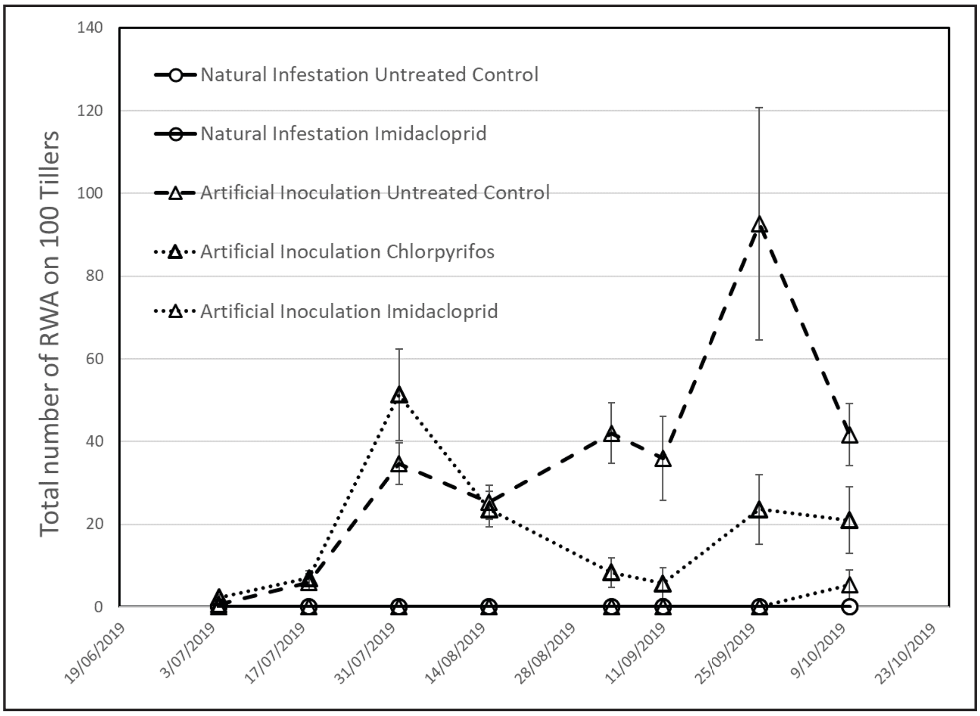

Figure 1. Russian wheat aphid dynamics in the trial (all commodities) at Minnipa in 2019. Bars show standard errors.

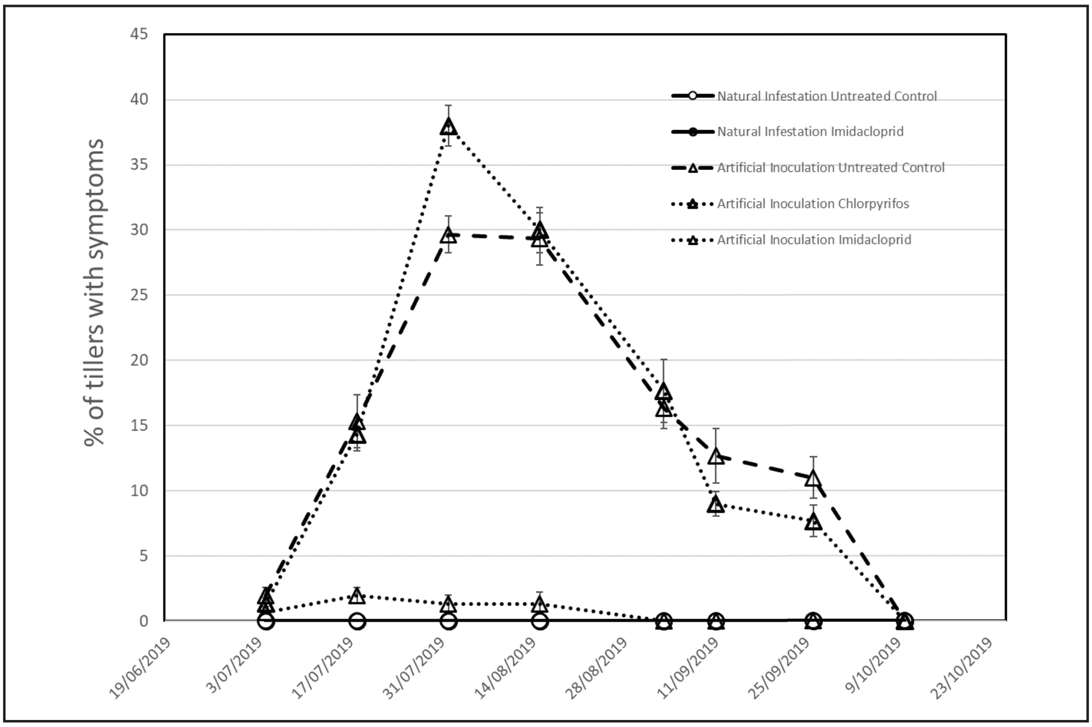

Figure 2. Percentage of tillers with symptoms (all commodities) at Minnipa in 2019. Bars show standard errors.

