Eyre Peninsula Farming Systems Summary 2020

SARDI - Minnipa Agricultural Centre

Government of South Australia
Department of Primary Industries and Regions

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Eyre Peninsula Farming Systems Summary 2020

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SARDI Foreword

It is my pleasure, on behalf of the Department of Primary Industries and Regions (PIRSA) research division South Australian Research and Development Institute (SARDI), to present the 2020 Eyre Peninsula Farming Systems Summary. This publication is highly anticipated and well-used by Eyre Peninsula (EP) growers and advisors, pulling together the latest research development and extension activities relevant to EP. The Farming Systems Summary is a valuable resource to assist growers to access the latest research results and use them on farm to make decisions.

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

Last year will be remembered as a year like no other because of the disruption and challenges presented by the coronavirus pandemic. The season presented its own challenges with a good break to the season, low winter rainfall and October rains and mild conditions helping with grain fill. Growing season rainfall varied from above average in lower Eyre Peninsula to below-average in Upper and Eastern EP, with late rain interfering with harvest in some areas. Grain yields were generally average for central and lower EP and below average for western and eastern EP.

SARDI delivers applied science that grows South Australia's primary industries. It works closely with industry to provide tangible and practical assistance particularly in these challenging times. Unfortunately, SARDI made the difficult decision to cancel the Minnipa Field Day in 2020 because of concerns that an event which aims to bring people together could also be responsible for spreading illness. We hope that 2021 will bring many opportunities to meet to share our results and bring growers, advisors and researchers together.

An important milestone in 2020 was the formation of Agricultural Innovation & Research Eyre Peninsula (AIR EP). AIR EP is the result of a merger between the Eyre Peninsula Agricultural Research Foundation (EPARF) and the Lower Eyre Ag Development Association (LEADA) farming systems groups. AIR EP creates a single Eyre Peninsula-focused organisation for farmer driven applied research, local validation and extension of agricultural technologies and innovations. SARDI looks forward to partnering with AIR EP on research, demonstration and extension programs over the coming years.

Another exciting development in 2020 was PIRSA's AgTech Program which aims to enhance the uptake of farm technology to increase the productivity, growth and sustainability across the South Australian primary industries sectors. The Minnipa Agricultural Centre (MAC) was chosen as an AgTech demonstration site, giving AgTech firms the opportunity to demonstrate their capabilities, providing farmers with demonstration of technology solutions, including information on performance and cost.

The demonstration of AgTech solutions at MAC aims to:

- Identify key farm decisions and processes that can be supported by AgTech, and highlight the use and value of AgTech solutions in informing these management decisions.
- Enable primary producers to interact with a wide range of AgTech solutions before identifying and adopting products and services that will improve their productivity and profitability.
- Enable technology developers and suppliers to engage constructively with primary producers to ensure products are end-user centric and capable of meeting their needs.
- Document and communicate the application and performance of AgTech products as applied to upper Eyre Peninsula production systems.

Congratulations to the SARDI team at the MAC for putting together the EP Farming Systems Summary. It is an important record of our shared research and I hope you find it both interesting and useful. SARDI staff across the state will continue to work closely with primary producers to develop relevant research programs and ensure excellence in our policy and program delivery, industry and regional engagement.
Best wishes for everyone for the 2021 growing season.

Dr Kathy Ophel Keller
Research Director, Crop Sciences
SARDI

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GRDC Foreword

Whilst the past year has been extremely challenging for all Australians, the grains industry has demonstrated an outstanding ability to respond and work through the circumstances that have come with a global pandemic and associated challenges to trade, travel, access to labour and farm inputs. Perhaps this should not come as a surprise based on the ongoing resilience of grain growers in dealing with the unexpected through a requirement to anticipate, plan and respond to seasonal variability and risks that have become the 'new normal'.

Seasonal variability is an inevitable challenge that we must continue to deal with. This requires resilient farming systems and good decision making to manage associated production risks including sufficient plant available water, frost events and terminal heat stress. Countless decisions collectively contribute towards a sustainable and profitable grains enterprise, but have you ever found yourself asking what really drives good decision making? Our decisions are informed by numerous and often complex factors (insert psychology and behavioural sciences disclaimer here) but the key to sound decision making is access to relevant information and knowledge, supported by credible, trusted advice.

This 2020 Eyre Peninsula (EP) Farming Systems Summary consolidates research, development and extension (RD&E) activities, providing information and insights aimed to assist on-farm decision making. The local RD&E findings presented within this report are the result of significant individual or collaborative investment by the Grains Research and 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; Ag Innovation and Research EP (formerly EP Agricultural Research Foundation and Lower Eyre Agricultural Development Association); and EP Natural Resources Management Board, in collaboration with local farm advisers and agribusinesses. The information is of direct regional relevance and value to local farmers and advisers, helping to maintain or improve business performance and profit.

The real impact from agricultural R&D does not come from excellence in research alone, but requires a focus upon awareness, extension and adoption of relevant solutions that demonstrate a clear value proposition. Success is highly dependent upon proper interpretation and excellence in implementation of new knowledge, practices and technologies by people like you. As such I encourage you to take some of these learnings within this publication and explore opportunities to apply them on-farm to continue to deliver sustainable and profitable outcomes.

In addition to the detailed reports from many stakeholders in this publication you will find a summary of just a few of the current GRDC investments of relevance to EP growers and the broader industry, including links to resources that may be of interest and value.

Congratulations are extended to all those involved in preparation and production of this comprehensive summary.

Happy reading.

Craig Ruchs,
GRDC Senior Regional Manager – South

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Minnipa Agricultural Centre update

Amanda Cook
SARDI Minnipa Agricultural Centre

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

We would like to thank project funders SAGIT, GRDC, the Australian Government (National Landcare Program, Rural R&D for Profit, CRC for High Performance Soils) and collaborators University of Adelaide and CSIRO 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. Current projects and contracted research conducted by SARDI MAC are listed in Table 1.

Staff

In 2020, we farewelled some Minnipa Agricultural Centre stalwarts, especially Dot Brace after 22 years of service to SARDI. Naomi Scholz left SARDI for a new role as AIR EP Executive Officer. Fabio Arsego and Neil King also finished SARDI employment within the last season. We thank these staff members for their valued contributions to MAC.

Dr Rhiannon Schilling joined SARDI as the Program Leader of Agronomy and will be involved with MAC research going forward. We also welcome Brian Dzoma back to research on the EP through his new role as Research Officer on the Soil CRC Calcareous soils project.

Visitors

The challenges of COVID19 limited MAC extension activities in 2020. Nevertheless, a range of events were held or attended by MAC staff, with details listed in Table 2.

Members of the SAGIT Board visited MAC and a number of project trial sites on their EP tour in September. This was a valuable exercise to gain insight into our local farming systems, meet with growers and experience first-hand some of the issues and opportunities for the region.

Thank you 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 supporting our research.

We look forward to seeing you all at farming system events throughout 2021 and wish you all the best for a productive and profitable season!

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

MAC Staff and Roles 2020

Dr Rhiannon Schilling	Manager, Agronomy Group
Dr Nigel Wilhelm	Leader (Farming Systems)
Amanda Cook	Senior Research Officer (Agronomy)
Jake Hull	Farm Manager
Jessica Gunn	Research Officer (Livestock)
Fiona Tomney	Research Officer (Pastures)
Morgan McCallum	Research Officer (Livestock)
John Kelsh	AgTech Extension Officer
Leala Hoffmann	Administration Officer
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Wade Shepperd	Agricultural Officer (MAC Farm)
Neil King	Agricultural Officer (Agronomy)
Brenton Spriggs	Agricultural Officer (Agronomy)
Sue Budarick	Casual Field Assistant
Katrina Brands	Casual Field Assistant
Steve Jeffs	Casual Field Assistant
Stephanie Hull	Casual Field Assistant

Table 1. Research projects delivered by SARDI Minnipa Agricultural Centre in 2020.

Project name	Funder	Summary
EPARF Sponsored Projects		
More profitable crops on highly calcareous soils by improving early vigour and overcoming soil constraints.	*High Performance Soils CRC project: 4.2.003. GRDC project: CSP2009-003RTX*	This project will develop integrated solutions to reduce the impact of multiple constraints to cropping in highly calcareous soils. The importance of rapid soil drying, fertiliser availability and rhizoctonia to establishment and early vigour of crops will be investigated by a linked project delivered by CSIRO Ag & Food and supported by GRDC. A demonstration trial was conducted at Poochera in 2020. End: March 2023
Improving the early management of dry sown cereal crops	SAGIT S419	This research project will assess the impact of management on seed germination and establishment on three different soil types in field trials and pot experiments which are kept very low in moisture; a red loam, a grey calcareous soil and a sand for: impact of fertiliser type [P and N] and fertiliser placement, impact of herbicides, impact of seed dressings. End: June 2022
Boosting profit and reducing risk of mixed farms in low and medium rainfall areas with newly discovered legume pastures enabled by innovative management methods	Rural R&D for Profit RnD4Profit-16-03-010	Dryland Legume Pasture Systems (DLPS) Develop recently discovered pasture legumes together with innovative management techniques that benefit animal and crop production and farm logistics, and promote their adoption on mixed farms over one million hectares in the low and medium rainfall areas of WA, SA, Victoria and southern NSW. At MAC, a large scale grazing trial and several small plot species evaluation trials will be conducted. End: June 2022
Updated nutrient response curves in the northern and southern regions	GRDC UQ00082	This project is developing critical levels for commercial soil tests of N, P, K and S for the major break crops. Three trial sites have been conducted on the EP. One was at Minnipa to calibrate Colwell P for canola on a red sandy loam. Another was at Mt Hope on a gravelly sand over limestone and calibrated the deep mineral N test for canola. The third site on a brown loam was at Yeelanna and also calibrated the deep mineral N test for canola. End: June 2022
Improving production on sandy soils in low and medium rainfall areas	GRDC CSP00203	There are opportunities to increase production on deep sands by developing cost effective techniques to diagnose and overcome the primary constraints to poor crop water-use or by reducing the impact of constraints with modified practices. Commonly recognised constraints that limit root growth and water extraction on sands include compaction (high penetration resistance), poor nutrient supply and low levels of biological cycling and poor crop establishment. The project has set up trials at Murlong and Brooker to investigate both low cost modified agronomy (e.g. use of wetters) and high cost interventions (e.g. spading incorporation of OM). End: June 2021
National Variety Trials	GRDC	Yield performance of cereal & break crop varieties at various locations across upper EP.
Crop Improvement Trials	Various	Various trials including; Ryegrass trials – University of Adelaide (B Fleet and G Gill). Deep ripping demonstrations - Davenport Soil Consulting. Improving sustainable productivity and profitability of Mallee farming systems with a focus on soil improvements – GRDC/SARDI (B Dzoma)
Project name	**Funder**	**Summary**
Project Delivery for AIR EP		
Demonstration sites - Dryland Legume Pasture Systems (DLPS)	MSF 9175959	Delivery of upper EP demonstration sites for DLPS project, local awareness raising activities, host a technical pastures workshop on EP, entry and exit surveys, publish 3 x local awareness articles in local media, case studies produced on demo sites. End: March 2022

A new paradigm for resilient and profitable dryland farming on the Eyre Peninsula using data to improve on-farm decision making (Resilient EP)	Aust Govt NLP2	A Regional Innovators group of farmers and advisers will engage researchers and link with the region's farmers to develop techniques to integrate information generated from the probe network, satellite imagery, climate and yield models. Farmers will be able to make more informed, timely decisions underpinned by innovations in agronomy and livestock management in order to optimise the region's productive potential whilst protecting soil and water resources in a changing climate. SARDI delivery of soil moisture probe measurements three times per season, full soil characterisations at soil moisture probe sites and yield prophet reports for focus paddock sites. End: 30 Nov 2023
Adapting cropping systems through improving crop competitiveness	NLP 4-BA9KBX5	The project will demonstrate the benefits of improving crop competitiveness with weeds by increasing the distribution of seed per m2 using innovative farmer equipment. Two demonstration sites will be monitored to measure ground cover, water use, erosion risk and weed numbers. The sites will be a focus for farmer discussion groups to discuss ways of incorporating the practices into their farming systems. AIR EP will promote the outcomes of the project to the broader farming community. End: September 2021
Perennial pasture systems for the upper Eyre Peninsula and other dryland farming areas	NLP 4-BA96C6H	This project will demonstrate perennial pastures as an option for improving the productivity of low productive cropping land on the upper Eyre Peninsula. The aim will be to turn this land into productive livestock pasture, with only minimal inputs of fertiliser, and without the need for herbicide and tillage. Two demonstration sites will be established; one on a grey calcareous soil and the other on a red sandy loam/typical Mallee soil. A mixture of species including grasses and legumes will be sown based on their suitability for local soil and rainfall conditions. End: September 2021
Demonstrating and validating the implementation of integrated weed management strategies to control barley grass in the low rainfall zone farming systems	GRDC 9176981	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
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 2021
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 2021

Table 2. Minnipa Agricultural Centre events in 2020

Event	Topic	Attendance
PIRSA Advance Ag - Adopting AgTech in South Australia 24 Feb	Unlocking Agricultural Potential 2020 Forum	4 MAC staff
2020 Harvest report farmer meetings Minnipa, Piednippie/ Wirrulla, Charra/ Kalanbi, Port Kenny/ Elliston, Cleve, Kimba, Cowell and Lock/Warramboo 18-22 March	Presenters (in person): • Amanda Cook (barley grass management, dry sowing, herbicide residues, ryegrass, economic analysis of hay oats, seeding in non-wetting sands) • Morgan McCallum (DLPS demonstration sites) • Fiona Tomney (DLPS results) • Fabio Arsego (Co-limitation of N and water, and proximal sensing) • Naomi Scholz (evaluation, coming events)	143 people attended (124 growers, 12 advisors, 4 research staff, 3 others)
DLPS Team Visit 12 August	Ross Ballard, David Peck and Phil Davies visited MAC for an update on trials. The Piednippie/Wirrulla demonstration site was also visited.	6 staff and grower demonstration host
SAGIT Board Tour 9 September	The SAGIT Board visited project trial sites and MAC. This was a valuable exercise to gain insight into our local farming systems, talk to growers and experience first-hand some of the issues and opportunities for the region. Current research projects at MAC were presented by Amanda Cook.	3 SAGIT Board members, 10 growers, 1 consultant, 3 SARDI staff
Resilient EP RIG Meeting 23 September	2019 GRDC Soil Characterisation of Wilksch's site was presented by Amanda Cook.	28 RIG committee members, 4 SARDI staff
Sticky Beak Days - Upper Eyre Peninsula 28 August to 15 October	• A series of 15 crop walks organised by local Agriculture Bureau Groups across the Eyre Peninsula. • Key contributions from the Minnipa Agriculture Centre staff included the Minnipa and Poochera Sticky Beak Day on 28 August where Amanda Cook presented Calcareous soils trial, SAGIT and GRDC low rainfall barley grass research and SAGIT Dry Sowing trials. • Wudinna Sticky Beak group visited MAC trials on 22 September, NVT sites, DLPS trials and GRDC low rainfall barley grass research was presented. • SAGIT Dry Sowing trials were visited by Streaky Bay Ag Bureau group on 25 September. • The Elliston Sticky Beak Day was held on 14 October and attended by Fiona Tomney and Neil King. Fiona Tomney spoke about her DLPS trials and NLP2 Perennial Pastures trial to 23 attendees. • Mount Cooper Sticky Beak was on 15 October and Calcareous soils trial, SAGIT and GRDC low rainfall barley grass research, SAGIT Dry Sowing trials and Resilient EP Soil Characterisations (Littles) were presented by Amanda Cook. DLPS large scale grazing trial and DLPS demonstration sites was presented by Morgan McCallum.	A total of 335 people: mostly growers
Grazing Grasslands Workshop, Mount Wedge 28 October	Attended by Fiona Tomney where she spoke about her DLPS trials and the NLP2 Perennial Pastures trial.	

DATES TO REMEMBER

MAC Annual Field Day: Wednesday 15 September 2021

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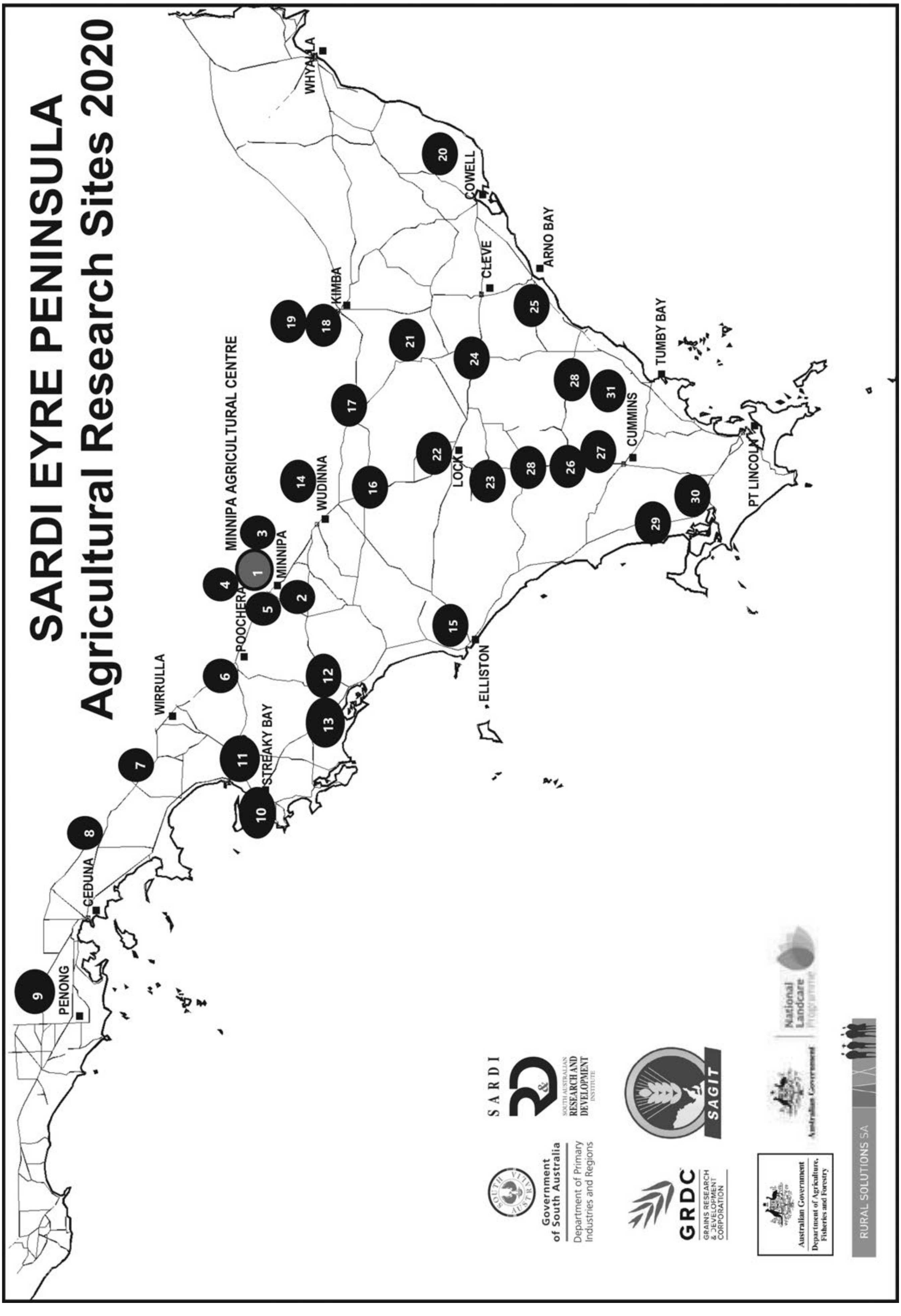
SARDI EYRE PENINSULA
Agricultural Research Sites 2020
MINNIPA AGRICULTURAL CENTRE
WHYALLA
COWELL
ARNO BAY
CLEVE
KIMBA
TUMBY BAY
CUMMINS
PT LINCOLN
LOCK
WUDINNA
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Eyre Peninsula agricultural research sites 2020 map references.