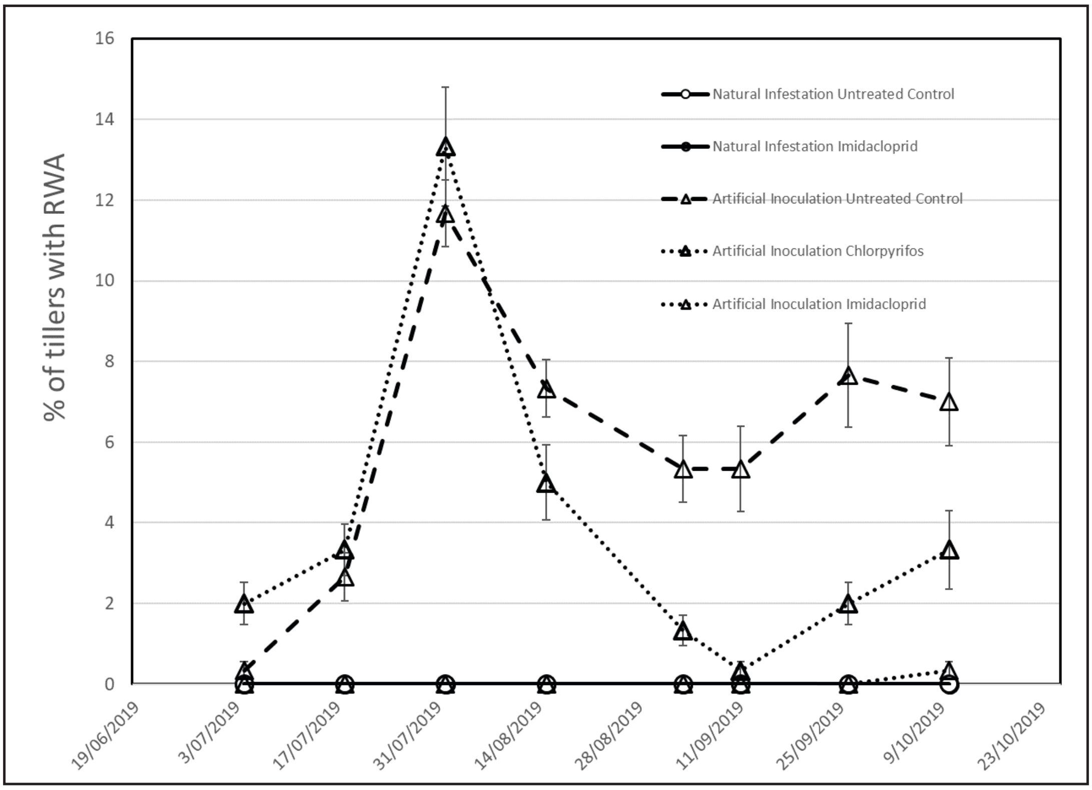

Figure 3. Percentage of tillers with Russian wheat aphids (all commodities) at Minnipa in 2019. Bars show standard errors.

The US intervention thresholds for RWA are based on the percentage of tillers with aphids. The intervention threshold is 10% of tillers with aphids after tillering (GS 35). This percentage of tillers with Russian wheat aphids is presented in Figure 3. Maximum frequency of occurrence (10-15% of tillers with RWA) is observed in late July and then drops in the chlorpyrifos treatment to ~1% after insecticide application. In the UTC a slow, more gradual, drop occurs later in season, showing that aphids leave the maturing crop at this stage. This means that the peak aphid population is slightly higher than the US intervention threshold for both the inoculated UTC and the Chlorpyrifos treatments.

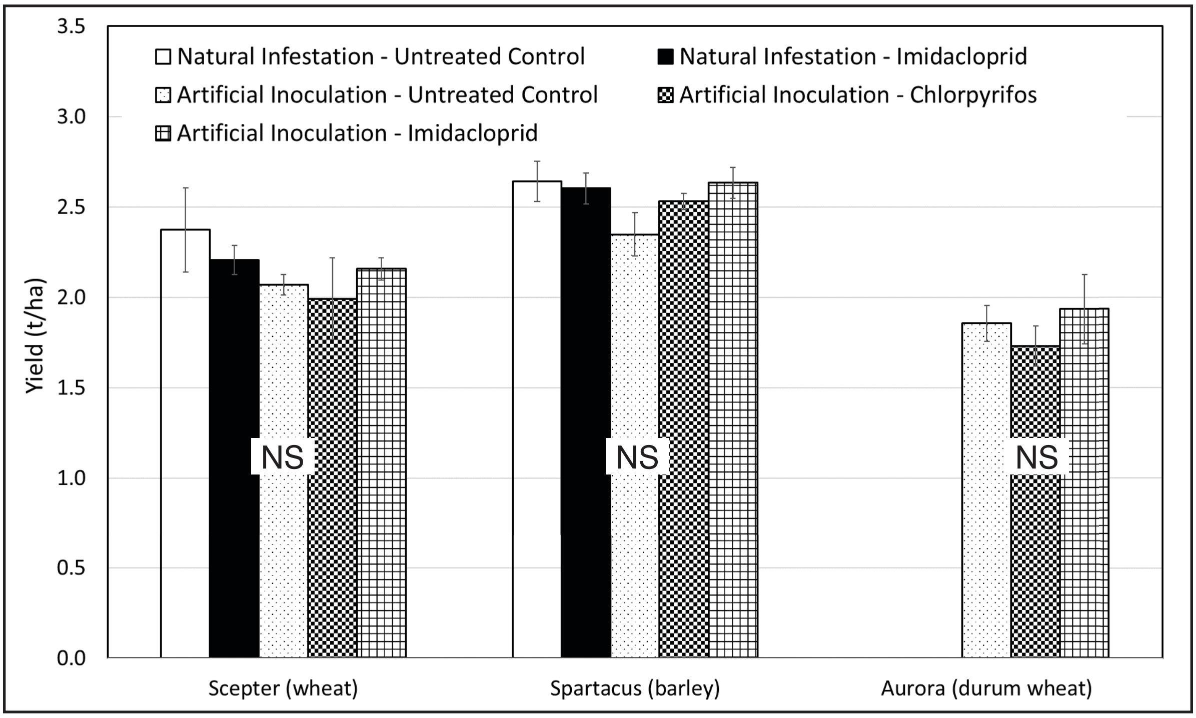

Figure 4. Harvest weight (t/ha) in each treatment and commodity at Minnipa in 2019. Bars represent standard errors. No statistically significant differences between treatments per commodity.

With these aphid populations being higher than the intervention threshold it was expected that yield differences would occur. However (Figure 4), there were no statistically significant differences per treatment for any of the commodities (wheat, barley, durum wheat).