Map reference	Location	Trials	Host farm / business
1	Minnipa	NVT wheat and early wheat, barley. Blackspot peas. Time of sowing beans and lentils. Low rainfall zone pulses. Lentil herbicides. Pea and vetch breeding. Intergrain wheat and barley. AGT wheat. Large scale annual pasture legume grazing trial. Annual pasture legume species evaluation. Nitrogen fixation annual pasture legumes. Barley grass management strategies. Herbicide residues. Soil & Tissue testing. Crop competition demonstration.	SARDI Minnipa Agricultural Centre
2	Minnipa	Rye grass management trials, soil characterisation.	Bruce Heddle
2	Minnipa	Herbicide residues, perennials.	Jerel Fromm
3	Minnipa	NVT Field pean & canola - TT, IMI.	Clint Oswald
4	Minnipa	Calibrating soil P test.	Gareth Scholz
5	Minnipa	Dry sowing, red loam and sand.	Matthew Cook
6	Poochera	Herbicide residue.	Paul Carey
6	Poochera	Calcareous soils.	Shard Gosling
7	Nunjikompita	NVT wheat and oats.	Craig Rule
8	Mudamuckla	Soil & tissue testing.	Peter Kuhlmann
9	Penong	NVT wheat.	Martin Chandler
10	Streaky Bay	Dry sowing.	Phil Wheaton
11	Piednippie	NVT wheat and barley.	John Montgomery
11	Piednippie	DLPS demonstration pasture species.	Dion Trezona
12	Port Kenny	Soil characterisation.	Nathan Little
13	Calca	Herbicide residue.	Craig Kelsh
14	Wudinna	Soil disease trials (field pea + vetch). Low rainfall chickpea, lentil & field pea, Low rainfall intercropping. Early sown and germinated faba bean, lentil (2 TOS).	Ashley Barnes
15	Elliston	NVT barley. Cereal pathology.	Nigel & Debbie May
16	Warramboo	NVT wheat.	Murphy Family
16	Warramboo	Perennials.	Kane & Veronica Sampson
17	Koongawa	Soil & tissue testing.	Wes Matthews
17	Koongawa	Soil characterisation.	Todd Matthews
18	Kimba	Pulse nutrition, Blackspot peas, deep ripping for frost, NVT wheat. Soil disease trials (field pea + vetch). pulse end-use, Vetch GA, termination of pulses, herbicide tolerance field pea.	Trevor Cliff
18	Kimba	Herbicide residue.	Dion Woolford
19	Buckleboo	Deep ripping in sandy soils.	Tristan Baldock
19	Buckleboo	Soil characterisation.	Paul Schaefer
20	Cowell	NVT wheat.	Kaden Family
21	Darke Peak	NVT barley.	Mark Edwards

Map reference	Location	Trials	Host farm business
22	Lock	Soil & tissue testing, soil characterisation, crop competition demonstration.	Andrew Polkinghorne
22	Lock	DLPS demonstration pasture species.	Kerran Glover
22	Lock	NVT Canola - conventional, TT, IMI.	Peter Durdin
23	Murlong	Sandy soils.	Mark Siviour
24	Rudall	Soil characterisation.	Jason Burton
25	Wharminda	Cereal pathology.	Tim Ottens
25	Wharminda	Soil characterisation.	Ed Hunt
26	Tooligie	Early sown and germinated pulses (and wheat).	Bill Long
27	Yeelanna	Pulse and bean agronomy.	Chad Glover
27	Yeelanna	Calibrating soil N test.	Jordan Wilksch
28	Brooker	Sandy soils.	Challinger Family
29	Mt Hope	Sclerotinia and blackleg in canola.	Ashley & Sam Ness
30	Mt Dutton	Soil characterisation.	Bruce Morgan
31	Stokes	Soil disease trial (lupin), pulse end use, faba bean nutrition.	Josh Telfer

Minnipa and Poochera farmer group visiting Minnipa Agricultural Centre trials, August 2020.

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Eyre Peninsula seasonal summary 2020

Brett Masters
PIRSA Rural Solutions SA, Pt Lincoln

Key messages

- Crop yields in 2020 varied widely depending upon early season rainfall and the impact of extreme weather events, including hot dry winds and frost in September.
- Crops and pastures germinated well following April rainfall and had good early vigour, but dry conditions in May and June checked growth and impacted on yield.
- Insect pests including Cut worm and Army worm damaged emerging crops and were present throughout the season. However, these were easily controlled with insecticide applications.
- Above average October rainfall resulted in regrowth of crops and pastures causing some issues at harvest.
- Cereal yields were mostly below average, with many farmers across the region reporting that crops yielded less than they expected based on spring biomass. However, this was generally balanced by good grain quality and reasonable prices.
- Canola and pulse yields on lower Eyre Peninsula were excellent.

Summer

Paddock surface cover over summer was low in most Western and Eastern Eyre districts with most farmers feeding stock in containment areas to protect vulnerable soils from erosion. Hot, dry conditions during January resulted in little weed growth and whilst most had sufficient feed on hand to continue feeding until pastures established, the extended dry period into late June severely depleted reserves of hay and grain in some Eastern Eyre districts. Due to low water levels in dams farmers in the Cleve Hills continued to cart water for livestock.

Intense thunderstorms on 1 February brought rainfall of up to 80 mm to isolated central and lower Eyre districts. Rainfall from this event varied by more than 25 mm between neighbouring properties. As a result, soil moisture at the end of summer varied greatly depending on where rain fell.

Given dry soil profiles, poor surface cover and the impact of frost on crop yields in recent seasons early indicators were that the area sown to crops such as peas and canola would be reduced and replaced with cereals to manage risk, improve early feed and provide options for weed control.

Autumn

Annual pastures germinated well in areas which received early rains and grew considerable biomass before cold weather set in, improving surface cover in many districts. Though this allowed some producers to stop supplementary feeding livestock, in districts which did not receive early rainfall this continued until pasture growth improved. Additionally, high levels of caltrop, heliotrope and capeweed were reported in some paddocks and control of these slowed pasture growth.

Some feed paddocks were sown around 10 April, but most growers did not begin sowing their winter crops until widespread opening rains were received around Anzac Day. Good opening rains enabled most growers to finish seeding before the start of June, including in the Cowell and Arno Bay districts, where poor surface cover and dry conditions had resulted in drifting paddocks in recent years. However, a large part of Eastern Eyre from Kielpa to Port Neill missed out on this rain, with many farmers not confident to sow non-wetting sands until further rainfall was received in late June.

Some stubble burning was undertaken to manage herbicide resistant weeds around Cummins in early May. Thunderstorms on 9 May brought 20 to 35 mm of rain resulting in above average May rainfall in Lower Eyre districts. Very strong winds on 30 May caused drift on paddocks with poor surface cover near Cleve, Arno Bay and Cowell and on exposed sandy rises near Darke Peak and Wharminda. Persistent wind events into late June saw many of these areas continue to drift. Whilst some areas were resown, good rainfall in July saw many of these areas recover without further intervention.

Good weed germination following earlier rainfall provided the opportunity for effective application of knockdown and pre-emergent herbicides, with generally low weed numbers in emerging crops. High numbers of insect pests, including Army worm, Red legged earth mite, Pasture web worm and Cut worm were reported. Whilst these caused some damage to emerging crops and pastures, they were easily controlled with insecticides. Russian wheat aphid was reported on volunteer cereals where February rain fell, and most growers treated at least some of their seed to protect early sown crops. Dry conditions in early summer resulted in low mice and snail numbers at seeding and only selected vulnerable paddocks were baited.

Supplementary feeding over summer maintained livestock health with reports of good lambing percentages despite the dry conditions. The region had good supplies of hay at the end of autumn and livestock producers only sowed a paddock or two for early feed and opportunistic hay cuts to replenish on-farm supplies. Despite good opening rainfall there was little runoff into dams in the Cleve Hills and producers continued to cart water for livestock well into winter.

Winter

Crop growth was highly variable depending on sowing date and soil type. Dry sown crops in areas which received early rains established quickly with good yield potential by the end of June. Growers applied small amounts of in-crop nitrogen ahead of forecast rain in the middle of June to maintain this potential, intending to apply more later if required. Rapid cereal growth in parts of lower EP saw some growers considering using growth regulators to reduce the risk of crop lodging and fungal infection later in the season. However, dry conditions in early winter restricted biomass growth and these were not required. Later sown crops were impacted by dry soils and cold conditions in June with some crops taking more than a month to germinate.

Multiple light frosts were reported during June, even in coastal areas not traditionally associated with frost. While this resulted in some crop yellowing and slowed pasture growth, it did not cause significant long-term damage. In-crop herbicides were applied in July and early August with drier July conditions helping paddock trafficability and herbicide efficacy.

Multiple cold fronts brought average to slightly above average August rainfall to most districts. These rains came at a critical time, with many crops showing signs of significant moisture stress. Following this rain, crops on the better soil types from Nunjikompita to Warramboo grew well, and by late August had reached stem elongation to head emergence. Even later sown crops in districts which did not receive early rainfall such as Arno Bay and Wharminda, recovered well and were tillering. However, despite these rains, moisture stress continued on crops on the heavier soils, near Streaky Bay, Chandada, Poochera, Kimba, Buckleboo, Tuckey and Kielpa which did not receive the early autumn rains.

With dry conditions in early winter and lower crop biomass, leaf disease was low with no additional fungicide required. Cut worm and Army worm continued to be reported but numbers were below control thresholds. Low numbers of Russian wheat aphid were also reported in cereal crops where seed was not treated, and an early flight of heliothis required farmers to spray to protect pulse crops.

Pastures responded well to August rain, improving soil surface cover in many districts. To help preserve paddock biomass most farmers chose to spraytop pasture paddocks in spring to minimise weed seed set rather than removing the grass weeds during winter, and many producers sold lambs as soon as they were weaned to reduce pressure on paddock feed reserves.

Spring

Regular rainfall events brought average September rainfall to most districts. Strong, hot winds experienced across the region on September 6 and 7 caused drying of some early crops and senescence of annual pastures. In most districts cool conditions and good rainfall soon after mitigated some of the damage from this, but crops which were in the middle of flowering, such as barley and pulses on lower EP; or were already filling grain, such as early sown barley and canola on upper EP, had reduced yields as a result. A number of frosts were reported during September in central and lower Eyre districts, even those not traditionally associated with frost such as Ungarra and Greenpatch, and large areas of frosted crops near Tooligie were cut for hay. Elsewhere frost damage was less obvious and with good grain prices and less demand for hay most growers left paddocks to harvest grain.

Thunderstorm activity brought above average October rainfall to the region. Whilst most districts received 25 to 50 mm, up to 105 mm fell near Kimba and Buckleboo. Runoff in the Cleve Hills filled many dams to 50% or more, reducing the need for livestock producers to cart water over summer.

A few paddocks of vetch were cut for hay in August to replenish on farm supplies, with more cut in early spring. Constantly changing weather conditions hampered baling operations and October rain rendered some cut hay unsuitable for baling. Straw discoloration from rainfall on paddocks cut for export hay near Buckleboo meant the hay did not meet export grade. More canola crops were windrowed in 2020 than in recent years due to large yield losses from wind in 2019.

Good rainfall and mild temperatures resulted in good spring growing conditions. Grasses and summer weeds germinated rapidly and most growers started spraying these whilst waiting for crops to ripen. Pastures which looked to have senesced with low biomass at the end of August and cereal paddocks cut for hay responded to October rainfall with extended biomass production, which improved paddock surface cover.

Whilst this growth provided extra spring feed, biomass at the end of spring was less than usual with grazing over summer needing to be carefully managed to protect vulnerable soils against wind erosion.

Late October rainfall caused widespread crop regrowth and uneven ripening in many eastern and lower Eyre districts. This complicated harvest with most growers having to patch out areas of paddocks as they ripened. Some barley crops near Kimba, produced a new head and filled grain between the start of October and Christmas.

Late season crop diseases and insect pests were generally low. Whilst some Diamond back moths were observed in canola and low levels of heliothis in pulses, these were generally adequately controlled with routine insecticide applications.

Harvest

Pulses near Kimba were desiccated in early October ahead of harvest. Small areas of pulses and barley were harvested in late October. However, continued damp conditions delayed harvest in most districts, with only around 10% of growers starting by the end of October. Dry conditions and a number of very hot days above 35°C in November helped crops ripen and despite delays due to poor weather (alternatively humid mornings and hot, windy weather) most growers finished harvest before Christmas.

Crop yields across the rest of the region varied considerably depending on soil type and rainfall distribution. Time of sowing seemed to have less influence on yields than in recent years, with crop maturity at the time of extreme weather events such as hot winds or frosts seeming to have a bigger impact. Much of the earliest grain came from crops on heavier soil types which suffered moisture stress throughout the season, particularly west of Ceduna and east of Koongawa, and yields were very poor with reports of cereal yields less than 0.5 t/ha common on these soils.

Other western Eyre districts yielded 70% to 80% of the long-term average with the exception of some central Eyre districts near Minnipa and Wudinna which produced yields close to the long term average.

Despite having good potential at the end of August crop yields near Kimba were severely limited by dry seasonal conditions. Pulse crops on the red soils near Buckleboo yielded very poorly, at less than 0.5 t/ha. Additionally, October rains damaged ripe pea and lentil crops resulting in grain quality issues. Cereal crops on other soils in the district yielded less than 70% of the long-term average, with the only exception near Pinkawillinie Conservation Park, where good seasonal rainfall and lighter textured soils resulted in some good yields above 2.0 t/ha.

Pulse and canola yields in other eastern Eyre districts varied significantly depending on soil type and early season rainfall. Canola on the Cleve flats varied from 0.8 to 1.3 t/ha, with lentil yields from 0.3 to 1.0 t/ha. Cereal crops on the heavier soil types yielded well below the long-term average, with the better yields (1.8 t/ha) reported on the sandier soils near Darke Peak, Rudall and Wharminda and up to 2.5 t/ha in the Cleve Hills which often experience an extended ripening period.

Canola and pulse yields on lower Eyre Peninsula were very high with canola yields from 2.0 to 3.0 t/ha, peas and lupins yielding 1.8 to 2.5 t/ha, beans yielding exceptionally from 2.5 to 3.0 t/ha and lentils yielding in the order of 1.5 to 2.0 t/ha.

Whilst lower Eyre cereal crops grew high levels of mid-season biomass, and isolated crops had exceptional yields (>5 t/ha), yields were not as good as initial estimates and most crops yielded average to slightly below the long-term average (3.2 to 3.5 t/ha). Frost was reported to have significantly impacted crop yields near Cummins, Kapinnie and Karkoo where growers were reaping more than 4.0 t/ha on rising ground and less than 0.5 t/ha in the lower lying areas of the paddock.

Good grain quality with high protein (up to 14%), and low screenings on cereals; and exceptional oil content (above 43%) on canola crops combined with good grain prices helped to offset the lower yields in most districts.

Acknowledgements

The author wishes to acknowledge that much of the information contained within this summary has been compiled from PIRSA's 2020 Crop and Pasture Reports.

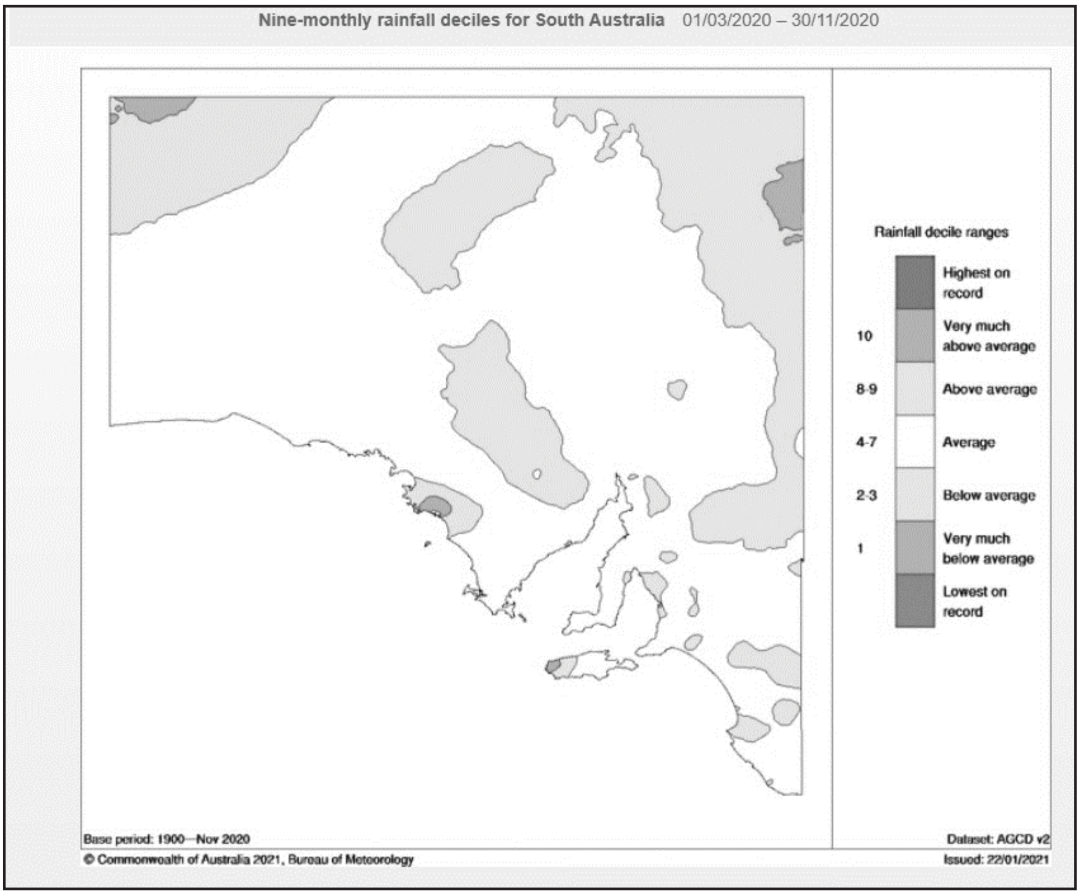

Figure 1. April to November rainfall deciles, 2020

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MAC Farm Report 2020

Jake Hull
Farm Manager, SARDI Minnipa

Location
Minnipa Agricultural Centre
Rainfall
Av. Annual: 324 mm
Av. GSR: 241 mm
2020 Total: 367 mm
2020 GSR: 255 mm

Key outcomes

- **High grain quality and test weights were achieved in 2020**
- **Broadacre variety comparisons were undertaken at MAC**
- **High weaning rates of merino lambs were achieved**
- **Early sown peas yielded 1.4 t/ha**

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 white peg trials in eight paddocks and continued to take full pedigree records and production measurements on the sheep research flock in the 2020 season.

What happened?