This shows that the US threshold is sufficiently conservative to be adopted in cropping situations as shown here (in a 2-2.5 t/ha environment). Fourteen similar trials were run elsewhere in Australia and combined analysis of the data will allow the currently recommended intervention threshold for RWA to be refined.

The absence of RWA in the natural infestation trial showed that very little pressure occurred around sowing time (May) in the Minnipa area. The same was observed in most other trials, showing that RWA pressure in 2019 was very low. It is expected that RWA survival is strongly dependent on the amount of host grasses present over summer (the ‘green bridge’), which allow populations to remain large and facilitate migration to establishing crops.

Commercial practice

Results from this trial (and others) show that RWA risk in Australia in 2019 was very low (http://cesaraustralia.com/sustainable-agriculture/rwa-portal/). From the limited information collected to date, Russian wheat aphid seems rarely present in cereal crops in damaging numbers. The use of prophylactic seed coatings using neonicotinoids (imidacloprid e.g. Gaucho® or thiamethoxam e.g. Cruiser®) as an insurance treatment for RWA seems unnecessary for Australian cropping conditions that we have observed to date. Therefore, growers are advised to adopt the FITE strategy (Find, Identify, Threshold, Enact). This is preferable since RWA is probably only an occasional problem, heavily influenced by seasonal climate (the green bridge). Symptoms are easy to observe; growers/advisors have a large time-period to check for symptoms and aphids before a decision is needed (after GS30-40) and such treatments, if needed, reduce RWA effectively.

This approach, treating only if needed, will be more economical, cause less off-target effects and reduce the risk of selecting for resistance to insecticides (that can occur in multiple pest species).

Acknowledgements

This research initiative is a GRDC investment (“Russian Wheat Aphid Risk Assessment and Regional Thresholds” project UOA1805-018RTX) that seeks to deliver information on Russian wheat aphid management for grain growers. This project is being undertaken by the SARDI and cesar. Special thanks to Fiona Tomney and Katrina Brands at Minnipa Agricultural Centre who did all the observations on these trials.

Snail management - learnings from recent studies

Helen Brodie, Greg Baker, Kate Muirhead and Kym Perry
SARDI, Entomology Unit, Waite

Key messages

- **Baiting efficacy requires adequate pellet densities (30-60 m^2).**
- **To minimise bait degradation, avoid baiting in significant rainfall or high temperatures and consider bait storage temperatures.**
- **Sound, evidence-based science is reinforcing the best practice management: baiting efficacy is higher earlier in the season than in spring.**
- **A better predictive ability around the optimal conditions for baiting in 2020 is expected to be gained when extensive analysis of snail video footage and microclimate data is completed.**
- **Baiting is a crucial snail management tool but often does not achieve high order control. Consequently, implementation and development of other integrated strategies remains important.**

Background

Four introduced snail species of European-Mediterranean origin remain a significant challenge for grain growers; the vineyard or common white snail, *Cernuella virgata*, the conical snail, *Cochlicella acuta*, the small pointed snail *Cochlicella barbara*, and the white Italian snail, *Theba pisana*. These species are advantaged by modern low-disturbance farming systems and pose an increasing market access threat. Over the past six years, GRDC investments (DAS00134 and DAS00160; led by SARDI) have aimed to improve snail management with a focus on molluscicidal baiting (products, rates, timing), evaluation of novel molluscicides and improving the parasitism success of the introduced parasitoid fly, *Sarcophaga villineaveana*, against the conical snail (CSE00061, CSIRO/SARDI). This work has provided guidelines to improve snail control using baits. However, further development of integrated controls is still required and is becoming more feasible with new technologies. Provided in this article is a brief overview of key learnings on snail management from recent projects and new directions for snail research and development.

Baits - products and rates

Australian grain growers are heavily reliant on a single molluscicidal active ingredient, metaldehyde, for snail control. This molluscicidal is marketed under various product formulations with different pellet characteristics (for example bran or flour-based pellets) and concentrations of active ingredient (ranging from 1.5 to 5% a.i. metaldehyde). Iron chelate (iron EDTA complex) has an alternative mode of action and is less common in baiting programs which is possibly due to its higher cost.

Baits are not considered attractive to snails, and therefore, efficacy relies on snail movement activity and sufficient pellet densities to ensure active snails encounter pellets and consume a lethal dose. During 2014 and 2015, SARDI conducted field arena trials investigating bait efficacy for two metaldehyde products (Metarex® and Meta®) and one iron-chelate product (Eradicate®) for different snail species at a range of snail densities. Snails were placed in the field within 0.2 m^2 bare earth arenas at one of five densities (40, 80, 160, 320, 640 snails/m^2) and exposed to one of five treatments (nil and 4 different pellet densities).

These trials found:

- At least 30 pellets per m^2 were required for optimal baiting efficacy. In areas of higher snail densities, up to 60 pellets per m^2 may be required to avoid complete consumption of pellets and maintain adequate rates of encounter.
- Across all trials, using more than 0.5 pellets per live snail per unit area did not greatly increase efficacy (Figure1); however, snail mortality often varied substantially between individual trials.
- Registered rates of some products gave fewer than 30 pellets per m^2 (Table 1), suggesting that repeat applications may be necessary in some instances.

- Trials conducted by SARDI and the Yorke Peninsula Alklaline Soils Group (YPASG) showed that bait spread was often uneven. It is important for bait spreaders to be calibrated for the selected bait product, then checked to ensure spread is occurring as expected (check for under-dosed strips and bait shattering).
- The SARDI snail and slug baiting guidelines assist growers with baiting decisions (see 'Useful Resources' section of this paper).
- Baits often do not achieve high order control; other integrated control methods are required.

Baits - timing

Pellets are considered a superior bait form compared with sprays for molluscs; they have the advantage of persisting in the field during periods of inactivity. One drawback is that successful baiting requires an element of prediction; baits must be applied just before prolonged periods of snail activity (driven by weather conditions) to ensure pellet encounter. Additionally, baiting aims to control populations by knocking out mature snails before significant reproduction has occurred.

Since 2017, a GRDC project (DAS00160) led by SARDI together with DPIRD, has investigated the seasonal activity patterns of snails with respect to weather, in order to improve prediction of optimal bait timing. Eight field sites were established across Western Australia (WA) and South Australia (SA). Approximately 45 snails were collected at monthly intervals and dissected to determine their reproductive status. Time lapse video was used to monitor snail movement continuously together with logging of climate variables.

The work has found:

- Snails show a highly seasonal reproductive cycle. Enlarged 'albumen' glands indicate that snails are (or are about to become) reproductively active.
- For common white snails in SA, reproduction generally occurred from April to mid-spring (Figure 2). Increasing proportions of snails 'shut down' breeding between August to October depending on the finish to the season.
- The timing of the onset of reproduction can vary greatly from year to year, driven largely by rainfall (for example; common white snails at Gairdner WA, Figure 3).
- Currently, climatic triggers for reproduction and snail movement are being investigated through statistical analysis (March 2020 completion).
- Interestingly, laboratory trials at SARDI show that baiting efficacy also follows a seasonal cycle. Snails collected in SA from Urania (1.5 years collection period) and Palmer (3.5 years collection period) and exposed to Metarex® in bioassays were killed more efficiently during periods coinciding with snail reproduction (approximately April to August; see Figure 4) compared with other times (for example, spring).
- Together, the results reinforce the need to concentrate baiting efforts in autumn prior to reproduction and when the baits kill the snails most efficiently.

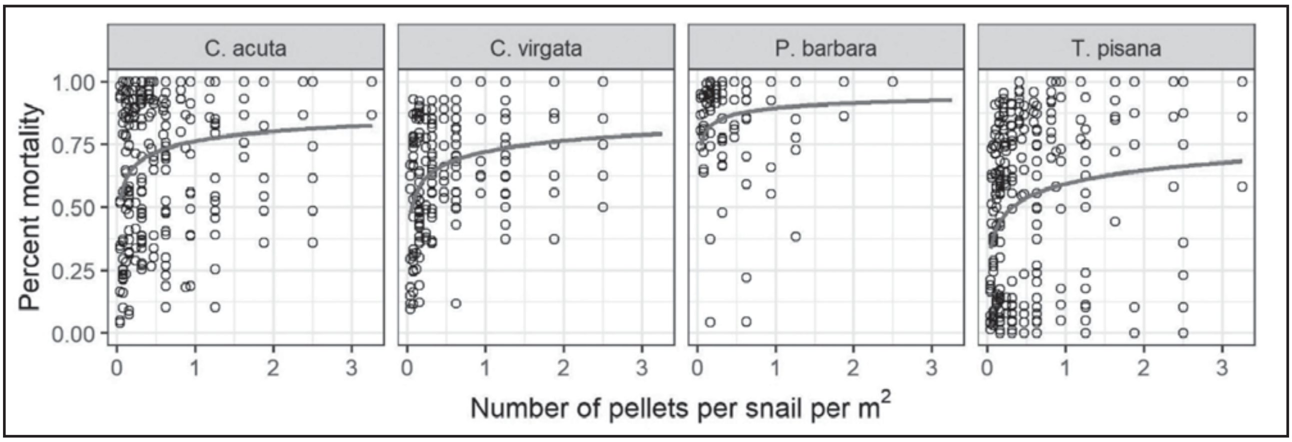

Figure 1. Mortality response versus density of pellets per snail per m^2 for four snail species (Cochlicella acuta, Cernuella virgata, Prietocella barbara and Theba pisana). Plots show pooled data for nine field cage trials with three different bait products. Circles represent mean mortality per cage; lines represent a crude model fit as an indicative guide.

Table 1. Pellet densities for registered rates of different bait products in Australian broad-acre grain production.

Product	Registered rate (kg/ha)	Pellets per m^2
Meta (15 g/kg metaldehyde)	7.5	25
Metarex (50 g/kg metaldehyde)	5	35
Eradicate (60 g/kg Iron EDTA complex)	10	25

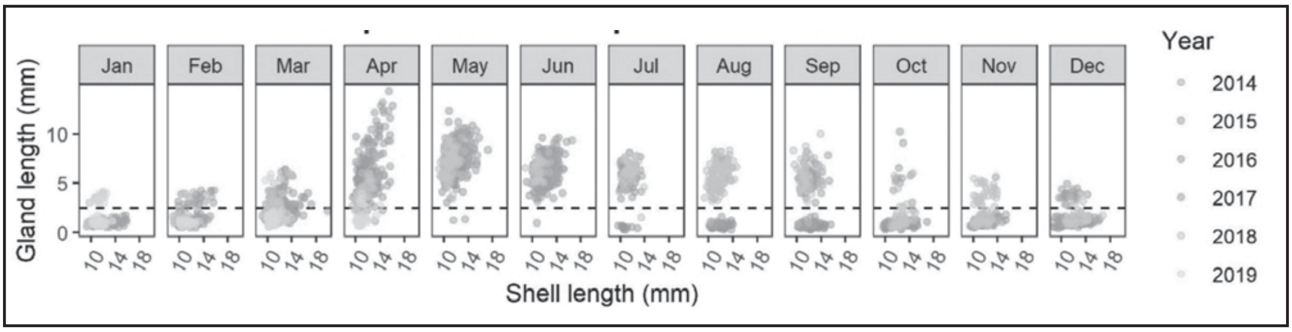

Figure 2. The seasonal reproductive cycle of common white snails at Palmer SA, shown by changes in the size of albumen glands over time. Each point represents one snail.