Weather

Where was our winter rainfall?! Things began with promise, with above average rainfall for January to April, then below average for May to July. Most barley crops had completed grain fill when we received a large rainfall event in early October of 40 mm, giving most wheat crops a boost. Late rain in October (25 mm) was of little use. The story of 2020 at the MAC farm was, “a reasonable rainfall year, but little of it falling at crucial times”.

Seeding

With a good early start, most of the program was sown into good moisture, starting on 26 April and being completed on 14 May.

Seeding rates:

- Wheat 70 kg/ha
- Barley 65 kg/ha
- Peas 120 kg/ha
- Canola 1.8 kg/ha

Fertiliser

70 kg/ha Granuloc Z with 3.5 L flutriafol

Varieties and area

- Wheat - 510 ha (Scepter, Ballista, Catapult, Razor CL, Hammer CL, DS Bennett, Vixen, Sherriff CL, Rockstar, EG Gold)
- Barley - 230 ha (Spartacus CL, Maximus CL, Leabrook, Laperouse, Beast)
- Canola - 48 ha (Trident, Stingray)
- Peas - 65 ha (PBA Butler)
- Pasture - 230 ha (self-regenerated medic/clover)
- Trials - 100 ha+ (DLPS, NVT, legume pasture varieties, low rainfall barley grass management demonstration, winter mixed cover crop trial, fertiliser trials, variety comparisons).

Demonstration type variety trials were established in S9, S2, S5 and S3 utilizing wheat, barley and canola seed supplied by breeders. Trials were implemented using the farm seeder on 9 m spacings and were replicated 3 or more times along full paddock runs. They were then harvested using the 9 m matching header front, collecting yield and quality data (see Table 1).

Livestock

Stock currently on the farm:

322 merino ewes, 192 merino ewe hoggets, 258 merino lambs and 10 merino rams.

Reproduction results overall for 2020: 367 ewes mated with 19 ewes scanned dry and 464 lambs marked.

Ewe and wether lambs weighed in at an average of 33.2 kg per animal weaned at 12.5 weeks.

Issues encountered in 2020

- Lack of winter rainfall/rain falling outside useful periods or too late/early for crucial times
- Wild oats and barley grass in crop
- Three corner jack population increasing on farm
- COVID-19

Things of Interest

- Variety comparisons in wheat, barley and canola
- Small plot trials
- Not COVID-19

Acknowledgements

MAC farm staff: Wade Shepperd and John Kelsh, MAC research staff: Morgan McCallum and Jessica Gunn, MAC Administration staff: Leala Hoffmann and Dot Brace.

Table 1. Minnipa Agricultural Centre harvest results, 2020 grain yields and protein aligned with paddock rotational histories.

Paddock	Paddock History 2016-2020	Crop 2020	Sowing Date	Harvest Date	Yield (t/ha)	Test Weight	Retention %	Protein %	Screenings %	Moisture %
North 1	M-W-M-W-M	Medic (B)								
North 2	C-W-M-W-B	Spartacus (B)	5 May	2 Nov	1.06	63.2		15.8	6.2	12.2
North 3/9	B-V-W-B-W	DS Bennett (W)	26 Mar		Grazed/Spray topped					
North 4	M-W-B-M-W	Scepter (W)	10 May	8 Nov	1.51	84.4		12.4	2.1	9.4
North 5 N	M-W-W/B-M-W	Scepter (W)	11 May	9 Nov	1.53	83.9		13.0	2.5	9.6
North 5 S	W-M-W-M-W	Scepter (W)	10 May	9 Nov	1.17	83.8		12.1	2.8	8.9
North 6	W-B-M-O/V/C-B	Spartacus (B)	4 Apr	1 Nov	1.70	63.8		14.6	5.7	12.9
North 7	M-C-W-B-M	Medic (B)								
North 8	M-C-W-W-M	Medic (B)								
North 10/11	W-M-B-V-W	Scepter (W)	9 May	8 Nov	1.70	83.6		12.6	1.7	10.2
North 12	W-C-W-M-B	Spartacus (B)	5 May	2 Nov	1.78	62.9		13.8	5.6	11.6
South 1	W-B-V/B/O-W-M	Medic (B)								
South 2	*Replicated broadacre trial data M-W-B-P-W	Scepter Vixen Ballista EG Gold Sherriff CL Razor CL (W)	8 May	7 Nov	2.05 1.80 2.05 1.60 1.98 1.92	84 82.2 82.8 81.8 83.2 84.2		11.3 12.3 10.4 14.5 10.8 10.9	1.30 0.90 1.50 0.70 1.01 1.00	11.2 11.1 11.0 11.5 11.1 11.5
South 3	B-V-W-B-C	Trident Stingray (C)	27 Apr	20 Oct	0.80 0.64	67.4 66.8		23.3 25.3	39% oil 37% oil	5.0 5.1
South 4	W-B-V-W-B	Spartacus (B)	4 May	27 Oct	1.47	62.2		15.3	5.2	12.5

Paddock	Paddock History 2016-2020	Crop 2020	Sowing Date	Harvest Date	Yield (t/ha)	Test Weight	Retention %	Protein %	Screenings %	Moisture %
South 5	*Replicated trial data W-B-M-W-B	Spartacus Maximus Beast Laperouse Leabrook(B)	7 May	3 Nov	1.52 1.65 1.74 1.48 1.70	64.8 66.2 64.2 65.4 63.6	79 84 86 81 88	13.6 14.1 14.4 14.8 13.3	4.3 3.0 2.4 2.8 2.6	10.8 9.6 9.6 9.6 9.6
South 6	M-W-B-C-W	Scepter (W)	9 May	7 Nov	1.75	82.6		13	2.9	11.0
South 7/10	W-B-M-W-B	Spartacus (B)	6 May		Hay 1.48					
South 8	W-B-M-M-W	Razor CL (W)	14 May	18 Nov	1.24	82.6		13.9	1.3	11.4
South 9	*Replicated broadacre trial data M-W-B-M-W	Scepter Catapult Rockstar (W)	3 May	5 Nov	2.16 2.09 2.30	84.4 82.2 82.6		12.6 12.7 11.7	1.1 0.9 1.5	11.0 10.9 11.1
Barn	O-M-W-O-W	DS Bennett (W)	6 Apr		Grazed/ Spray topped					
House	O-M-W-O-W	DS Bennett (W)	6 Apr		Grazed/ Spray topped					
Various		Hammer CL (W)	29 May	8 Nov	1.5	80		14.5	2.5	11.1
AP HWY	W-V-W-B-P	PBA Butler	29 Apr	14 Oct	1.4	40			4.1	10.7

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

Table 2. Lambing data, Minnipa Agricultural Centre 2010-2020.

	Ewes joined	Lambs scanned	Lambs born	Lambs marked	Scanning (%)	Marking (%)	Survival at birth (%)	Survival at marking (%)
2010	335	421	372	333	126	99	88.4	79.1
2011	338	426	414	410	126	121	97.2	96.2
2012	337	540	558	439	160	130	103.3	81.3
2013	350	534	531	448	153	128	99.4	83.9
2014	349	442	443	386	127	111	100.2	87.3
2015	424	555	534	437	131	103	96.2	78.7
2016	422	532	632	502	126	119	118.8	94.4
2017	366	428	458	361	117	99	107	84.3
2018	335	434	382	294	130	88	88	67.7
2019	342	486	485	434	142	127	99.8	89.3
2020	367	543	551	464	148	126	101	84
Av.	360	486	487	410	135	114	100	84

**2010, 2011, 2014, 2015, 2016, 2017 all had 1 x sire failure*
Shearing of the flock completed on 25-26 August at six months, with the previous shearing 26-27 February.
See fleece weight data in the table below.

Table 3. Wool measurements 2020.

Sheep class	Ewes (2014-2018 drop)					Hogget ewes (2019 drop)				
Date shorn	Feb-20		Aug-20		Total (annual)	Feb-20		Aug-20		Total (annual)
Measure	AV.	RANGE	AV.	RANGE	TOT/AV	AV.	RANGE	AV.	RANGE	TOT/AV
GFW (kg)	3.2	2.1-6.3	3.7	2-6.2	6.9	2.4	1-5.2	3.2	2-4.8	5.6
Staple length (mm)	62	35-85	60	41-75	61	62.5	35-75	62.9	45-76	59.4
Colour (1-5)	1.15		1.4		1.28	1.8		2		1.9

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Understanding trial results and statistics

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

The average (or mean)

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

The LSD test

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

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

Results from replicated trial

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

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

Treatment	Grain Yield (t/ha)
Control	1.32 a
Fertiliser 1	1.51 a,b
Fertiliser 2	1.47 a,b
Fertiliser 3	1.70 b
Significant treatment difference	$P \leq 0.05$
LSD (P=0.05)	*0.33*

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

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

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

On-farm testing - Prove it on your place!

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

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

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

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

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

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

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

Some useful conversions

Area

1 ha (hectare) = 10,000 m^2 (square 100 m by 100 m)

1 acre = 0.4047 ha (1 chain (22 yards) by 10 chain)

1 ha = 2.471 acres

Mass

1 t (metric tonne) = 1,000 kg

1 imperial tonne = 1,016 kg

1 kg = 2.205 lb

1 lb = 0.454 kg

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

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

Wheat = 60 lb, Barley = 48 lb, Oats = 40 lb

1 bu (wheat) = 60 lb = 27.2 kg

1 bag = 3 bu = 81.6 kg (wheat)

Volume

1 L (litre) = 0.22 gallons

1 gallon = 4.55 L

1 L = 1,000 mL (millilitres)

Speed

1 km/hr = 0.62 miles/hr

10 km/hr = 6.2 miles/hr

15 km/hr = 9.3 miles/hr

10 km/hr = 167 metres/minute = 2.78 metres/second

Pressure

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

25 psi = 1.7 bar = 172 kPa

Yield

1 t/ha = 1000 kg/ha

Yield Approximations

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

Section Editor:
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Section 1

Industry

Agricultural Innovation & Research Eyre Peninsula update 2020

Bryan Smith and Naomi Scholz
Agricultural Innovation & Research Eyre Peninsula

Formation

Agricultural Innovation & Research Eyre Peninsula (AIR EP) was officially incorporated on 26 May 2020, with the aim of creating a single entity for farmer driven applied research, local validation and extension of agricultural technologies and innovations on the Eyre Peninsula.

AIR EP is the result of a merger between the Eyre Peninsula Agricultural Research Foundation (EPARF) and the Lower Eyre Ag Development Association (LEADA) farming systems groups, who have been very effective in providing local research, development and extension (RD&E) outcomes for upper and lower Eyre Peninsula respectively over the past 15 years. By joining forces, the new organisation will create efficiencies in administration and operations, and provide a stronger face for regional RD&E to future funders, partners, members and supporters.

The vision for AIR EP is a professional farmer owned and directed organisation that drives the advancement and practical application of agricultural scientific research, development and extension in dryland farming systems relevant to Eyre Peninsula and like environments across Australia. The organisation will access funds to support projects that address key issues and opportunities that will increase the profitability and resilience of farming businesses in the region.

Structure

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

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

RD&E Committee Members: Greg Scholz (Chair Low Rainfall), Bruce Morgan (Chair Medium Rainfall), Ex-EPARF Board and Research & Review Committee members, Ex-LEADA Committee members, Researchers, Advisors. Nominations for RD&E Committee members will be open in February/ March 2021.

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

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

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

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Projects in 2020

Project title	Funder	Delivery organisation	Project summary
AIR EP hosted projects			
A new paradigm for resilient and profitable dryland farming on the Eyre Peninsula using data to improve on-farm decision making (Resilient EP) 4-CS70YDN	Aust Govt NLP2	EPAG Research SARDI CSIRO Regional Connections	A Regional Innovators group of farmers and advisers will engage researchers and link with the region's farmers to develop techniques to integrate information generated from the probe network, satellite imagery, climate and yield models. Farmers will be able to make more informed, timely decisions underpinned by innovations in agronomy and livestock management in order to optimise the region's productive potential whilst protecting soil and water resources in a changing climate.
Crop Competition 4-BA9KBX5	Aust Govt NLP2	SARDI	Demonstrate the benefits of increasing the distribution of crop seed per m^2 using innovative farmer equipment to compete with weeds.
Perennial Pastures 4-BA96C6H	Aust Govt NLP2	SARDI	Demonstrate perennial pastures as an option for improving the productivity of low productive cropping land on the upper EP.
Warm and cool season mixed cover cropping - upper & lower EP 4-60A5VY4	Aust Govt NLP2	SARDI/AIR EP	Identify and demonstrate suitable cover crops across south eastern Australia. The impacts of cover cropping on soil health, nutrient cycling, organic carbon, and soil moisture will be measured, and the optimum timing and method to terminate the cover crops will be determined.
Deep ripping 4-BA163YG	Aust Govt NLP2	Davenport Soil Consulting	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.
Regional Agricultural Landcare Facilitator (RALF) services DEW-1648	Aust Govt NLP2 (EPLB)	AIR EP	Delivery of the EPLB's RALF services (see EPLB article for more detail).
Sustainable Agriculture Program DEW-1604	Aust Govt NLP2 (EPLB)	AIR EP/RSSA	Delivery of the EPLB's sustainable agriculture program (see EPLB article for more detail).
Eastern EP Soil Management G2021-5	EPLB	Davenport Soil Consulting	Increase soil cover of bare soils over 20/21 summer. Gain increased understanding of summer crops/other activities to affect soil surface cover, erosion potential and plant growth.
Southern Pulse Extension - Pulse Check Groups upper & lower EP BWD9175825	GRDC	George Pedler Ag/ Bates Ag Consulting	Establishment of 'pulse check discussion groups' across the southern region to focus upon 'back to basics' approach to pulse production using a group learning approach and practical in-field learning.
Soil & plant testing 9176604	GRDC	SARDI	Using soil and plant testing data to better inform nutrient management and optimise fertiliser investments for grain growers.
Barley grass management strategies 9176981	GRDC	SARDI	Test localised integrated weed management strategies against barley grass utilising large plot replicated demonstration sites within key areas of the low rainfall zone.
Increasing production on sandy soils in low and medium rainfall areas CSP00203	GRDC	PIRSA	Investigating the physical, chemical impediments and the biological constraints in sandy soils and crop establishment on non-wetting soils.

Delivery of DLPS Demo Sites on upper & lower EP 9175959	Rural R&D4P/ GRDC/ MLA/ AWI	SARDI/EPAG Research	Delivery of upper and lower EP demonstration sites for the Dryland Legume Pasture Systems project and local awareness raising activities.
Intern Research Officer EP120	SAGIT	EPAG Research	Annually engage a recent graduate to work as an intern/ trainee in applied grains RD&E, located on EP.
Taking canola profitability to the next level LEA120	SAGIT	EPAG Research	Determining the maximum achievable water limited yield of canola on Lower EP.
1.4.002: Building farmer innovation capability	Soil CRC	EPAG Research	Implement, refine and adapt an Innovation Capability partnership model developed by Pitt & Nelle (2008) for large agribusiness, and build the innovation capability, systems and culture of farmers.
1.2.004: Surveying on farm practices	Soil CRC	AIR EP	Surveying land managers across EP to improve understanding of current practices, including farmer aspirations; motivations and their perceptions of existing and proposed R&D initiatives.
4.2.001 Herbicide residues in soil	Soil CRC	SARDI	Develop new knowledge and tools to better understand the factors regulating herbicide persistence and bioavailability, giving farmers increased confidence in crop choice, timing of sowing and herbicide management to ensure soil and crop performance is not limited by herbicide residues.
1.2.002: Understanding adoptability of techniques and practices for improved soil management	Soil CRC	AIR EP	Building on existing models of adoption by investigating at a farm and regional scale the social drivers and forms of adaptation and learning that make soil improvement strategies and techniques adoptable.
Partnerships in other projects			
4.2.003 More profitable crops on highly calcareous soils by improving early vigour and overcoming soil constraints.	Soil CRC/ GRDC	PIRSA/ SARDI	Outcomes will be modified agronomic practices and improved soil conditions which increase WUE of crops and farm profitability as well as improved knowledge of the impact of high carbonate on crop performance.

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EP Farming Systems Summary 2020 - GRDC Investment Snapshot

Recognising and acknowledging the unique conditions, constraints and challenges associated with grain production on Eyre Peninsula (EP), the Grains Research and Development Corporation (GRDC) continues to invest in bespoke research, development and extension to underpin farming systems advances across the region.

The portfolio of regionally relevant investments spans the breadth of issues and opportunities confronting growers, from soil-based yield limitations, diseases, weeds and pests, through to crop nutrition, varietal testing and rotations. Trial results from many of these investments are reported in this publication, and a range of online resources relating to these investments are included in this article.

Pivotal in informing these investments has been the on-the-ground insights and intelligence delivered to the GRDC on behalf of growers and industry through EP-based members of the Southern Grower Network (formerly Regional Cropping Solutions Network) and the Southern Region Panel.

The Panel now has significant EP representation, with Port Lincoln-based research agronomist Andrew Ware and Cummins grower Michael Treloar appointed as members in 2020.

The Southern Region Panel was influential in informing the relatively new collaborative research initiative focused on **calcareous soils**, which limit crop yields and grower profitability across large parts of the southern cropping region and in particular the EP.

The investment, announced by the GRDC in conjunction with the Cooperative Research Centre for High Performance Soils (the Soil CRC), aims to boost understanding of the constraints to crop yield and profitability on highly calcareous soils and develop novel management practices to address these barriers.

The three year investment, comprising two separate but complementary projects, involves research partners Department of Primary Industries and Regions (PIRSA), New South Wales Department of Primary Industries (DPI) and the Commonwealth Scientific and Industrial Research Organisation (CSIRO). The SA Grain Industry Trust (SAGIT) is also supporting the initiative through the Soil CRC. Total joint investment is $6.75 million.

The investment builds on previous research into calcareous soils, but has a particular research focus on highly calcareous soils, such as those prevalent on the upper EP.

With research now underway, the GRDC recently published a suite of videos (available at http://bit.ly/3aiZB64) and podcasts (https://grdc.com.au/news-and-media/audio) featuring lead researcher Dr Nigel Wilhelm, of the South Australian Research and Development Institute (SARDI) which is the research division of PIRSA, and Mudamuckla grower Peter Kuhlmann detailing this important investment for EP growers.

Meanwhile, the EP continues to be a focus of the CSIRO-led 'Increasing production on **sandy soils** in the low-medium rainfall areas of the southern region' GRDC investment. This investment is looking to identify opportunities for the management of constraints to crop productivity on sandy soils using combinations of mitigation and amelioration strategies.

The work, which involves a number of field research experiments, local replicated validation trials, larger scale demonstration trials and grower demonstrations sites on upper and lower EP, is revealing new insights and knowledge to support growers with problem sands.

The Baldock family at Buckleboo has been hosting trials for the sandy soils project, as well as the 'Improving sustainable productivity and profitability of Mallee farming systems with a focus on soil improvements' initiative which is part of the strategic research partnership between the GRDC and SARDI.

You can read more about the work being undertaken on the Baldocks' property in a GRDC Ground Cover story at https://groundcover.grdc.com.au/grower-stories/southern/ripping-combination-aims-to-remediate-sands.

Elsewhere, **water repellent** sandy soils have been a particular focus of research by Dr Jack Desbiolles from the University of South Australia, who has been evaluating seeding tactics to improve crop productivity in non-wetting sandy soils and the effectiveness of available soil wetter chemistries.

Two field trials run in 2018 and 2019 at Murlong involved a seeder strategy evaluation trial, comparing a number of seeding strategies, such as on-row sowing (which is demonstrating potential for positive impact on EP) and moisture delving. Results from those trials and a soil wetter evaluation trial are explored in a GRDC podcast, available at https://grdc.com.au/news-and-media/audio/podcast/soil-wetter-and-seeder-strategies-for-non-wetting-sands.