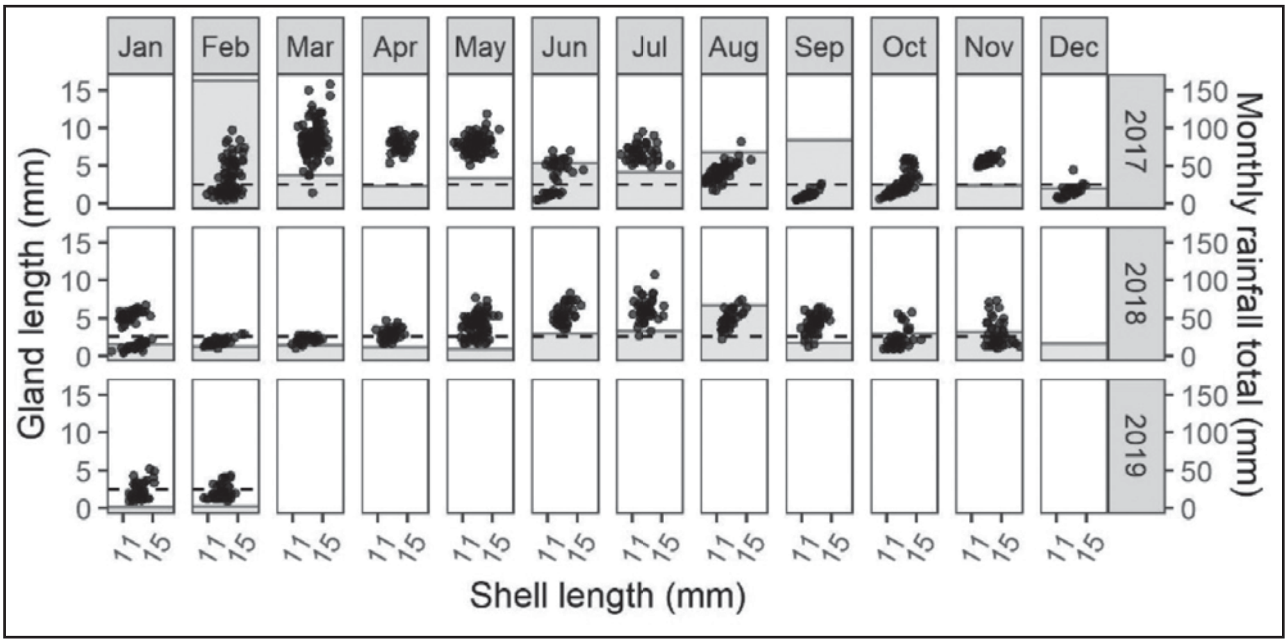

Figure 3. The seasonal reproductive cycle of common white snails at Gairdner WA together with total monthly rainfall (shading). Note that gland enlargement commenced in February of 2017 coinciding with high summer rainfall, compared to May of 2018 coinciding with a dry start.

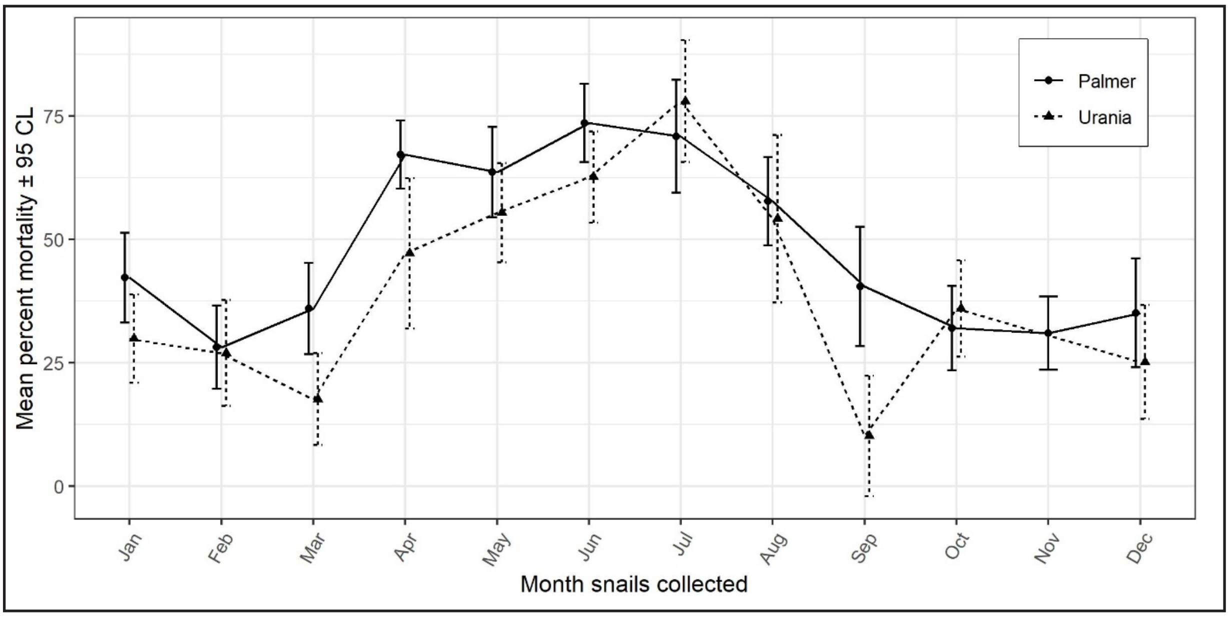

Figure 4. Mortality of common white snails exposed to Metarex baits in laboratory trials, for snails collected in each month of the year. Results from samples taken at Palmer include combined data for 2016-2019; Urania includes combined data for 2018-2019.

Baits - degradation

In recent years there has been more interest in baiting opportunistically during late summer following rain events. To investigate the possible effects 'baiting opportunistically' has on bait persistence, laboratory assays were conducted to test efficacy of baits exposed to ultra violet light (UV), high temperatures and rainfall. In each trial, eight pre-exposed baits were placed into arenas with five white Italian snails for three days and snail mortality recorded after eight days.

These trials found:

- There was no evidence that UV exposure degrades baits.
- High rainfall (35 mm) on iron chelate products reduced bait efficacy.
- Meta and Metarex baits stored at high temperatures for seven days had reduced snail mortality following use.
- Third party laboratory analysis of the heat-treated Meta and Metarex pellets revealed a significant reduction in active ingredient following the heat treatments (20°C (stored) to 60°C). The concentration of metaldehyde in Meta baits declined at an approximately linear rate of 1 g/kg lost for every 10°C above 20°C during the seven days of storage. Metaldehyde in Metarex baits degraded at a faster rate of approximately 4 g/kg lost for every 10°C above 20°C during the seven days of storage.
- Baits should be stored in cool conditions and consideration given to the forecast weather for the period following bait application.

Novel molluscicides

Between 2015 and 2016, numerous potential molluscicides have been evaluated on snails in the field and laboratory. Tested products have included: copper oxychloride, copper oxide (Cu_2O), copper sulphate ($CuSO_4$), iron sulphate ($FeSO_4$), paraquat, diquat, omethoate, thiodicarb, caffeine, UAN, Perlka®, methomyl, carbendazim and *Bacillus subtilus*. Unfortunately, these products all gave nil or low or highly variable (carbendazim) effects on snail mortality. Usage of the fungicide carbendazim, against snails has increased in recent years, but growers must strictly adhere to registered crop situations to avoid chemical residue violations and market access risks. The above-mentioned products are only to be used in accordance with the label Directions For Use including the crop, rate and all withholding periods being followed.

In the hope of discovering a new control tool, any suggestions or observations regarding other novel molluscides are welcome.

Biological control of the conical snail

A parasitoid fly, *Sarcophaga villeneuveana*, was imported from Europe, reared at SARDI and released in SA during 2001-2004 at 21 sites (19 on Yorke Peninsula and two sites on the Limestone Coast) to control the conical snail, *C. acuta* (Leyson *et al*. 2003; Hopkins 2005; Coupland & Baker 2007). The fly has established on Yorke Peninsula, but has only dispersed approximately 20 km from its original release sites on the southern 'foot', and it displays low parasitism rates (0-25%) (Muirhead, Brodie, Baker and Perry, unpublished). Under a current GRDC investment (CSE00061, CSIRO, SARDI), a geographic strain of the fly that is better matched genetically and climatically to *C. acuta* in Australia, was imported in early 2020 for host specificity testing which will be followed by a rear-and-release program in snail-affected regions.

Synthesis and directions

Baiting programs can be optimised by achieving adequate pellet densities (30 to 60 m^2), monitoring the effectiveness of spreader settings and taking care to minimise bait degradation before snails encounter them by avoiding high temperatures or significant rainfall. The science is providing a sound, evidence base which is reinforcing best practice management (for example, baiting causes higher mortality earlier in the season, and therefore, avoid spring baiting). It is expected that a better predictive ability around the optimal conditions for baiting will be gained on the completion of DAS00160 (March 2020). Baiting is a crucial management tool, but it often does not achieve high order control Therefore, continuing to implement and develop other integrated strategies remains important.

Future risks for the industry include the tightening of delivery standards for snail/grain contamination for export markets and the heavy reliance on a single molluscicide active ingredient (regulatory risks and potential for resistance to evolve). Behind the scenes, researchers, growers and funding bodies around Australia are working together to identify and integrate new technologies that can provide transformational change for snail control in modern farming systems (Perry 2018, Perry *et al*. 2019). In the foreseeable future, new systems approaches involving biological, sensing and mechanical solutions are likely to be required to meet the challenges posed by snails.

Acknowledgements

The research undertaken as part of this project is made possible by the significant contributions of growers through both trial cooperation and the support of the GRDC; the authors would like to thank them for their continued support.

Much of the project work under DAS00134 and DAS00160 was undertaken with the leadership of Dr Michael Nash (formerly SARDI). We thank him for the establishment of these projects.

We also acknowledge the contribution of Michael Richards (formerly NYNRM) who initiated the use of time-lapse cameras to spy on snails and assisted with the establishment our own monitoring sites.

GRDC project codes: DAS00134, DAS00160, CSE00061, DAS300, DAS00174, YPA0002.

Useful resources

SARDI snail and slug baiting guidelines http://www.pir.sa.gov.au/__data/assets/pdf_file/0004/286735/Snail_and_slug_baiting_guidelines.pdf

https://grdc.com.au/__data/assets/pdf_file/0024/117249/grdc-fs-snailbait-south_lr-pdf.pdf.pdf

https://grdc.com.au/__data/assets/pdf_file/0016/109060/snail-management-fact-sheet.pdf.pdf

References

Baker GJ, Brodie H, Nash MA, Salehi L. 2017. Improved management of pest slugs and snails. Final report for GRDC (project DAS00134). South Australian Research and Development Institute.

Coupland JB & Baker GH. 2007. Search for biological control agents of invasive Mediterranean snails. In: Vincent C, Goettel MS, Lazarovits G. (eds). Biological Control: A Global Perspective. CAB International, Wallingford, UK. Pp.7-12.

Hopkins DC. 2005. Final report for the Grains Research and Development Corporation Project DAS300 'Integrated Snail Management in the Southern Region'

Leyson M, Hopkins DC & Charwat S. 2003. Release and establishment in South Australia of Sarcophaga pencillata (Diptera: Sarcophagidae), a biological control agent for Cochlicella acuta (Mollusca: Hygromiidae). BCPC Symposium Proceedings No. 80: Slugs & Snails: Agricultural, Veterinary & Environmental Perspectives. Pp 295-300.