Another ongoing initiative, informally known as the **Dryland Legume Pasture Systems (DLPS)** project, is continuing to generate interest among EP growers and advisers, especially the trials at Minnipa Agricultural Centre.

Evaluating a diverse range of annual pasture legumes on mixed farms in the low to medium rainfall zone, the DLPS project aims to provide a critical assessment of the regional performance of existing and new pasture lines; determine if pasture legumes can be established more efficiently; and quantify the benefits provided by pasture legumes to crops and livestock.

The DLPS project is supported by investment from the Australian Government Department of Agriculture as part of its Rural R&D for Profit program, the GRDC, Meat and Livestock Australia and Australian Wool Innovation. The research partners include SARDI, Murdoch University, CSIRO, the Western Australian Department of Primary Industries and Regional Development and Charles Sturt University, as well as grower groups (including AIR EP).

In a podcast available at https://grdc.com.au/news-and-media/audio/podcast/choosing-the-best-pasture-legumes-for-lower-rainfall-areas, SARDI researcher Ross Ballard shares information on the new and existing commercial lines tested so far, including a new strand medic (*Medicago littoralis*) cultivar which is well adapted to the EP and scheduled for release this year. A new GRDC video about the national project is available at https://www.youtube.com/watch?v=I54PJQ-KYyA&feature=youtube_gdata_player.

In terms of priority diseases for the EP, the GRDC's **National Canola Pathology Program** continues to provide the region's growers with new knowledge and advice around the management of blackleg and sclerotinia.

The program releases the latest blackleg disease ratings in autumn and spring and these are contained in the GRDC Blackleg Management Guide (https://grdc.com.au/RDC-FS-BlacklegManagementGuide) which can be used by growers to determine whether they are in a high-risk situation and the best management practices to reduce or prevent yield loss from blackleg.

The BlacklegCM blackleg management app is also updated with the latest disease ratings. The app, a GRDC investment, provides growers with a tool that can forecast the likelihood and severity of the disease, associated yield loss and economic returns on a paddock-by-paddock basis.

The Blackleg Management Guide and app emphasises that fungicides will only provide an economic return if a crop is at high risk of yield loss.

The key message that growers should never rely solely on fungicides to control disease - as this poses a high risk for development of resistance - is central to the communication platform of the **Australian Fungicide Resistance Extension Network (AFREN**) which has been established by the GRDC to provide growers with the information and support they need to reduce the emergence and manage the impacts of fungicide resistance.

AFREN brings together regional plant pathologists, fungicide resistance experts and communications and extension specialists to provide growers and advisers with the tools and knowledge to prevent and manage its impact.

Project partners include AgCommunicators, Agriculture Victoria, CCDM, Centre for Crop Health at the University of Southern Queensland, Department of Primary Industries and Research Development in Western Australia, Foundation for Arable Research Australia, Independent Consultants Australia Network, Marcroft Grains Pathology, SARDI and the University of Melbourne.

Management strategies should be crop, disease and region specific, which is why AFREN will develop and deliver regionally specific resources.

To that end, EP agronomists and grain growers are invited to discuss the cutting edge of cereal and canola disease and fungicide resistance management in a two-day workshop at Cummins on July 19-20. For more details, go to https://grdc.com.au/events/list. More information on AFREN is available at www.afren.com.au.

Eyespot is another disease of particular concern to EP growers. In some years it literally flattens cereal crops in parts of the region. For more information go to the GRDC Fact Sheet at https://grdc.com.au/resources-and-publications/all-publications/publications/2020/eyespot-factsheet).

Through the strategic research partnership between the GRDC and SARDI, in collaboration with the University of Adelaide, SA researchers are perfecting techniques to screen new germplasm for eyespot resistance in a controlled environment - which should help plant breeders advance the delivery of resistance traits.

With no established eyespot pathogen artificial inoculation method, a system had to be developed where consistent numbers of infected field collected stems could be used to inoculate plants growing in pots. While developing this screening system, researchers also developed methods for identifying and producing eyespot spores on stems collected from the field, so they can now generate single spore isolates.

The 2020 season was the first where the research team used its techniques to evaluate cultivars in the GRDC's NVT program as well as commercial bread wheat varieties.

Other GRDC investments of note for growers and industry on EP include:

- 'Demonstrating and validating the implementation of integrated weed management strategies to control barley grass in the low rainfall zone farming systems'
- 'Using soil and plant testing data to better inform nutrient management and optimise fertiliser investments for grain growers in the southern region'
- Southern Pulse Extension - Pulse Check Groups
- Delivering value from soil moisture probes on Eyre Peninsula
- 'Cultural management for weed control and maintenance of crop yield'.

On the resource front, the GRDC's National Variety Trials (NVT) program in 2020 published the inaugural suite of regional **NVT Harvest Reports**, providing the latest independent varietal information on yield, quality, and disease ratings from the 2019 NVT program. One of these publications was tailored especially for EP growers and advisers.

The *EP Harvest Report* (https://grdc.com.au/resources-and-publications/all-publications/nvt-harvest-reports) provided information to support decisions on variety selection for the region. The publication also included a summary of the 2019 and long term yield performance of varieties of crop species suitable for production on EP, together with their quality and disease responses.

The *Harvest Reports* are designed to complement - not replace - the GRDC-supported state-based Sowing Guides, which are published prior to harvest. The SA Sowing Guide, available at https://grdc.com.au/NVT-south-australian-crop-sowing-guide, is published by the GRDC and compiled by SARDI in partnership with the South Australian Grain Industry Trust (SAGIT).

A report from the 2020 NVT program on EP will be published in March this year and will be emailed to subscribers (go to https://grdc.com.au/grdc-subscriptions to ensure your subscription details are up to date) and available via the GRDC and NVT Online websites.

Another GRDC publication, which has been well received by many on EP, is the **Nitrogen Reference Manual For The Southern Region**.

The reference manual, available for viewing and downloading at https://grdc.com.au/a-nitrogen-reference-manual-for-the-southern-cropping-region, is a comprehensive guide to understanding, managing and estimating nitrogen requirements from paddock to paddock and season to season, and includes information about the various nitrogen decision support tools available to growers and advisers.

Collated by a team from the University of Adelaide, University of New England, the University of Melbourne and advisers as part of a GRDC-invested project, the manual includes a case study with Wharminda grower and consultant Ed Hunt. Tooligie Hill grower and consultant Bill Long is a co-author of the manual.

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

or 08 9230 4600.

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Eyre Peninsula Landscape Board update

The Eyre Peninsula Landscape Board was established on 1 July 2020 when the South Australian Government reformed how our landscapes are managed. Underpinning its approach, is the Landscape South Australia Act 2019, which repealed the Natural Resources Management Act 2004.

This reform resulted in the Eyre Peninsula Natural Resources Management Board becoming the Eyre Peninsula Landscape Board. As part of the reform, National Parks and Wildlife Services SA now sits outside our area of work, sitting directly under the Department for Environment and Water while we report direct to the Minister for Environment and Water.

As the Eyre Peninsula Landscape Board, we continue to work with community, industry, and government agencies to ensure a sustainable approach to the management, protection and restoration of our soil, water, native plants and animals.

We support local communities and land managers to be directly responsible for managing their region's natural resources with an emphasis on land and water management, biodiversity and pest animal and plant control.

We also partner with government and regional communities to deliver a strong, back-to-basics system that's autonomous and flexible in response to the regions' needs.

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

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

Water resources

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

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

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

Managing plants and animals

Pest animals and plants can pose significant threats to agriculture, the natural environment and public health and safety on the Eyre Peninsula.

We work closely with land managers to find ways of reducing the number of pests, help restore native biodiversity and reduce losses in the agricultural industry.

Sightings of pest animals can be reported on the Feral Scan website: www.feralscan.org.au.

If you would like assistance for managing pest animals and plants on your property, you can contact your local landscape officer or your nearest team leader of landscape operations.

- Team Leader Landscape Operations, Eastern (Whyalla): Tim Breuer, E: timo-thy.breuer@sa.gov.au, Ph: 8688 3111
- Team Leader Landscape Operations, Southern (Port Lincoln): Ben Smith, E: benjamin.smith@sa.gov.au, Ph: 0427 188 546
- Team Leader Landscape Operations, Western (Streaky Bay): Liz McTaggart, E: liz.mctaggart@sa.gov.au, Ph: 8626 1108

Mallee seeps

We are currently supporting a two year mallee seeps project to support farmers in managing this rising issue, through funding from the Australian Government's National Landcare Program. See the project information in this booklet for more details or visit our web page - www.landscape.sa.gov.au/ep/Sustainable_agriculture/Mallee_seeps.

LANDSCAPE SOUTH AUSTRALIA EYRE PENINSULA

Delivery of the Eyre Peninsula Landscape Board's agricultural programs in 2020

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

The **Regional Agricultural Landcare Facilitator (RALF)** role provides a central contact point for farmers, industry, and community groups; and supports agriculture related activities. Amy Wright was appointed to the Eyre Peninsula RALF role in September 2020 as an employee of AIR EP.

It is part of Amy's role to keep all stakeholders informed of new government policy, sharing results from trials or other extension, building awareness of new advances in technology and emerging issues, etc. Specifically, Amy is assisting EP farmer groups with the organisation of agricultural events such as farmer meetings, field days, workshops and sticky beak days.

Amy can also support agricultural groups to develop new projects and seek grant funding, for example through the Commonwealth Smart Farms Small Grants, Smart Farm Partnership rounds and other possible funding opportunities. Amy links in with a network of RALF's across Australia. Amy provides feedback to the Board and the national network on the needs of the agricultural community and keeps abreast of emerging challenges, issues or threats that may affect the agricultural sector in the region.

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

The **Regenerative Agriculture Program (RAP)**, also known as the Sustainable Agriculture Program, aims to support farmers with increased awareness and adoption of sustainable land management practices.

The RAP provides general sustainable agriculture support to the Board. The project officer works closely with local landholders with priorities including:

- Addressing soil acidification through organising workshops with a local land management consultant, for farmers to identify areas of current or emerging acidification, and working out a plan to address the issue.
- Managing the small grants program that farmers can access for soil organic carbon and mixed species demonstrations across the EP. Aimed at improving soil health and sustainability, the sustainable agriculture grants are available to individual farmers or farmer groups for a range of activities to reduce soil erosion, increase soil biodiversity and soil health across a range of soil types, in large 'farmer scale' demonstrations.

There are two funding streams available - plant-based options to improve soil health using mixed species crops or pastures and summer cover crops; and using interventions intended to overcome subsoil constraints and that might have long term benefits for increased soil organic carbon and productivity across a range of soil types. Interventions might include deep ripping, rock crushing, and addition of soil amendments such as gypsum, lime or other organic/nutrient amendments.

The small grants are open each year and farmers are encouraged to contact the Sustainable Agriculture Project Officer for more information.

- Mallee seeps awareness raising, identification of emerging sites and organisation of local workshops or field days for farmers.
- One-on-one site visits with farmers to identify soil-related issues and provision of reports.
- Various communication activities and information dissemination, including organisation of an annual Regenerative Agriculture Forum on EP.

Much of the program is being delivered by Josh Telfer, who was appointed the Sustainable Agriculture Project Officer in November 2020. Josh can assist farmers in any of the areas listed above, with Rural Solutions SA also providing soils technical expertise to support the program.

For more information, please contact Josh Telfer, Sustainable Agriculture Project Officer, susag@airep.com.au or 0460 000 290.

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

This monitoring of the activities being undertaken by farmers is being delivered by David Davenport, Davenport Soil Consulting. A report on outcomes will be generated later in 2021.

Positives ahead for SA grain

Adrian McCabe
Grain Producers SA Chair

Grain Producers SA exists to advance the interests of our state's 4,500 grain farming business enterprises by developing policy, advocating for change and providing leadership in managing emerging issues impacting the profitability and sustainability of grain production in our state.

We also play a leading role in industry development, supporting our grain producers and contributing to attracting the best and brightest people to the agricultural sector.

An example of GPSA's advocacy is the GM crop moratorium. For the first time, South Australian growers have the choice to plant genetically modified crops this coming season following an historic change in the state's agricultural policy with the lifting of the moratorium on the commercial cultivation of GM crops on mainland SA.

This followed years of advocacy from GPSA and the wider SA grain industry, with our growers now on a level playing field with their mainland interstate counterparts and significant opportunities ahead for our worldclass researchers.

As we make the transition, GPSA is now taking a leading role in the responsible adoption of new crop varieties within SA's farming systems.

The decision to lift the moratorium across mainland SA will unlock the economic potential of SA's cropping sector in line with the South Australian Grain Industry Blueprint's vision to create a $6 billion industry by 2030.

The Blueprint has been warmly received by industry and government. Several projects with strong linkages to the document already announced, generating investment in SA's grain industry.

GPSA will continue to work with government and industry throughout 2021 and beyond to progress more initiatives outlined in the Blueprint so we can achieve the targets designed to develop our industry's potential.

There is a lot of interest in the competing port proposals on the Eyre Peninsula. GPSA does not favour projects between competing commercial interests and will continue to seek clarity on growers' behalf.

In early 2021, GPSA has been busy rolling out workshops across the state. This includes Trade & Market Access Workshops throughout February, with workshops held at Wudinna and Cummins. These workshops coincide with our Market Ready and Beyond the Silo campaigns. Head to the GPSA website for more information on these campaigns.

We are also rolling out the second round of Roadworthy Heavy Vehicles…Made Easy! workshops, which includes three workshops on the Eyre Peninsula in March.

GPSA will be focusing on several policy priority areas throughout 2021 which include the future of innovation for SA growers; industry resilience to drought and climate change; biosecurity, trade and market access; national representation; and agrichemical regulation.

If you would like to contribute in any of these areas, please do not hesitate to get in touch with the GPSA office or one of GPSA's regionally based directors.

Section 2

Section Editor:

Nigel Wilhelm

SARDI Minnipa Agricultural Centre/ Waite

Farming Systems

Improving the early management of dry sown cereal crops

Amanda Cook[1,2], Nigel Wilhelm[1,3], Ian Richter[1] and Neil King[1]

[1]SARDI Minnipa Agricultural Centre, [2]University of Adelaide Affiliate Associate Lecturer, [3]University of Adelaide Affiliate-Senior Lecturer

Location
Minnipa-Condada

Rainfall
Av. Annual: 325 mm
Av. GSR: 241 mm
2020 Total: 359 mm (100 mm summer rainfall event)
2020 GSR: 222 mm (May - Oct)

Soil type
Red loam and white sand

Paddock History

Red Loam
2020: Scepter wheat
2019: Seed Vetch
2018: Vetch and oats (grazing)

White sand
2020: CL Barley
2019: CL Wheat
2018: Wheat

Plot size
12 m x 1.7 m x 3 replicates

Key messages

- **Better plant establishment was achieved with fertiliser placed 3 cm below the seed.**
- **Lower plant establishment occurred with urea placed with the seed.**
- **Dry sowing reduced wheat yield by 0.23 t/ha across all sites compared to sowing at the break of the season in 2020.**
- **Dry sowing early with barley was a good management option for the second growing season.**
- **Sowing seed in a position to best utilise moisture for germination is important.**
- **Dry sowing in sand resulted in deeper seeding as furrows collapsed with wind events.**
- **Most herbicides and fungicides evaluated in the trial did not impact on plant establishment when dry sowing, except in the sand.**

Why do the trial?

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

On the upper Eyre Peninsula in 2017 and 2018, seed was placed in the soil for many weeks with limited soil moisture; some seed still germinated but the delayed plant emergence often resulted in 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 2020 at three sites.

Location
Streaky Bay
Rainfall
Av. Annual: 377 mm
Av. GSR: 303 mm
2020 Total: 303 mm
2020 GSR: 240 mm
Soil type
Grey calcareous sandy loam
Paddock History
2019: Oaten Hay
2018: 1.4 t/ha Mace wheat
2017: Medic pasture
Plot size
12 m x 1.7 m x 3 replicates

How was it done?

Each site had two trials with CL Razor wheat sown @ 72 kg/ha, aiming for 180 plants/m^2. The 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). The trials were sprayed with Weedmaster DST @ 1.5 L/ha, Hammer @ 80 ml/ha and LI700 @ 400 ml/100L at both times of sowing. On 3 June broadleaf weeds were sprayed with Volley @ 115 g/ha and BS1000 @100 ml/ha. A trace element mix of zinc sulphate @ 1 kg/ha, manganese sulphate @ 1.5 kg/ha and copper sulphate @ 0.5 kg/ha was applied on 9 June. The Minnipa sand trial received 50 kg/ha of urea broadcast on 1 July. Hoegrass 375 @ 1L /ha and BS1000 @ 250 ml/ha were applied on 23 July.

The treatments in the trials at each site were:

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

- Nil - Control (no fertiliser)
- 60 kg/ha DAP (diammonium phosphate, 18:20:0:0) with the seed
- 60 kg/ha DAP below the seed
- 80 kg/ha DAP with the seed
- 80 kg/ha DAP below the seed
- 54.5 kg/ha MAP (monoammonium phosphate, 10:22:0:1.5) and urea (5.35 kg N/ha to balance nitrogen with 60 kg/ha of DAP) with seed
- 54.5 kg/ha MAP with seed and urea below the seed (5.35 kg N/ha to balance nitrogen)
- 60 kg/ha DAP split; 30 kg/ha with the seed and 30 kg/ha below the seed (deep)
- Phosphoric acid (12 kg P/ha) and urea (10.8 kg N/ha) with the seed.

Trial 2: Management - Dry sown with 10 management treatments

Nil - Control (no fertiliser), dry sown CL Razor with 60 kg/ha DAP with the seed, CL Spartacus barley, herbicides (Trifuralin @ 2 L/ha, Boxer Gold @ 2.5 L/ha and Sakura @ 118 g/ha), shallow sowing (2-3 cm), deep sowing (6 cm), and fungicides (Tebuconazole @ 50 ml/100 kg seed, and Flutriafol on fertiliser @ 166 ml/100 kg DAP).

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. Plant establishment was counted 5 times from first emergence, early dry matters were taken at 10 weeks (3-4 leaf stage) on the dry sown trial on 22 June, and with the break sowing on 13 July. Early NDVI was measured on 9 July.

Rhizoctonia root disease was scored at 10 weeks (GS Z20) on 23 June by randomly sampling 20 plants per plot. The roots were washed and scored using a (0-5) scale with 0 being a healthy non-infected root system. Late dry matter (GS Z43-45) and NDVI was taken on 11 September. The Minnipa red site was harvested on 21 October, Streaky Bay trial on 28 October and Minnipa sand on 5 November.

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

What happened?

The 2020 season had below average rainfall for most regions on upper Eyre Peninsula and very little rainfall was received during May, June and July. Streaky Bay had decile 3 rainfall and Minnipa a decile 4. The 2020 season at Minnipa started with some areas having subsoil moisture from late January rains. Good opening rains were received in late April/early May at both sites which enabled seeding to be within the ideal sowing window. The rest of May, June and July were below average rainfall resulting in very little crop growth until August and later in the season, with October having above average rainfall. The subsoil moisture at Minnipa meant the dry sowing treatments emerged before the early May rainfall events and before the second time of sowing.

Table 1. Sowing dates and emergence for "dry sowing" and "break" treatments at Minnipa and Streaky Bay in 2020.