Perry KD. 2018. Exploring postharvest technologies to manage snails in harvested grain. Workshop report. South Australian Research and Development Institute. March 2018

Perry KD, Brodie H, Muirhead K. 2019. Future directions for snail research: A national workshop of researchers and growers. South Australian Research and Development Institute. December 2019

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Section 11

Sharing Info

Emotional intelligence is usually lacking

Ken Solly
Solly Business Services

During the two decades of private consulting I was called on on numerous occasions to help mend broken relationships. In most cases it was a breakdown in communication between father and son and the expectation was that I would repair the relationship in a couple of hours, not likely. When determining the cause of the dispute I would review the situation in terms of the mental, physical or emotional circumstances at the time that the relationship became damaged. In the majority of cases it was the lack of emotional intelligence that created the problem. To get better in this area, it is important that Emotional Intelligence is fully understood. In her book Emotional Intelligence author, Gill Hasson describes emotional intelligence as being about using your emotions to inform your thinking and then using your thinking to understand and manage your emotions. Once the science of emotion is studied it becomes easier to understand why a lack of emotional intelligence gets us into so much trouble. Emotional responses appear to come from one area of the brain: the amygdala; a small structure within the limbic system, one of the first areas of the drain to develop says Gill Hasson. The Limbic system enables you to respond quickly, instinctively, without having to think about it she adds. The neo cortex is the thinking and reasoning part of the brain and is much slower to process conscious thought, language and spatial reasoning. Just biting your tongue for ten seconds when that initial emotion comes into your brain may just save you from making an ass of yourself.

Whether we like it or not we are experiencing emotions every minute of our life. We can be happy, anxious, envious, lonely, critical, sad, elated and the list goes on. I have travelled through life aligning intelligence with that of academics. Someone who has gained a university degree I would deem to be intelligent. But now having considered the subject I realise that intelligence comes in so many forms.

One of the most obvious displays of emotional intelligence can be seen when we experience major fires, floods, drought and storms. Some victims cannot move on due to their emotional state, whilst others almost develop a sixth sense and make excellent decisions given the circumstances.

During my TAFE lecturing days one of my young farmer trainees told me of how he had made a major mistake on the farm and his father has gave him an almighty blast immediately using the most powerful swear words to denigrate and criticise him as a person. Emotions were high on both sides, one of attack and the other of defence. When this happens the chances of a solution remains low. The worst thing that comes out of criticism is that the person who makes an error usually sets about defending a wrong position. The problem with this situation was not that Dad had given a blast but his failure to come back and apologise once he had cooled down. Some Dads seem to forget that they made mistakes of similar proportions at the same age as their sons. Remember the old term “shit happens”. Once a fence is wrecked the most important thing is to get on and repair it. That is where emotional intelligence plays a vital role. Moving from a negative to a positive emotion within a short space of time is very difficult for most but well worth trying. It is a sure-fire way of regaining respect and allows both parties to reform a team approach.

Don’t get me wrong a blast for an employee may just be the appropriate strategy for an employee, provided you play the ball and not the man. A lot of blasts usually end up as character assassinations and do very little to rectify the problem. It is what is done immediately after the blast is so important and how you feel about each other at that point is the key to whether the castigation was the right strategy or not.

It is what is done immediately after the blast is so important and how you feel about each other at that point is the key to whether the castigation was the right strategy or not.

The sad thing with the young farmer is that twenty years on he has never regained the same respect for his father that he had prior to that memorable day. Later that day they had to sit at the same kitchen table for the evening meal and not a word was said. All quite silly really, life is too short for that. Many of us would be well advised to identify the emotions where we do not perform all that well and think of some intelligent strategies that we could use next time we find ourselves experiencing these emotions. The starting point is to have the courage to change.

If at some stage of your life you have acted with low emotional intelligence and continue to regret it all these years later, go back and apologise and show genuine remorse for your actions. You will be surprised how healing that apology will be.

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
Buttress- registered trademark of Nufarm Australia Limited
Goal - registered trademark of Dow Agrowsciences
Gramoxone - registered trademark of Syngenta Group Company
Hammer - registered Trademark of FMC Corporation
Kyte 700 WG - registered trademark of Nufarm Australia Limited
Nail 240EC - registered trademark of Crop Care Australasia Pty Ltd
Nuquat - registered trademark of Nufarm Australia Limited
Revolver- registered trademark of Nufarm Australia Limited
Roundup Attack - registered trademark of Monsanto Australia Limited.
Roundup PowerMax - registered trademark of Monsanto Technology LLC used under licence by Nufarm Australia
Spray Seed - registered trademark of Syngenta Group Company
Striker - registered trademark of Nufarm Technologies USA Pty Ltd
TriflurX - registered trademark of Nufarm Australia Limited
Weedmaster DST – registered trademark of Nufarm Australia Ltd

Cereal Broad Leaf

2,4-D amine - registered trademark of Dow AroSciences
Agritone 750 - registered trademark of Nufarm Australia Limited
Ally - registered trademark of Du Pont (Australia) Ltd or its affiliates
Amicicde625 - registered trademark of Nufarm Australia Limited
Archer - registered trademark of Nufarm Australia Limited
Broadside - registered trademark of Nufarm Australia Limited
Broadstrike - registered trademark of the Dow Chemical Company or an affiliated company of DOW
BromicideMA - registered trademark of Nufarm
Dual Gold - registered trademark of a Syngenta Group Company
Ecopar - registered trademark of Sipcam Pacific Australia Pty Ltd
Logran 750WG - registered trademark of Syngenta Group Company
Lontrel - registered trademark of Dow AroSciences
LV Ester 680 - registered trademark of Crop Care Australasia. Pty Ltd
LVE MCPA - registered trademark of Dow AroSciences
Tigrex - registered trademark of Bayer
Velocity - registered trademark of Bayer

Clearfield Chemical

Intervix - registered trademark of BASF

Triazine Tolerant (TT)

Gesaprim 600Sc - registered trademark of Syngenta Group Company
Lexone - registered trademark of Du Pont (Australia) Ltd or its affiliates
Supercharge - registered trademark of Syngenta Group Company