Sowing dates	Dry sowing	Break/wet sowing	Dry sowing first emergence	Break first emergence
Minnipa-Condada red loam	15 April	4 May	25 April	11 May
Minnipa-Condada white sand	16 April	4 May	2 May	11 May
Streaky Bay	17 April	5 May	2 May	14 May

Farming Systems

Trial 1: Sowing trial

Germination was determined by sowing time, more than in the 2019 season but emergence was lower than 2019 despite the same seeding rate and reasonable seeding conditions. The Minnipa red dry sown treatments began emerging on 25 April and the break seeding treatments on 11 May. The sandy soil dry sown treatments emerged on 2 May and break sown treatments on 11 May. The Streaky Bay dry sown treatments began emerging on 2 May and the break sowing on 14 May (Table 1).

The sandy soil trial experienced some wind erosion especially on the southern side, and this generally resulted in an increase in sowing depth especially in the dry sowing treatments due to the furrows filling with blown sand.

On 18 May dry sowing had slightly higher establishment with 100 plants/m^2 and sowing at the break having 93 plants/m^2. On 1 June, when the last emergence count was taken, overall germination over the 3 sites was 101 plants/m^2 which was lower than expected. The Minnipa sand had the lowest overall emergence with 98 plants/m^2, Minnipa red soil 101 plants/m^2 and Streaky Bay 104 plants/m^2. Sowing at the break achieved 110 plants/m^2 and sowing dry achieved 92 plants/m^2 (Figure 1).

The treatments with urea and fertiliser placed with the seed had lower crop establishment than those where the seed and fertiliser was separated (Figure 1 and Figure 2). The treatments which separated the fertiliser from the seed, 60 and 80 kg/ha DAP below the seed, and MAP fertiliser with the seed and urea deep, had similar germination to the Nil fertiliser treatment (Figure 2). The treatments with urea placed with the seed had lower germination (Figure 2). Similar to the results achieved in 2019 the red soil type showed less variability in germination compared to the other soils.

Sowing after the break of the season had greater dry matter production 10 weeks after sowing than dry sowing (Table 3). Minnipa red soil had the greatest early dry matter production overall. The highest early dry matter occurred with 80 kg/ha DAP banded below the seed, and the lowest early dry matter were those with urea banded with the seed and the Nil Control (data not shown).

Rhizoctonia root disease was highest at Streaky Bay and lowest on the Minnipa sand (Table 3).

Seeding at the break of the season had slightly higher infection levels of 2.8, than at the dry sowing timing with a 2.5 score for Rhizoctonia infection.

In 2020 sowing at the break of the season increased grain yield at all sites by 0.23 t/ha (Table 5), and there were no differences in yield between fertiliser treatments at any site. The seasonal conditions in 2020 with slow early growth and late rains may have favoured the later sowing time. Grain protein was highest at Minnipa red and Streaky Bay grey calcareous sites (Table 4). The grey calcareous soil and Minnipa sand had higher screenings.

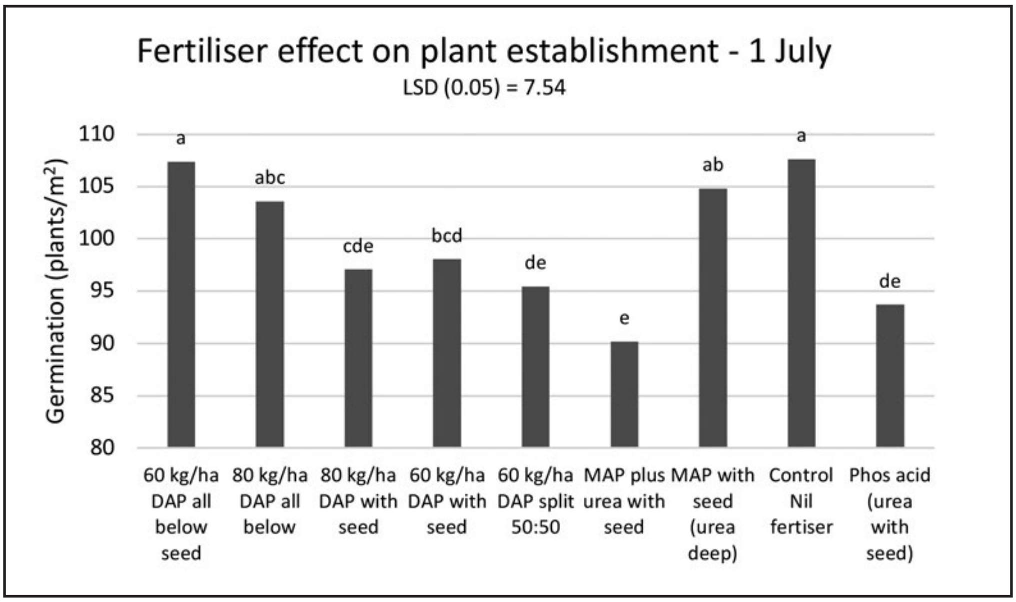

Figure 2. Plant establishment of CL Razor wheat over the three trial site locations with given fertiliser treatments on 1 July, 2020. (LSD (P=0.05) = 7.5).

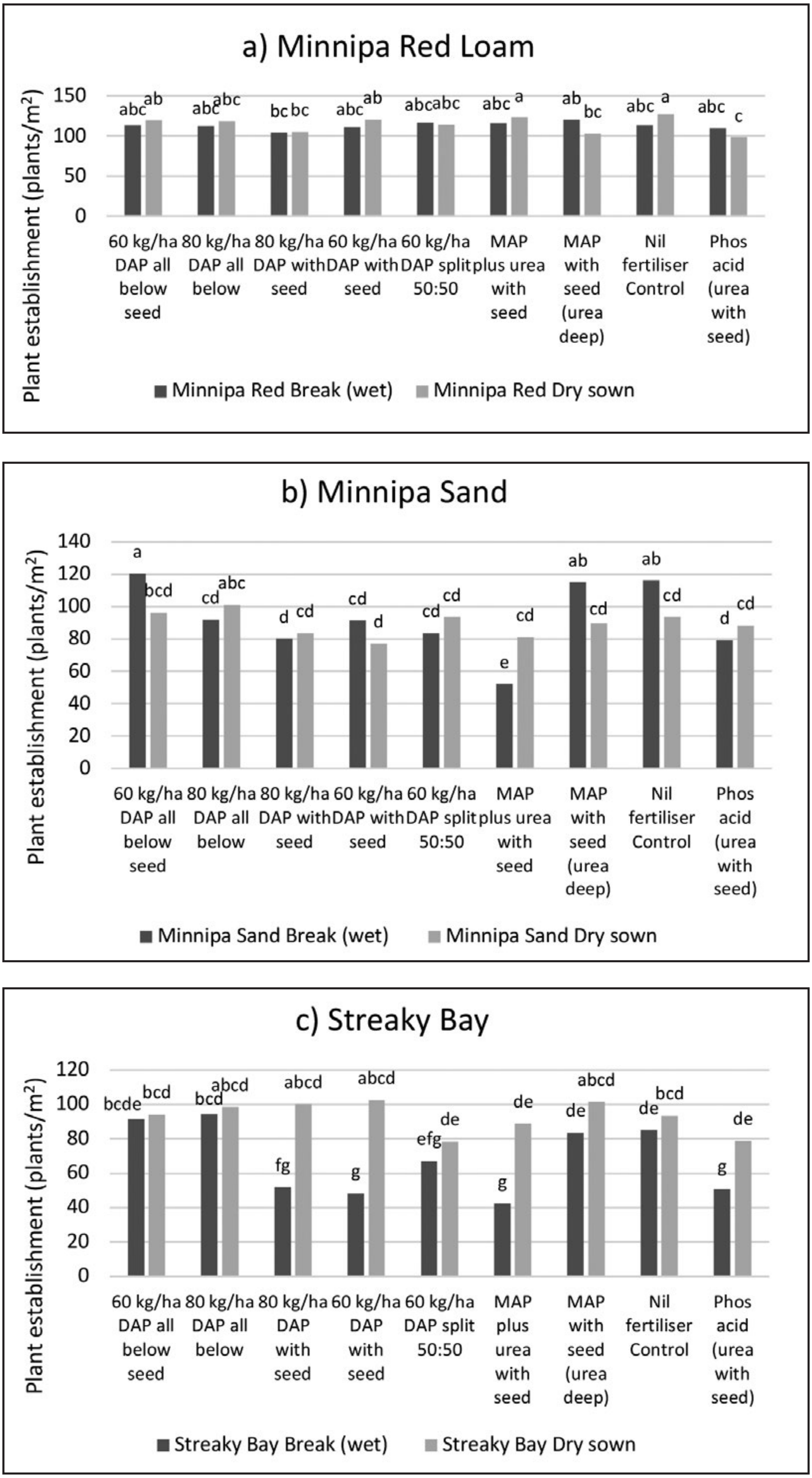

Figure 1a, b and c. Plant establishment of CL Razor wheat at the three trial site locations a) Minnipa red loam, b) Minnipa sand and c) Streaky Bay on 18 May, 2020. (LSD (P=0.05) = 20.8).

Table 3. Early and late dry matter (t/ha) and Rhizoctonia score of CL Razor wheat at three locations in 2020.

Trial location	Early Dry Matter after 10 weeks from sowing		Rhizoctonia Score (0-5)	Late Dry Matter (t/ha)
	Dry sowing 22 June	Break 13 July	23 June	All on 11 Sept
Minnipa red	0.75 a	0.68 a	2.7 b	3.64 a
Minnipa sand	0.34 b	0.34 b	2.3 c	2.63 b
Streaky Bay	0.19 bc	0.11 c	3.0 a	1.13 c
LSD (P=0.05)	*0.17*		*0.19*	*0.21*

Table 4. Grain yield (t/ha) and quality of CL Razor wheat at three locations in 2020.

Trial location	Yield	Protein (%)	Screenings (%)
Minnipa red	2.46 a	11.8 a	3.0 c
Minnipa sand	1.52 b	10.0 b	7.4 b
Streaky Bay	0.77 c	11.7 a	10.2 a
LSD (P=0.05)	*0.13*	*0.24*	*0.51*

Table 5. Grain yield (t/ha) of CL Razor wheat at different times of sowing in 2020.

Dry sowing	Break
1.47 b	1.70 a
LSD (P=0.05)	*0.11*

Trial 2: Management trial

The Minnipa sandy soil had lower establishment than the other sites (Table 6) which was at least partly due to wind erosion increasing seeding depth because of in-filling of the dry sown furrows. Some dry sown herbicide treatments had lower plant establishment at the sand site due to sand being blown into the furrow and moving the herbicide into the crop row (Figure 3).

Deeper sowing at (6-7 cm) at the Minnipa red site resulted in better establishment due to utilisation of soil moisture from the January rainfall events. At the grey calcareous site the shallow sowing (2-3 cm) established earlier and similar to the barley treatment (Figure 3). All other management options had similar establishment to the control.

Early dry matter was higher at the Minnipa red site compared to the Streaky Bay site, and late dry matter was different between all sites (Table 7). Barley had higher early dry matter production and Nil fertiliser lower dry matter production (Figure 4). Early and late NDVI was higher at the Minnipa red trial site compared to the sand and grey calcareous soil (data not presented).

Minnipa red had higher yields than the other sites (Table 6). In 2020 the management strategies evaluated in the trial did not impact on grain yield when dry sowing. Grain protein was higher at Minnipa red and grey calcareous sites and screenings lower than at the sandy site.

Although not significant for grain yield, CL Spartacus barley performed well for a second time in the management dry sown sites compared to wheat (Figure 4). Sowing seed in a position to utilise moisture was also important as it was observed dry sown deep had earlier emergence at the Minnipa red site following good summer rainfall events, and dry sowing shallow at Streaky Bay resulted in earlier emergence (Figure 3).

Table 6. Site averages for crop performance of dry sown management trials in 2020.

Trial location	Establishment (plants/m²) 1 July	Tillering dry matter (t/ha)	Rhizoctonia Score (0-5)	Flowering dry Matter (t/ha)	Yield (t/ha)
Minnipa red	107.3 a	0.71 a	2.8	3.30 a	1.99 a
Minnipa sand	74.4 b	0.31 ab	2.5	2.16 b	0.95 b
Streaky Bay	100.2 a	0.16 b	3.0	1.25 c	0.77 b
LSD (P=0.05)	*13.1*	*0.54*	*NS*	*0.36*	*0.2*

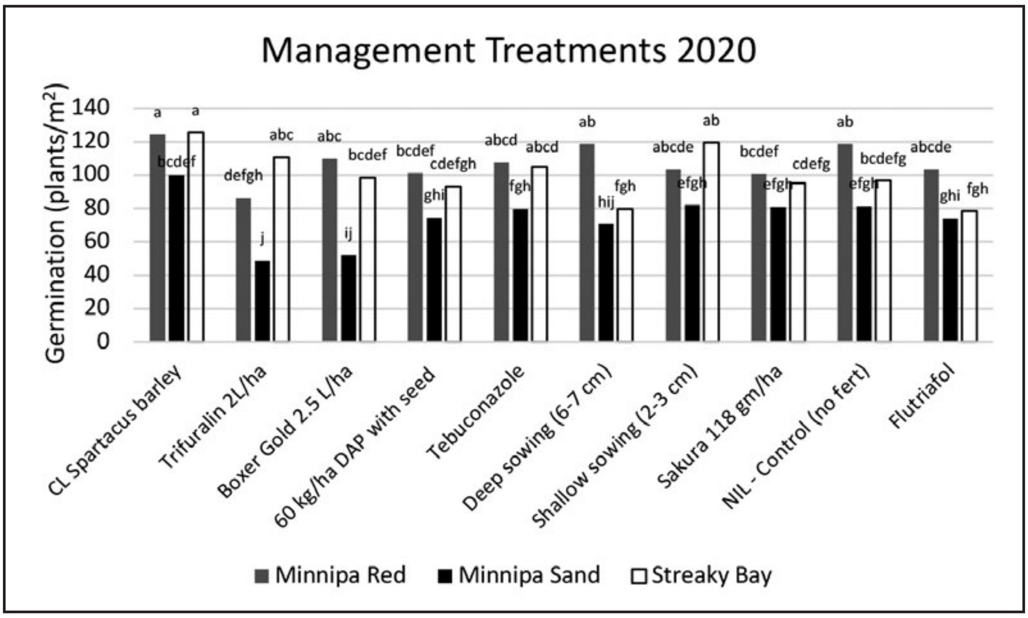

Figure 3. Establishment of CL Razor wheat over the three trial site locations with Management treatments on 18 May, 2020. (LSD (P=0.05) = 22.7).

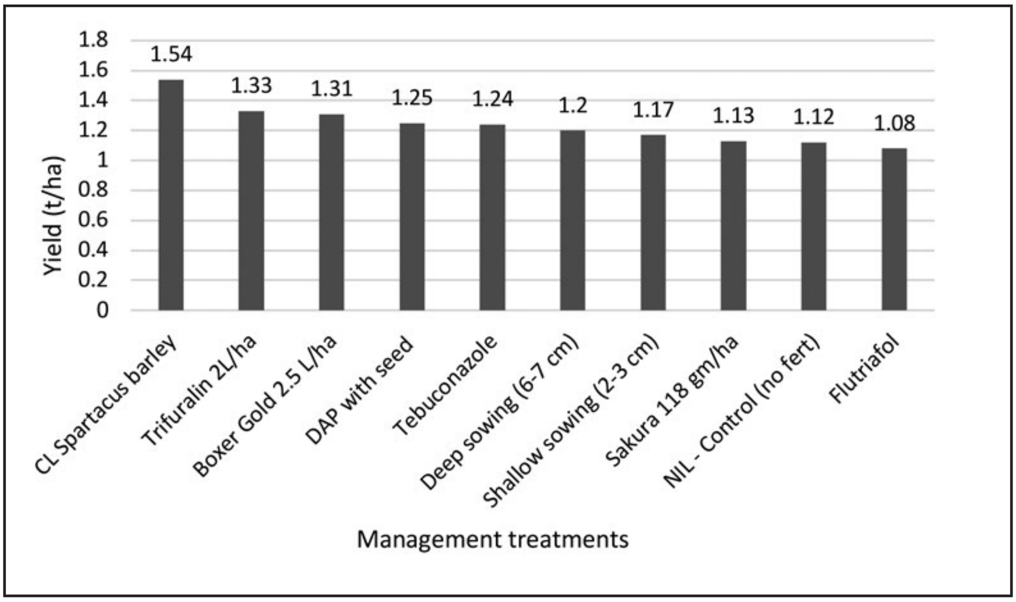

Figure 4. Yield (t/ha) of management treatments averaged across three sites in 2020. (LSD (P=0.05) NS).

What does this mean?

With a reasonable start to the season the overall plant establishment achieved at all sites was much lower than the 180 plants/m^2 expected. Sowing at the break of the season into a moist seed bed resulted in higher plant establishment compared to dry sowing at all sites.

Better plant establishment was achieved by separating the fertiliser to 3 cm below the seed, which achieved similar germination to the no fertiliser treatment. Those fertiliser treatments which had urea with the seed had lower plant establishment, so if possible place urea below the seed at sowing or consider applying urea post seeding. If fertiliser separation cannot be achieved due to seeding systems then using MAP (10:22:0:1.5) is a safer option than placing DAP with the seed.

The highest early dry matter was achieved by the 80 kg/ha DAP banded below the seed treatment, and the lowest early dry matter were those with urea banded with the seed and the Nil Control (no fertiliser) treatments. Dry sowing reduced early dry matter compared to sowing at the break of the season.

Dry sowing does not necessarily result in better yields then seeding on the break. Sowing at the break of the season increased grain yield at all sites by 0.23 t/ha this season, and there were no differences in yield between fertiliser treatments at any of the sites. The late rains in October may have favoured the two week later sowing time in 2020.

Dry sowing in sands had lower plant establishment as wind erosion resulted in the furrows collapsing and increased the sowing depth. On the sand some herbicide treatments had lower plant numbers potentially due to soil movement hence moving herbicide into the crop row.

In the dry sown management trial most of the treatments evaluated in the trial did not impact on plant establishment or wheat grain yield, so are safe to use in dry sown systems. For the second season dry sown CL Spartacus barley had improved early dry matter production compared to wheat, indicating barley performs well with early dry seeding relative to wheat.

Sowing position depending on the soil moisture in the profile was important for plant establishment when dry sowing. Sowing deeper resulted in earlier establishment at the Minnipa red site where there was soil moisture from summer rainfall events. If there is soil moisture in the profile make sure the seed is placed in that layer.

This research will continue for another season with further trials to be established to determine the impacts of dry sowing and management on plant establishment, along with additional research through a new Soils CRC and GRDC funded Calcareous soils research project.

Acknowledgements

This research was funded by SAGIT through the ‘Improving the early management of dry sown cereal crops’ (S419).

Sincere thanks to SAGIT and their extremely valuable input into regional South Australian research and researchers. Thank you to Phil & Jan Wheaton and Matt Cook for having field trials on their property. Thank you to Katrina Brands, Steve Jeffs and Steph Hull for field work and processing samples.

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Impact of fertiliser on wheat emergence under dry conditions

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Key messages

- **Seedling germination and emergence was faster in a Minnipa white siliceous sand and red loam compared to a grey calcareous soil.**
- **Germination percentages achieved for the different soil types were sand 91%, red loam 87% and grey calcareous soil 53%.**
- **Fertiliser placed with the seed reduced wheat emergence on calcareous soils.**
- **Growers may want to consider the fertiliser placement as it may be beneficial to move fertiliser further away from the seed if this is an option.**

Why do the research?

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

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

This article summarises a 2020 pot trial which assessed the impact of fertiliser type and placement on wheat establishment on three different soil types; a red loam (Minnipa-Condada), a grey calcareous soil (Streaky Bay) and a white siliceous sand (Minnipa-Condada). In 2019 a similar pot trial was conducted using diammonium phosphate fertiliser, see EPFS 2019 Summary, p 38.

How was it done?

Soil was collected from 0-10 cm depth from three research trial sites in April 2020 in non-sprayed and non-cropped areas of the paddock. The red loam was following a vetch crop in 2019, the grey calcareous soil was following a pasture, and the sand was following a wheat crop. The soils were dried after collection at 70°C for 48 hours.

The soil was potted on 15 June into plastic tubs at 5% (w:v) soil moisture before fertiliser and seed were placed into the tubs in two seed and fertiliser rows following the treatments listed below. The tubs were placed in a glasshouse in a randomised block design with 3 replicates per treatment.

Eight fertiliser treatments were imposed using diammonium phosphate (DAP, 18:20:0:0) or mono-ammonium phosphate (MAP, 10:22:0:0). Nitrogen was balanced with urea placed 3 cm below the seed.
The treatments were:

- Nil Control (no fertiliser)
- 60 kg/ha DAP with seed
- 60 kg/ha DAP 3 cm below the seed
- Split application with 30 kg/ha DAP with seed and 30 kg/ha of DAP 3 cm below the seed
- 60 kg/ha DAP with the seed but spread in a 3 cm ribbon to replicate a splitter boot system
- 54.5 kg/ha MAP with seed and urea (5.35 kg/ha) 3 cm below the seed
- 54.5 kg/ha MAP and urea (5.35 kg/ha) all 3 cm below the seed
- Split application with 27.25 kg/ha MAP with seed and 27.25 kg/ha of MAP and urea (5.35 kg/ha) 3 cm below the seed.

The equivalent of 72 kg/ha of CL Razor wheat seed, 32 seeds per pot, was sown at 3 cm below the soil surface, at the equivalent of 22.5 cm (9") row spacing.

Water was applied at a rate equivalent to 5 mm of rain one week after sowing (23 June), followed by the equivalent of 25 mm of rain two weeks later on 1 July. To encourage further germination, 50 mm was applied on 6 July and a final 25 mm on 20 July to ensure all viable seed germinated.

The experiment was harvested eight weeks after seeding on 11 August as there was no further seedling emergence. Shoots were dried and processed for leaf tissue analysis. A composite soil sample from around the seed at harvest from selected treatments (Table 2), was analysed for pH, nitrate-N and ammonium-N.

Table 1. Initial soil analysis of 0-10 cm soil from three sites in 2020.

Soil	Minnipa white sand	Minnipa red loam	Streaky Bay calcareous soil
pH ($CaCl_2$)	6.5	7.9	7.8
Texture	Sand	Sandy loam	Sandy Clay Loam
Phosphorus (ppm, Colwell)	23	52	70
PBI	11	109	204
Nitrate-N (mg/kg)	12	65	114
Ammonium-N (mg/kg)	1	1	2

Farming Systems

What happened?

The early water applications were chosen to reflect a dry start, with a larger watering in July to promote maximum seedling emergence.

Seedlings started emerging in the sandy soil on Day 8 and seedling emergence was then recorded on most days until Day 56 (11 August). The first seedlings emerged in the red soil on 29 June (Day 14) and in the grey calcareous soil on 21 July (Day 36).

Nil fertiliser and fertiliser placement below the seed resulted in earlier emergence in the white sand after 8 days from seeding (Figure 1). DAP with the seed caused lower emergence than MAP. Simulation of a splitter boot with 3 cm spread did not improve emergence compared to a single row, but splitting DAP between the seed row and below resulted in emergence intermediate between compared to all DAP with the seed and all below the seed. These observations indicate fertiliser placement with the seed are causing fertiliser toxicity effects.

In the red loam, seedling emergence was similar for all fertiliser treatments after 16 days from seeding (July 14) (Figure 2).

Plant growth in both the white sand and the red loam was vigorous after emergence. Emergence was later in the grey calcareous soil (Day 36) with poor plant growth after emergence. On Day 49 (4 August) the calcareous soil emergence in the nil control was better compared to both fertilisers placed with the seed (Figure 3).

At seedling harvest on 11 August (Day 56), eight weeks after sowing and with good soil moisture, the overall emergence percentages for white sand and red loam were similar at 91% and 87%, respectively. Emergence in the grey calcareous soil was poor with only 53%.

By eight weeks after sowing, the effects of fertiliser type and placement in all three soils was similar. Figure 4 is a summary of those effects averaged for the three soils. Nil fertiliser and both fertilisers placed below the seed had better emergence than when placed with the seed. The wider row simulation resulted in emergence better than with the narrow row. DAP with the seed reduced emergence compared to MAP.

Soil analysis from near the seed at harvest showed that pH was lower in the white sand compared to the other two soils. The nitrogen levels reflect the higher N content of the DAP fertiliser compared to MAP (Table 2). There were no differences in the nutrition content of the plant leaves between treatments (data not presented).

What does this mean?

Seedling emergence was faster in the Minnipa white sand and the red loam with 91 and 87% respectively after eight weeks, and slower in the grey calcareous soil with only 53% plant emergence after eight weeks with adequate moisture.

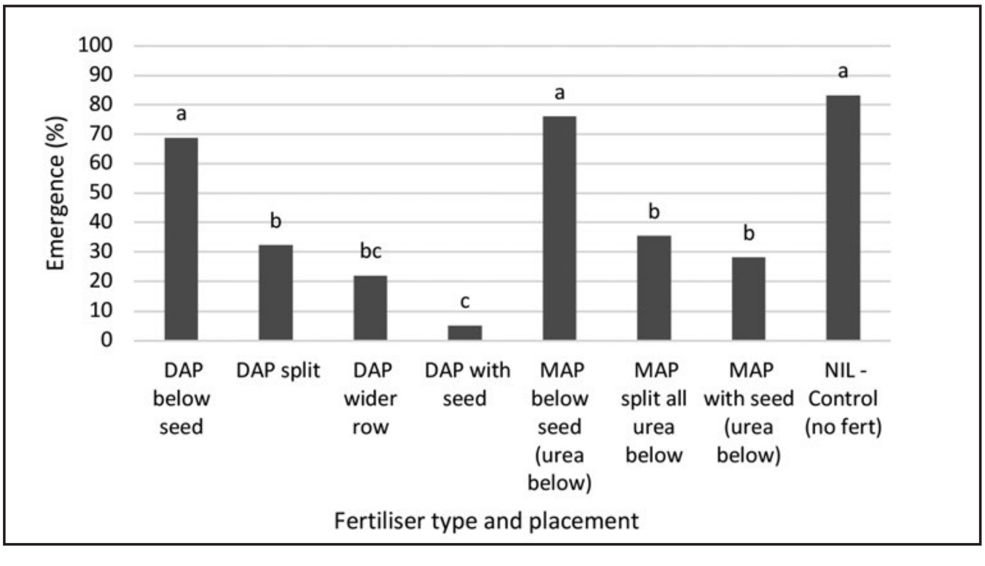

Figure 1. Emergence of wheat 8 days after seeding (% of seeds planted) in a white sand with different fertiliser and placement. Columns with the same letter are not statistically different at P=0.05.

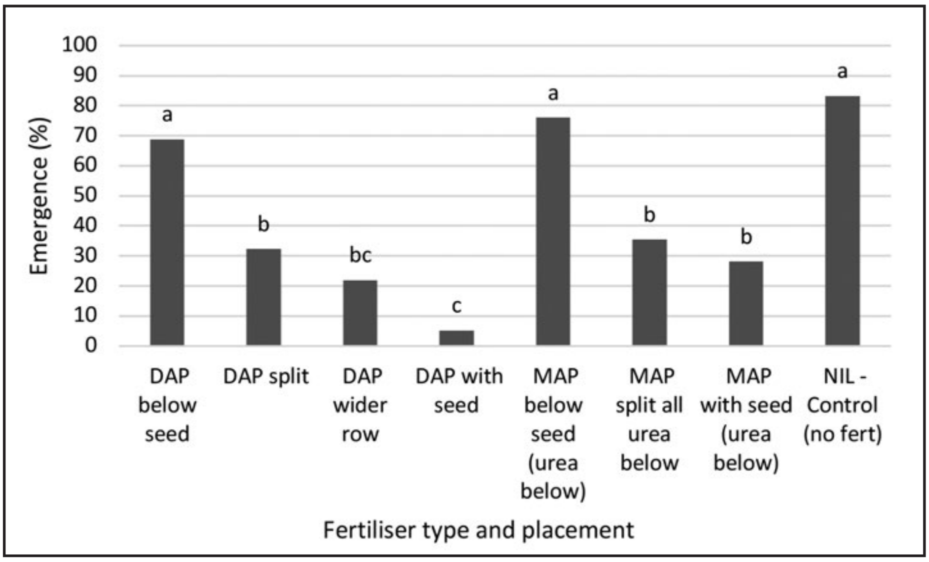

Figure 2. Emergence of wheat after 16 days in a red loam (% of seeds planted) with different fertiliser types and placement. Columns with the same letter are not statistically different at P=0.05.

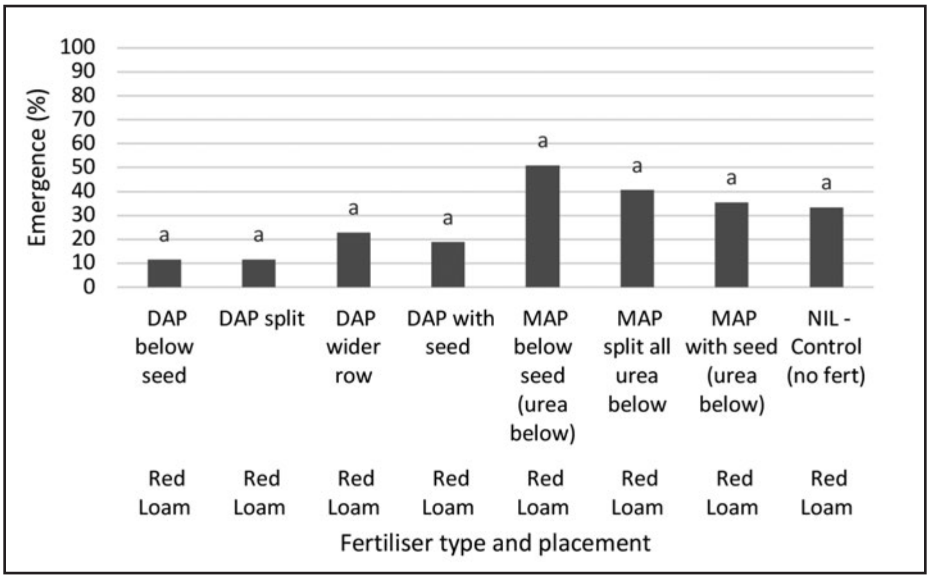

Figure 3. Emergence of wheat 14 days after first emergence (Day 49) in a grey calcareous soil (% of seeds planted) with different fertiliser types and placement. Columns with the same letter are not statistically different at P=0.05.

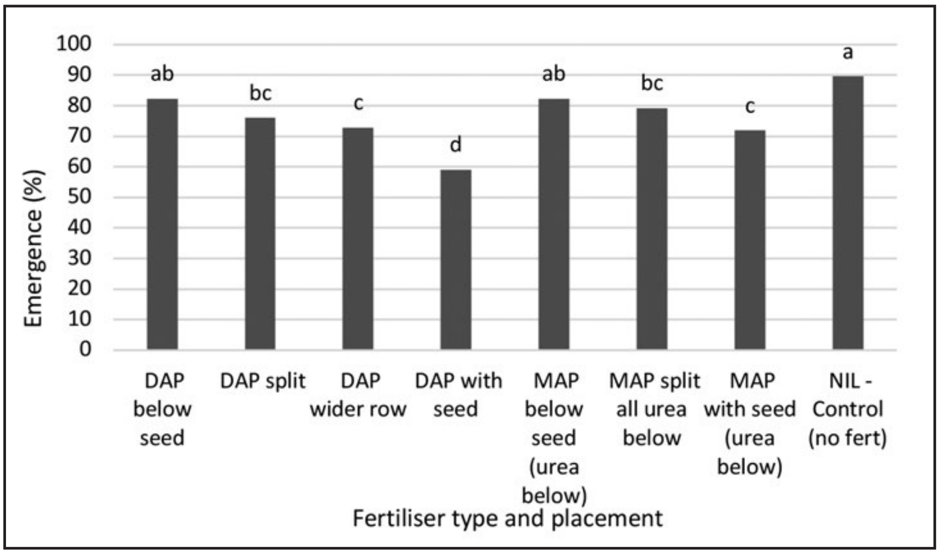

Figure 4. Effect of fertiliser type and placement on wheat emergence (% of seeds planted) averaged for all three soil types together after 56 days. Columns with the same letter are not statistically different at P=0.05.

Figure 6. DAP at 60 kg/ha with the seed spread in a 3 cm ribbon to replicate a splitter boot system, and Figure 7. The experiment in the MAC hot house, 2020.

Table 2. Soil analysis from samples collected around the seed at harvest.

Fertiliser Treatment	DAP below seed	DAP with seed	MAP below seed (urea below)	MAP with seed (urea below)	NIL Control (no fertiliser)	*LSD (P=0.05)*
pH $CaCl_2$						
White Sand	6.2	5.7	5.8	6.0	6.8	
Red Loam	7.7	7.7	7.7	7.6	7.8	*0.3 (interaction)*
Grey Calcareous	7.7	7.5	7.7	7.7	7.7	
Nitrate N (mg/kg)	84	76	44	46	26	*21*
Ammonium N (mg/kg)	7	13	7	9	4	*4*

After eight weeks in all soils there was a fertiliser effect, with fertiliser placed with the seed, spread in a 3 cm row and split applications reducing germination compared to the nil fertiliser treatment. Fertiliser placement and toxicity may be an issue which is reducing wheat emergence even at quite low application rates of 30 kg/ha with the seed. The red loam and sandy soils achieved high establishment levels, despite the fertiliser effects and resulted in vigorous seedlings by eight weeks compared to the grey calcareous soil with reduced overall germination and vigour.

On the calcareous soils with a high pH (8-9), adding a fertiliser product with the seed is reducing seedling germination. In 2019 pot trials with DAP this was due to increased salinity near the seed. The salinity effects would possibly be most severe in lower moisture conditions. Current fertiliser guidelines would consider 30 kg/ha of fertiliser with the seed a safe rate. The results from this pot experiment indicate even MAP fertiliser near the seed may be impacting on emergence.

Growers may want to consider placing fertiliser below the seed if this is an option. DAP placed in a wider row, replicating a splitter boot system with 3 cm spread, did not appear to have the same benefit as fertiliser placed below the seed. The fertiliser placement and dry sowing effects on wheat on red loam soils appear not to have the same negative impacts. Further research on fertiliser placement and rates will be undertaken in 2021, and the Calcareous soils project will also further research these 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 Katrina Brands, Ian Richter and Steve Jeffs for their help with the experiment.

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The 2020 growing season: what happened, what about the forecast and what can we learn?

Peter Hayman and Dane Thomas
SARDI Climate Applications, Waite

Key messages

- **Forecasts made early in the season were for a wetter than average winter. There are several explanations for the dry winter including an unusual cyclone and an abrupt change to a positive Southern Annular Mode (SAM), these factors were partially captured in later forecasts.**
- **We need to be careful about communicating and using forecasts early in the season and check for regular updates. We need to understand that a forecast of 75% to 80% chance of above average rainfall includes the forecast of 1 in 4 or 1 in 5 years being drier than average.**

Growing season rainfall in 2020:

As can be seen in Table 1 all sites had decile 7 to decile 8 rainfall in January and February, the northern sites had good March rain and all sites had decile 8 rain or wetter in April.

Due to the wet April and October, the 2020 growing season rainfall (April to October) will be recorded as Decile 5 or above for all sites except the Decile 4 at Minnipa. The May to September deciles (last column in Table 1) indicate that this part of the growing season was below decile 5. The pattern of a wet start, dry winter and wet October was widespread across the southern grains region. Overall, cropping production from Eyre Peninsula in 2020 was reasonable despite the difficult year. This shows that farming systems on Eyre Peninsula have evolved to be able to use out of season rainfall. Saving rainfall from January, February and March requires summer weed control, saving rainfall from mid-April is due to no-till and efficient seeding.

Growing Season Temperature: Cool winter and hot spring

Table 2 shows the average temperature (Max+Min)/2)) for a range of sites across EP. Winter (June, July and August) at most sites was cooler than average but spring (September, October and November) was warmer. All locations experienced decile 10 average temperature for September. As discussed in the following section there were a series of heat spikes in September, most of which occurred on crops with limited moisture in the profile.

Table 1. Rainfall in mm and decile using a base period from 1900 to 2020 for eight focus paddocks used in the Resilient EP project. Above median deciles (deciles (D) 6 to 10) are shown in bold. Data from Silo Data Base as patched point data.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Apr-Oct	May-Sep
Port Lincoln (Woolga)	**20 D8**	**46 D10**	14 D5	**92 D10**	**75 D7**	67 D3	46 D1	**108 D8**	**86 D8**	**89 D10**	21 D5	17 D5	**564 D8**	383 D5
Port Lincoln (Big swamp)	**18 D8**	**19 D7**	11 D4	**81 D10**	**68 D6**	62 D4	42 D1	**96 D8**	**71 D8**	**67 D9**	20 D5	12 D4	**487 D7**	*339 D4*
Cummins	**10 D7**	**22 D8**	6 D4	**52 D9**	30 D3	51 D5	25 D1	58 D5	**49 D7**	**68 D10**	8 D3	**15 D6**	333 D5	*213 D2*
Wharminda	**17 D8**	**20 D8**	3 D3	**40 D8**	17 D3	22 D3	15 D1	36 D5	29 D5	**87 D10**	4 D2	**23 D8**	247 D5	*120 D1*
Lock (Terre)	**16 D8**	**23 D8**	5 D4	**46 D9**	28 D4	37 D4	28 D2	**44 D4**	**36 D6**	**79 D10**	3 D2	**20 D7**	**297 D6**	*173 D2*
Waddikee	**21 D8**	**28 D8**	**23 D8**	**36 D8**	16 D3	19 D2	24 D3	44 D6	**43 D7**	**70 D10**	4 D2	**16 D6**	**251 D6**	*145 D3*
Minnipa	**11 D7**	**46 D9**	**19 D7**	**35 D9**	16 D3	16 D2	16 D1	36 D5	**33 D6**	**65 D10**	1 D1	**22 D8**	217 D4	*117 D2*
Buckleboo	**14 D7**	**28 D8**	**26 D8**	**35 D9**	14 D3	21 D3	24 D3	**47 D7**	**36 D7**	**95 D10**	6 D3	**19 D7**	**272 D8**	*142 D4*

Table 2. Mean temperature ((Max + Min)/2) (°C) and decile using the base period from 1957 to 2020 for eight focus paddocks used in the Resilient EP project. Above median deciles (deciles 6 to 10) are shown in bold. Data from Silo Data Base as patched point data.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Apr-Oct
Port Lincoln (Woolga)	**20 D7**	20 D4	**19 D7**	16 D4	13 D1	11 D3	10 D2	**11 D4**	**14 D10**	**15 D7**	19 D10	18 D3	13 D5
Port Lincoln (Big swamp)	**20 D7**	20 D4	**19 D7**	16 D4	13 D1	12 D3	11 D1	**11 D4**	**14 D10**	**15 D7**	19 D10	18 D3	13 D4
Cummins	**22 D8**	**21 D6**	**20 D7**	16 D4	13 D1	11 D2	10 D1	**11 D5**	**15 D10**	**16 D7**	20 D10	19 D4	13 D3
Wharminda	**22 D6**	21 D3	**20 D6**	17 D4	14 D1	**12 D4**	11 D2	**12 D4**	**16 D10**	**17 D7**	21 D10	20 D3	**14 D4**
Lock (Terre)	23 D5	22 D3	**21 D6**	17 D5	14 D2	**12 D7**	11 D5	**12 D8**	**16 D10**	**17 D8**	22 D10	21 D3	**14 D9**
Waddikee	23 D5	22 D3	20 D4	17 D5	13 D2	12 D7	**11 D6**	**12 D7**	**16 D10**	**17 D6**	22 D10	21 D3	**14 D8**
Minnipa	23 D5	23 D3	21 D5	18 D5	14 D1	12 D5	**12 D7**	**12 D6**	**16 D10**	**18 D8**	23 D10	21 D3	**15 D7**
Buckleboo	23 D5	23 D4	21 D4	**18 D7**	13 D3	**11 D7**	**11 D8**	**12 D8**	**16 D10**	**17 D7**	22 D10	21 D3	**14 D9**

Spring heat spikes and frost

Figure 1 shows minimum and maximum temperatures recorded by data loggers in a plastic shield and installed at 1.2 m. Not only were there a series of heat spikes through September (7, 10 and 18) there were frosts from late August through September

What happened with the forecast?