Adjuvants

Bonza - registered trademark of Nufarm Australia Limited
Chemwet 1000 - registered trademark of Nufarm
Hasten - registered trademark of Victorian Chemical Company Pty. Limited
Kwicken - registered Trademarks of Third Party SST Australia Pty Ltd
LI 700 - registered trademark of United Agri Products.
Spreadwet - registered trademark of SST Australian Pty Ltd

Grass Selective

Avadex Xtra - registered trademark of Nufarm
Clethodim - registered trademark of Syngenta Group Company
Elantra Xtreme - registered trademark of Sipcam Pacific Australia Pty Ltd
Factor - registered trademark of Crop Care Australasia Pty Ltd
Hoegrass - registered trademark of Bayer
Monza - registered trademarks of Monsanto Technology LLC used under license by Nufarm Australia Limited
Propyzamide - 4 Farmers Australia Pty Ltd
Raptor - registered trademark of BASF
Rustler - registered trademark of Cheminova Aust. Pty Ltd.
Sakura - registered trademark of Kumiai Chemical Industry Co. Ltd
Select - registered trademark of Arysta Life Sciences and Sumitomo Chemical Co. Japan
Targa - registered trademark of Nissan Chemical Industries, Co Japan
Verdict - registered trademark of the Dow Chemical Company or an affiliated company of DOW

Insecticide

Alpha Duo - registered trademark of registered trademark of Syngenta Group Company
Astound Duo - registered trademark of Nufarm Australia Limited
Dimethoate - registered trademark of Nufarm Australia Limited
Dominex Duo - registered trademark of Crop Care Australasia Pty Ltd
Karate Zeon - registered trademark of Syngenta Group Company
Lemat - registered trademark of Bayer
Lorsban - registered trademark of Dow Agrowsciences

Fungicide

Baytan - registered trademark of the Bayer
Cruiser Maxx - registered trademark of a Syngenta Group Company
EverGol - registered trademark of the Bayer
Gaucho - registered trademark of the Bayer
Helix - registered trademark of a Syngenta Group Company
Impact - registered trademark of Cheminova A/S Denmark
Jockey - registered trademark of the Bayer
Prosaro - registered trademark of Bayer
Raxil - registered trademark of the Bayer
Stayer - registered trademark of the Bayer
Uniform - registered trademark of a Syngenta Group Company
Vibrance - registered trademark of a Syngenta Group Company

Acronyms and Abbreviations

ABA	Advisory Board of Agriculture
ABARES	Australian Bureau of Agriculture and Resource Economic and Sciences
ABS	Australian Bureau of Statistics
ADWG	Average daily weight gain
AFPIP	Australian Field Pea Improvement Program
AGT	Australian Grain Technologies
AH	Australian Hard (Wheat)
AM fungi	Arbuscular Mycorrhizal Fungi
APSIM	Agricultural Production Simulator
APW	Australian Prime Wheat
AR	Annual Rainfall
ASW	Australian Soft Wheat
ASBV	Australian Sheep Breeding Value
AWI	Australian Wool Innovation
BCG	Birchip Cropping Group
BYDV	Barley Yellow Dwarf Virus
CBWA	Canola Breeders Western Australia
CCN	Cereal Cyst Nematode
CfoC	Caring for our Country
CLL	Crop Lower Limit
DAFF	Department of Agriculture, Forestry and Fisheries
DAP	Di-ammonium Phosphate (18:20:00)
DCC	Department of Climate Change
DEWNR	Department of Environment, Water and Natural Resources
DGT	Diffusive Gradients in Thin Film
DM	Dry Matter
DMD	Dry Matter Digestibility
DOMD	Dry Organic Matter Digestibility
DPI	Department of Primary Industries
DSE	Dry Sheep Equivalent
DUL	Drained Upper Limit
EP	Eyre Peninsula
EPARF	Eyre Peninsula Agricultural Research Foundation
EPFS	Eyre Peninsula Farming Systems
EPNRM	Eyre Peninsula Natural Resources Management Board
EPR	End Point Royalty
GM	Gross Margin
GRDC	Grains Research and Development Corporation
GS	Growth Stage (Zadocks)
GSR	Growing Season Rainfall
HLW	Hectolitre Weight
IPM	Integrated Pest Management
LEADA	Lower Eyre Agricultural Development Association
LEP	Lower Eyre Peninsula
LSD	Least Significant Difference
LW	Live weight
MAC	Minnipa Agricultural Centre
MAP	Monoammonium Phosphate (10:22:00)
ME	Metabolisable Energy
MED	Molar Ethanol Droplet
MIR	Mid infrared
MLA	Meat and Livestock Australia
MRI	Magnetic Resonance Imaging
NDF	Neutral Detergent Fibre
NDVI	Normalised Difference Vegetation Index
NLP	National Landcare Program
NRM	Natural Resource Management
NVT	National Variety Trials
PAWC	Plant Available Water Capacity
P	Probability
PBI	Phosphorus Buffering Index
PEM	*Pantoea agglomerans, Exiguobacterium acetylicum* and *Microbacteria*
pg	Picogram
PGR	Plant growth regulator
PIRSA	Primary Industries and Regions South Australia
RD&E	Research, Development and Extension
RDTS	Root Disease Testing Service
SAGIT	South Australian Grains Industry Trust
SANTFA	South Australian No Till Farmers Association
SARDI	South Australian Research and Development Institute
SASAG	South Australian Sheep Advisory Group
SBU	Seed Bed Utilisation
SED	Standard Error Deviation
SGA	Sheep Genetics Australia
SU	Sulfuronyl Urea
TE	Trace Elements
TT	Triazine Tolerant
UNFS	Upper North Farming Systems
WP	Wilting Point
WUE	Water Use Efficiency
YEB	Youngest Emerged Blade
YP	Yield Prophet

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Deciding what to do
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