At the start of the season, SARDI Climate Applications, along with many agronomists and farmers and most climate scientists expected 2020 to be wet. We were surprised by the dry winter but relieved that a late developing La Niña brought rain in October which helped most, but not all, regions.

Farmers and agronomists that were following seasonal climate science had invested time to understand that a negative IOD and La Niña was encouraging. They also understood that there were many climate models and sources of information and that when all the models were pointing to the same outcome that this increased confidence. The strong forecast for wet conditions was followed by an extremely dry May to July. Perhaps the month that was perceived to be the biggest failure of the forecast was July. This was in part because July is expected to be a wet month and partly because on many paddocks the wet April provided moisture to buffer the early crop growth across May and June.

There has been increasing media discussion and GRDC funded communication on the impact of climate drivers such as ENSO and the Indian Ocean Dipole on winter growing season rainfall in southern Australia. Sites such as https://forecasts4profit.com.au/ show that these climate drivers swing the odds and are best represented as probabilistic forecasts. For example, a La Niña is best understood as increasing the likelihood of wetter deciles and decreasing the likelihood of dry deciles rather than the easier to follow but incorrect statement that it will be wet. There is a strong tendency for media to simplify the message to a negative IOD will lead to wet conditions. This simple causal thinking is easier to understand and more natural for most of us. In contrast, probabilistic thinking is harder work.

In recent years, climate drivers have performed in a way that supports causal thinking. The very dry spring across southern Australia in 2015 was associated with an El Niño and the following wet year of 2016 was consistent with a negative IOD. The climate drivers of ENSO and IOD were neutral in 2017 and 2018, however as pointed out by Bureau of Meteorology scientist Andrew Marshall, during these winters the drier outcomes across southern Australia were consistent with the unusually strong subtropical ridge. In 2017 the Southern Annular Mode (SAM) was in a positive phase; in 2018 a higher than normal number of high-pressure systems formed over the Tasman Sea. The very dry spring of 2019 was linked to a positive IOD (Climate Kelpie website 2020). The media coverage of 2020 was framed around a bounce back to a good year after the widespread drought and bushfires that ended 2019.

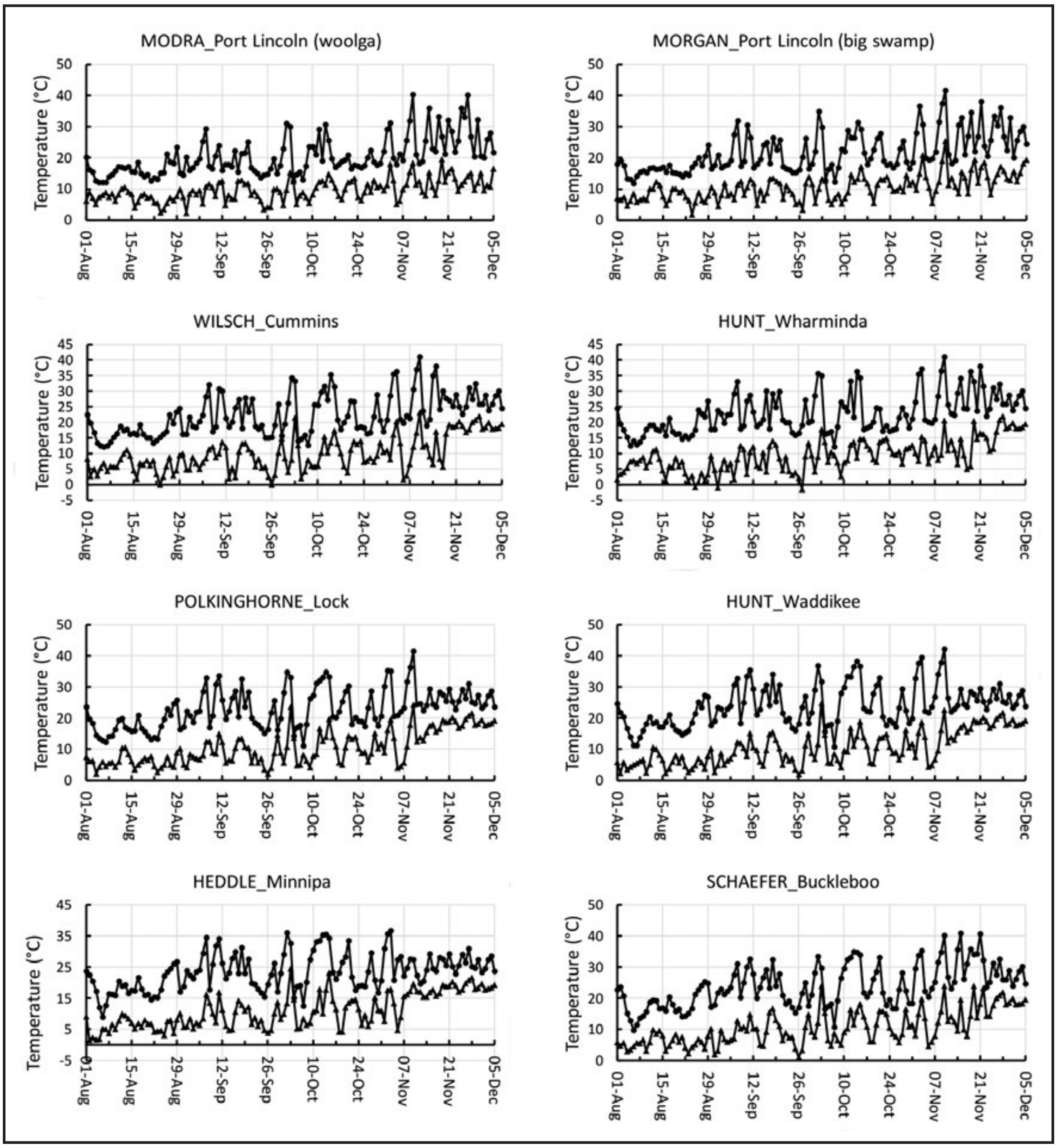

Figure 1. Maximum temperature (circles) and minimum temperature (triangles) for eight reference sites as part of the Resilient EP project.

The positive outlook for the 2020 season started with summer rainfall and widespread April rainfall, and this was bolstered by discussion on climate drivers for the 2020 growing season. This is captured in an ABC article from 18 April titled "Wet winter likely as speculation over La Niña and a negative IOD mounts". The article cites a Bureau of Meteorology spokesperson *"I think it's a little better than rumours now, which feels like a good thing to say," "There are really strong odds, probably the strongest we've seen since 2016." "Looking at other models from around the world, it's amazing they are all saying a very similar thing and I've probably looked at half a dozen or more of the top models now," "They are all suggesting that the odds are increased of having some good rainfall over the next few months for much of Australia." The ABC article continued "The outlook suggests there is an above 60 per cent chance of above-median rainfall for most of the country for at least the next three months."*

The emphatically wet outlook for winter was followed by an equally emphatic but actual dry winter which had an impact on both crop growth and level of trust in the forecast.

Blame the dry winter on an unusual cyclone and positive SAM

The oceans were strongly primed for a negative IOD and this was picked up by all six international climate models reviewed by the Bureau of Meteorology. The time series of the IOD index (Figure 2) starts with the negative IOD associated with the wet spring of 2016 and shows how the strongly positive IOD from 2019 dropped to a weakly negative IOD over March to May in 2020. The encouraging signs of a fall in the IOD and warming of waters to the NW of WA surprisingly swung to a posi-tive IOD in June and July.

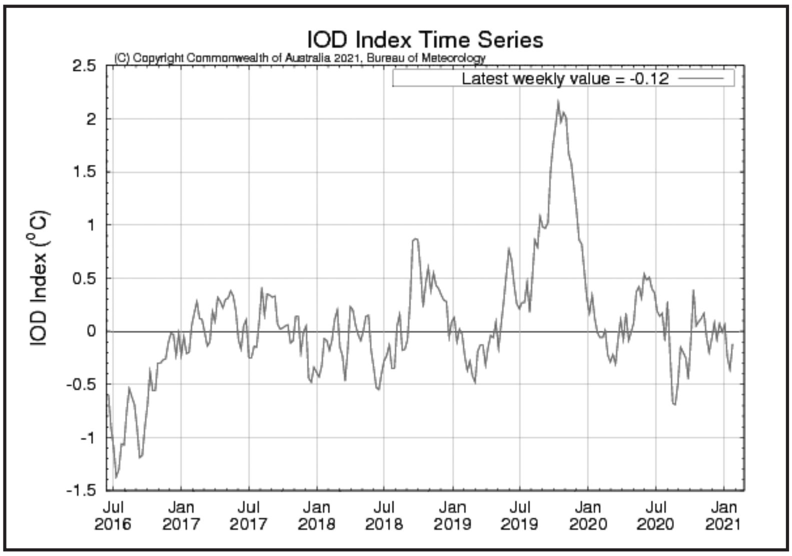

Figure 2. Time series of the Indian Ocean Dipole from Bureau of Meteorology website (http://www.bom.gov.au/climate/enso/indices.shtml?bookmark=iod).

One explanation for the abrupt change in the IOD in July was tropical Cyclone Mangga which was not only unusually late (19 - 23 May), but also followed an unusually southward track. There were wild storms, flooding and power cuts across WA including Perth and a cooling of a section of the SE tropical Indian Ocean to the NW of Australia which reversed the trend in the IOD. A further complicating factor was the rapid development towards a positive Southern Annular Mode (SAM) which contributes to drier conditions in southern Australia in winter.

A general pattern for 2020 was the forecast for the month after next to be wet, and then to see the forecast switch to neutral or dry. For example, the forecast in May was emphatically for a wet July but by June the forecast for July had switched to neutral or dry. This was because the model was picking up the influence of the cooling of the ocean from cyclone Mangga and the development of the positive SAM. SAM events can only be forecast about 2 weeks ahead and cyclones are weather events that can be forecast less than 2 weeks in advance. According to the Bureau of Meteorology, large swings in the seasonal outlook as seen in 2020 are unusual. The key drivers of our climate, which rely on patterns of ocean temperatures such as IOD and ENSO, typically change slowly and users are more used to a shift from neutral to wetter or drier but not a swing from wet to dry. Obviously checking the latest forecast is important, but there are many agricultural decisions that require the longer-term outlook such as the decision to plant a riskier crop such as canola or taking a more optimistic view on top-dressing nitrogen.

The late developing La Niña led to a slowly building confidence for wet conditions. As shown in Table 3, Bureau of Meteorology issued a La Niña watch on 23 June followed by La Niña alert on 18 August and declared a La Niña under way on 29 September. The emphatic forecast for a wet October was followed by an actual emphatically wet October.

What should users of climate forecasts learn from 2020?

1. Remember that the skill of the forecast increases from a low base through the winter growing season.

The skill of seasonal climate forecasts comes from the main climate drivers of ENSO and IOD which haven't settled into a neutral, positive or negative phase until later in our growing seasons. Graeme Anderson (Ag Vic) has the useful analogy of following a football team where there is a lot of pre-season speculation which starts to firm up as the season progresses. The consistency of models in April and May suggesting increased odds of a wetter than average growing season tended to over-shadow the point that all models have low skill at this time of the year and that models can be consistently wrong.

2. Because dynamic seasonal forecasts are influenced by new developments in the ocean and atmosphere during the season, we need to check the latest update.

The reason why the skill of the forecast is low in autumn is because patterns in the ocean and atmosphere evolve over the season. These processes move at different time scales and 2020 is an example where a weather event (cyclone Mangga off the NW coast of WA) and a rapid shift in SAM played a major role. The Bureau of Meteorology are issuing more forecasts (weeks, fortnights, months and seasons) which are updated more often. It is obviously an advantage for forecasts to be updated with the latest information, but this can be a challenge for users. GRDC has funded the monthly Break newsletter from Ag Victoria to comment on South Australian conditions (https://grdc.com.au/news-and-media/newsletters/fast-break/south-australia). This is useful for updates.

Table 3. Headlines from Bureau of Meteorology Climate Drivers Update through 2020 http://www.bom.gov.au/climate/enso/.

7 January	Indian Ocean Dipole returns to neutral
21 January	Pacific and Indian ocean patterns neutral
4 February	Tropical Pacific Ocean remains ENSO neutral
18 February	El Niño - Southern Oscillation remains neutral
3 March	El Niño - Southern Oscillation likely to remain neutral to mid-year
17 March	ENSO and IOD likely to remain neutral through southern winter
31 March	Southern Oscillation and Indian Ocean Dipole neutral
14 April	Chance of negative Indian Ocean Dipole increases
28 April	Negative Indian Ocean Dipole possible in 2020
12 May	Negative Indian Ocean Dipole possible in 2020, tropical Pacific likely to cool
26 May	Tropical Pacific cools; negative Indian Ocean Dipole possible in 2020
9 June	Tropical Pacific cooling expected to continue during winter
23 June	La Niña WATCH - likelihood of tropical Pacific reaching La Niña in spring increases
7 July	La Niña WATCH continues - likelihood of La Niña in spring around 50%
21 July	La Niña WATCH continues as Tropical Pacific cools
4 August	El Niño–Southern Oscillation neutral but La Niña indicators continue to develop
18 August	La Niña ALERT - likelihood of La Niña in spring has increased
1 September	La Niña and negative Indian Ocean Dipole likely during spring
15 September	Shift towards La Niña continues
29 September	La Niña underway in the tropical Pacific
13 October	La Niña likely to continue through summer 2020-21
27 October	La Niña likely to continue until at least the end of summer 2020-21

3. Appreciating that even 80% chance of above median rainfall includes 20% chance of the opposite happening.

Seasonal climate forecasts from the Bureau of Meteorology are rarely more emphatic than 80% chance of exceeding the median rainfall. As quoted from the ABC article from 18 April 2020, most of Australia had above 60% chance of exceeding median rainfall but some parts of the map had up to 80% chance. Although a high number, 80% leaves a 1 in 5 chance of drier than median rainfall. This chance of the minority outcome is nowhere near the level used in most agricultural experiments (95%) which is 1 in 20 chance of the result being due to chance. Most AgVet chemicals set a much higher level (99% or 1 in 100) of the treatment working and in human health we are used to chances of 1 in 1000 and in aviation safety 1 in 10 Million. The 80% chance is more like the probability of a professional golfer missing a five-foot putt (compared to 99.4% for three feet, 91.4% for four feet and 60% for six feet). This is also similar to the chance of a penalty shoot-out in professional soccer (83%) (Golf website 2020). Watching a professional golfer or penalty shoot-out is interesting because it is uncertain. Even if we know the statistics it remains uncertain and interesting. We don't say *"because there is more than 80% chance the result is guaranteed and I won't bother watching"* rather, if we care about the results, we think about the two possible outcomes even though one is much more likely than the other.

Acknowledgements

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Trends in temperature and rainfall on Eyre Peninsula

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Key messages

- **High quality temperature sites indicate that the Eyre Peninsula, like the rest of the planet is getting warmer.**
- **Changes in rainfall are less clear with a recent study by the Bureau of Meteorology finding little difference in the annual rainfall when comparing the three decades 1989-2019 with 1959-1989.**
- **Detection of climate trends is different to attributing causes to trends. Detection and attribution are clearer for temperature than rainfall.**
- **It is naïve to assume that rainfall will not change, we need to be humble when discussing how it will change.**

Detection and attribution

Whenever the weather is unusually hot, cold, wet or dry it is common to hear someone say that the weather is changing from normal. Sometimes, this is followed by a conclusion that this event supports or challenges climate change with others responding that the weather has always been variable. This discussion involves detection and attribution.

Detecting a trend is different to attributing causes for the trend. As humans, it is not easy to detect a trend. Numerous studies by psychologists have shown that our memories just don't work as reliable records and ranking of past events; we remember events that are more recent and vivid. For climate science, detecting trends against background noise is difficult, this is especially the case where there is limited high quality data due to recording stations being closed down or moved.

Most of us humans find attribution quick and easy, we are just not very good at it. Psychology studies show that we tend to be over-confident and assign causes to events in situations where we should simply acknowledge that we don't know. Attribution in climate change science is the difficult process of evaluating the relative contributions of multiple interacting causal factors. Climate scientists are humans and prone to the same biases as the rest of us. Carefully designed scientific studies which are subject to peer review are an imperfect way to overcome these biases, but arguably the best we have.

Climate variability and climate change - waves and tides; cycles and trends

Farmers on Eyre Peninsula are familiar with climate variability as the year-to-year changes in seasonal conditions due to the internal forcing of the climate system (e.g. El Niño Southern Oscillation ENSO or Indian Ocean Dipole). Climate change is manifest as a longer-term trend due to external forcing that comes from astronomy (distance from the sun), volcanoes and changes to levels of greenhouse gases. Human induced climate change or the enhanced greenhouse effect refers to the changes in the radiative properties of the atmosphere due to human activity. Earlier reports of the Intergovernmental Panel on Climate Change (IPCC) stated that the warming of the climate system is unequivocal. The fifth and most recent assessment report states "Human influence on the climate system is clear" and assess that there is a 95-100% probability that human influence was the dominant cause of global warming in the last 50 years. The attribution of the cause of warming increases confidence in the trend and indicates that the future depends on choices made by the global community.

A simple but powerful analogy used by the late eminent climate scientist Stephen Schneider is to consider a vulnerable system like a grain crop as being similar to a sandcastle being impacted by waves (climate variability) and tides (climate change). Following any damaging climate event such as drought, fire, heatwave or flood, the question is often posed as to how much can be attributed to climate change (the tide) and how much to climate variability (the wave). It is almost always the wave that destroys the sandcastle, but on a rising tide the waves do more damage. Another analogy for the same purpose is a man walking in a consistent direction (trend) with a dog on a lead (variation) (https://www.climate.gov/teaching/resources/dog-walking-weather-and-climate).

Recent analysis of trends in climate change for Eyre Peninsula

In 2019 the Bureau of Meteorology, CSIRO and FarmLink were funded by the Commonwealth Government in a $2.7M project to develop regional weather and climate guides for all natural resource management regions across Australia. These guides compared the weather records of the last 30 years (1989-2019) with the previous 30 years (1959-1989). http://www.bom.gov.au/climate/climate-guides/.

NRM regions and GRDC were consulted on the design of the information.

Comparing 1989-2019 with 1959 - 1989 the study concluded:

- There have been more hot days, with more consecutive days above 40 °C
- Annual rainfall has been relatively stable
- Dry years have occurred 12 times and wet years 11 times
- Rainfall has decreased in the autumn and spring months.

These comments reflect a clearer picture for changes in temperature but not for rainfall. There are changes in seasonality of rainfall but these can be sensitive to the exact time periods being compared.

In the next section of the paper we check the trends for the three high quality temperature stations (Port Lincoln, Kyancutta and Ceduna) and four of the seven high quality rainfall stations on the Eyre Peninsula (Cummins, Arno Bay, Wudinna and Ceduna (Goode). The other three high quality rainfall sites are North Parnda (between Arno bay and Cummins), Penong, and Pennalumba (West of Ceduna). http://www.bom.gov.au/climate/change/index.shtml#tabs=Tracker&tracker=site-networks

We have not conducted statistical analysis on the trends in the sites. We have included the raw data and a 10 year moving average. The 10 year moving mean is a short period for statistical analysis, however it is relevant for farmer experience, changes in farming systems and impacts on farm businesses. For easier comparison between sites and seasons the temperature data is shown as difference from the long-term median and the rainfall data is shown as a fraction of the median.

Trends for growing season and non-growing season at three high quality temperature sites

Port Lincoln, Kyancutta and Ceduna are the only high-quality temperature stations on the Eyre Peninsula and all show a similar trend in warming. The warming is greater in summer than winter. Temperature bounces around from year to year with warm years followed by cooler years (grey circles) but at all sites what is considered a cool year in the last 10 or 15 years was a warm year earlier in the record (Figure 1).

The trends in rainfall are much noisier than the trends in temperature. As a general pattern there has been a slight decline in growing season rainfall which has been partially offset by a slight increase in non-growing season rainfall. This has coincided with farming practices which have been able to save more of the non-growing season rainfall for the growing season. Total non-growing season rainfall is suprisingly similar across the four sites (80 to 87 mm) compared to the range in winter rainfall (215 to 340 mm).

An interesting feature of growing season rainfall is that while it is difficult to see differences in the frequency or intensity of very dry years, there seem to be fewer very wet years. Although the lack of very wet years can have implictions for groundwater recharge, modern grain farming seems capable of producing good yields on years that are average or above. In medium to higher rainfall zones the very wet years can bring challenges from diseases and waterlogging while many paddocks in lower rainfall regions have inadequate inputs to benefit from the very wet years. Towards the end of the Millennium drought, a decline in growing season rainfall at Cummins seemed relatively clear.

However, over the last decade the 10 year moving average seem to be returning to the longer-term mean. This highlights the difficulties in dealing with the year to year and decade to decade variability in rainfall.

Reasons to be concerned about rainfall in Southern Australia

In 2018, the National Environmental Science Programme (NESP) built on the 2015 Climate Change in Australia Report producing a summary document on long term trends and future projections for rainfall in Southern Australia. http://nespclimate.com.au/wp-content/uploads/2018/12/ESCC-NESP-Southern-Australia-6pp-WEB.pdf.

The report concludes that the general drying trend over southern Australia over the past 50 or so years is likely to continue in the future. Key findings are as follows:

1. The intensification of the subtropical ridge (Pepler *et al* 2018). The pattern of cooler wetter winters and hot dry summers is driven by annual progression of the subtropical ridge from a summer position of 40°S (between mainland and Tasmania) and a winter position of 30°S (roughly at line from Maree SA to Bourke NSW). There is more confidence in the intensification (higher pressures) across Southern Australia than a consistent latitudinal shift.
2. A trend towards positive Southern Annular Mode (SAM) (Lim *et al* 2016). A positive SAM indicates a contraction of westerly winds and reduced winter rainfall for southern mainland Australia (and wetter summers). The impact of SAM on winter drying is more pronounced on the southern edge of the continent.

3. An increase in extreme ENSO and IOD events leading to greater variability (Power *et al* 2018).
4. After assessing the 70 models used in the "*Climate Change in Australia*" report, Grose *et al* 2017 used 15 models that best represented rain-bearing circulation for southern Australia. These 15 models showed a stronger drying especially in winter.

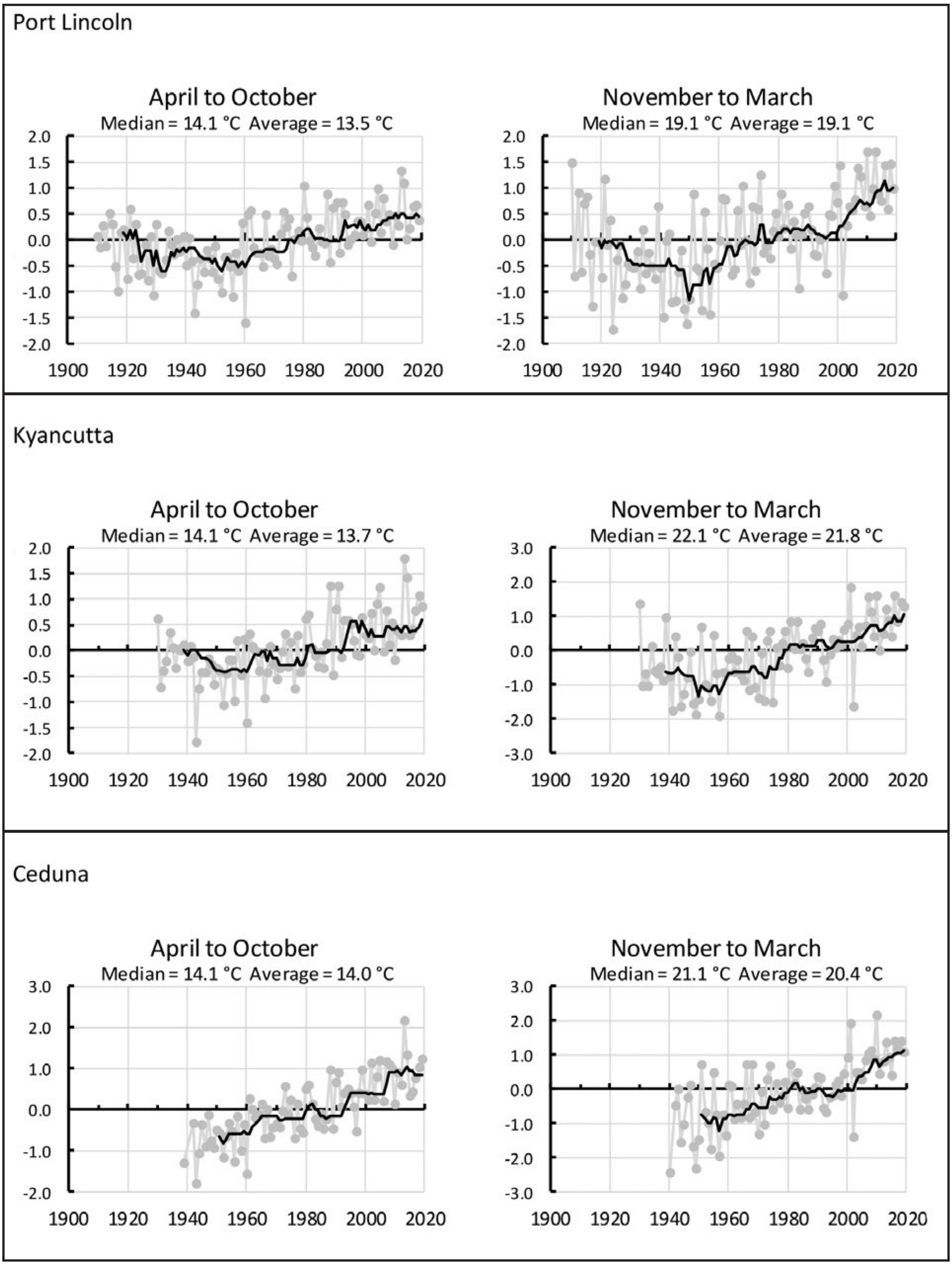

Figure 1. Time series of temperature for growing season (April to October) and non-growing season (November to March) for Port Lincoln, Kyancutta and Ceduna. The Y axis is difference from the median in degrees Celsius. Annual (grey circles) and 10 year moving average (black solid line). The median and average are for the period of the record. Note the change of scale on the Y axis.

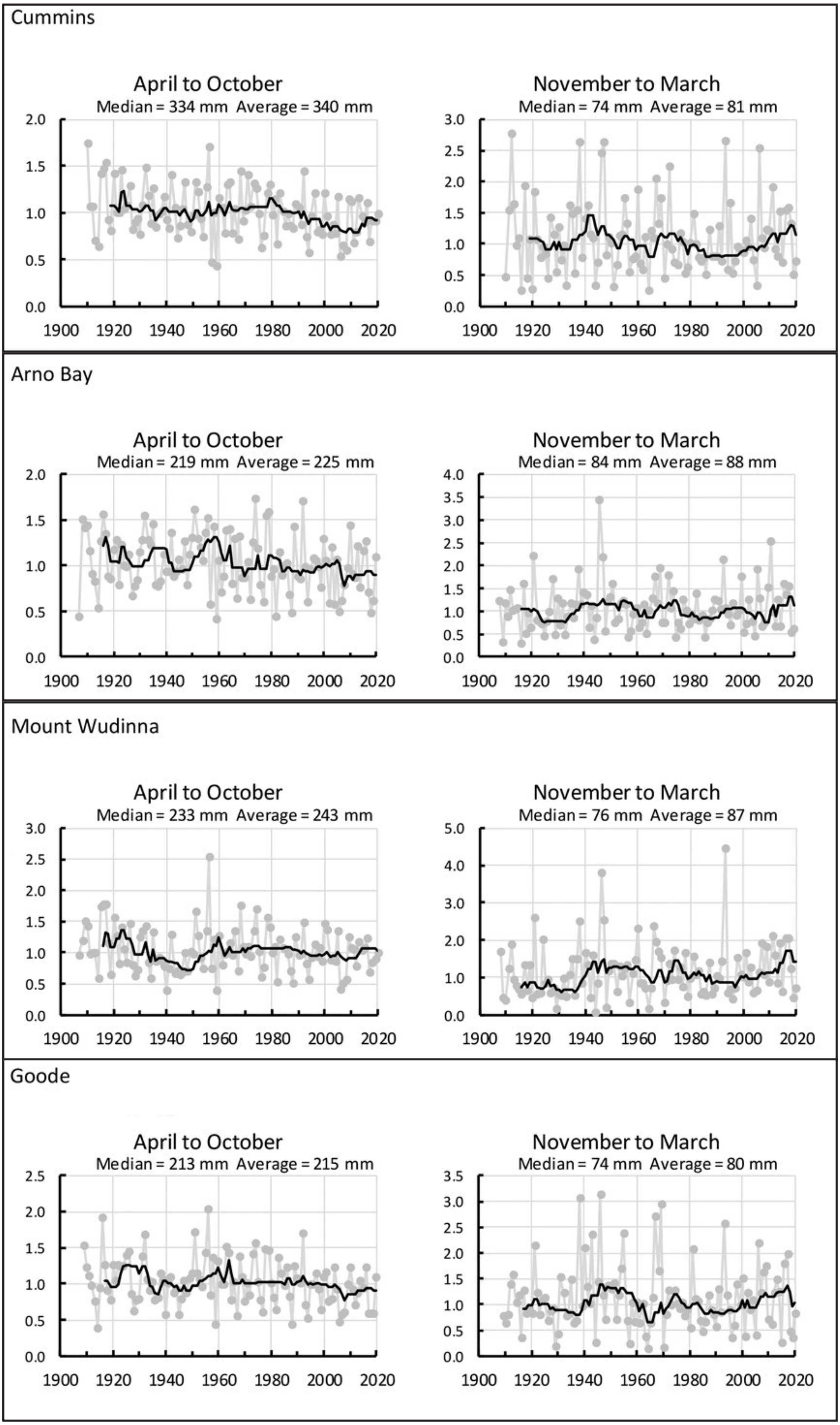

Figure 2. Time series of rainfall for growing season (April to October) and non-growing season (November to March). The Y axis is the ratio to the median. Annual (grey circles), and 10 year moving average (black solid line). The median and average are for the period of earliest record (1907 to 1910 depending on location) to 2020. Note the change of scale on the Y axis.

Table 1. The level of agreement between 15 climate scientists of their beliefs that the latest climate models represent specific extremes (model capability), the quality and length of the observational record for extremes (observations) and the level of physical understanding of how anthropogenic forcing influenced the extreme (understanding). The percent of disagreement amongst the 15 workshop participants represents approximately the number of participants expressing "strong disagreement".

Event	Model capacity	Observational record	Understanding	Percent disagreement
Extreme cold	H	H	H	0%
Extreme heat	H	H	H	0%
Marine heatwaves	H	H	H	0%
Fire relevant fuel	L	L	M	0%
Fire weather	L	M	M	10%
Extreme rain	M	H	M	10%
Drought	M	M	L	40%

https://view.joomag.com/bamos-vol-32-no4-december-2019/0270132001576909864
High agreement (H), medium agreement (M), low agreement (L).

It is important to note that the qualitative rankings from a workshop (Table 1) are more usefully interpreted as relative rankings rather than objective ratings of confidence. The lower level of understanding of the process of drought and the high level of disagreement with the rankings on drought indicate that this in an area of active debate and research. It would be a mistake to interpret the lack of understanding or agreement as an indication that rainfall won't change. It is also a mistake to attribute the same level of confidence in the warming and the drying.

Communication of climate change to the Eyre Peninsula community has generally been presented as a warming and drying trend that will continue to a warmer and drier future. Although drying trends will grab the attention of dryland farmers, combining warming with drying could be problematic if trying to communicate with farmers who may place a greater weight on their lived experience and own rainfall records than experts from outside of the region. As argued earlier, it is very hard to remember a trend of even one degree in average temperature because we don't experience average temperature. We experience weather events not climate. While crop development is a good measure of accumulated temperature, this is much harder to notice in annual crops with different sowing times and varieties compared to a perennial crop such as wine grapes. Rainfall is not only easier to measure and record, rainfall accumulated over a season is evident in the yield of crops and pastures along with income and debt for the enterprise.

Farmers on Eyre Peninsula, like the rest of us will form their own views on climate change. They will come across various experts on climate science, they also bring their political identity and social networks. These factors interact in complex and hidden ways with our own set of lived experiences and accumulated knowledge. This short paper suggests that for clarity when discussing climate change, it is important to separate climate change into what is happening and what is projected to happen with temperature compared to rainfall.

Acknowledgements

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Eyre Peninsula
Government of South Australia
Department of Primary Industries and Regions
SARDI
SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE
Resilient EP
For a profitable farming future

Resilient EP: A new paradigm for resilient and profitable dryland farming on the Eyre Peninsula using data to improve on-farm decision making

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Location
Minnipa
Bruce Heddle
Minnipa/Poochera Farming Group
Rainfall
Av. Annual: 325 mm
Av. GSR: 241 mm
2020 Total: 359 mm
2020 GSR: 253 mm
Yield-adjacent to soil moisture probe
Potential: 3.9 t/ha (W)
Actual: 3.1 t/ha Scepter
Paddock history
2019: Lentils
2018: Wheat
2017: Pasture
2016: Wheat
Soil type
Sandy loam over clay sand loam
Soil test
Comprehensive, variety of testing over 19 points across the paddock to a depth of 110 cm
Yield limiting factors
Boron, calcium carbonate

Location
Wharminda
Ed Hunt
Verran Ag Bureau
Rainfall
Av. Annual: 337 mm
Av. GSR: 252 mm
2020 Total: 272 mm
2020 GSR: 168 mm
Yield-adjacent to soil moisture probe
Potential: 1.8 t/ha (W)
Actual: 1.3 t/ha Vixen
Paddock history
2020: Wheat
2019: Pasture
2018: Wheat
2017: Pasture
Soil type
Sandy loam over clay

Key messages

- **The ability to make the best use possible out of rainfall and stored soil moisture continues to be the largest driver of crop and pasture production on the Eyre Peninsula.**
- **Being able to measure what plant available soil moisture is present at any time of the year, not only at soil moisture probe points but across the landscape offers the potential to improve productivity and limit risk.**
- **In the next 12 months, tools such as an improved platform (website/app) to display soil moisture probe information will be rolled out.**

Why do the trial?

Between 2017-19, the Eyre Peninsula Agricultural Research Foundation (EPARF) (through SARDI), delivered a SAGIT funded project to develop a publicly available platform that provided soil moisture information (with some interpretation) from a collection of soil moisture probes found at 32 locations across Eyre Peninsula (EP). When farmers and advisors were surveyed at the conclusion of the project, the most common use of probe information was to assist with nitrogen application decisions, followed by providing information that assisted with grain marketing decisions, improving confidence around sowing opportunities, and understanding the benefits of summer weed control.

However, many growers and advisors provided feedback suggesting the website platform the information was delivered on could be made more user friendly and would like more information on how the soil characteristics immediately around where the soil moisture probe is located relates to the rest of the paddock, and possibly the wider regional landscape.

To build on the information generated from soil moisture probes and to make better use of an increasing array of other data sources, funding was secured from the Australian Government's National Landcare Smart Farming Partnerships program. The project aims to unlock value in existing data to drive innovation in agronomy and livestock management by bringing together data from a range of sources including satellite, soil moisture probe networks, weather stations, proximal sensing and yield models. By working with farmers and advisors to link data with decision making, the project aims to make more informed and significantly improved land management decisions.

Soil test
Comprehensive, variety of testing over 19 points across the paddock to a depth of 90 cm
Yield limiting factors
Poor establishment, boron, calcium carbonate, chloride, frost

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Location
Mount Dutton
Bruce Morgan
Wangary Ag Bureau
Rainfall
Av. Annual: 519 mm
Av. GSR: 436 mm
2020 Total: 456 mm
2020 GSR: 303 mm
Yield-adjacent to soil moisture probe
Potential: 6.25 t/ha (W)
Actual: 6.25 t/ha Scepter
Paddock history
2019: Wheat
2018: Canola
Soil type
Gravel loam over clay
Soil test
Comprehensive, variety of testing over 15 points across the paddock to a depth of 110 cm
Yield limiting factors
Poor water holding capacity, N leeching

Location
Cootra
Todd Matthews
Rainfall
Av. Annual: 336 mm
Av. GSR: 251 mm
2020 Total: 366 mm
2020 GSR: 190 mm
Yield-adjacent to soil moisture probe
Potential: 3.5 t/ha (W)
Actual: 3.1 t/ha Scepter
Paddock history
2020: Wheat
2019: Pasture
2018: Barley
2017: Wheat
Soil type
Dune swale system. Deep sands to sand loams over clay to heavy clay flats
Soil test
Comprehensive, variety of testing over 19 points across the paddock to a depth of 90 cm
Yield limiting factors
Fertility (N, S)

Location
Yeelanna
Jordan Wilksch
Lower Eyre Peninsula (previously LEADA)
Rainfall
Av. Annual: 441 mm
Av. GSR: 330 mm
2020 Total: 362 mm
2020 GSR: 308 mm

How was it done?

AIR EP has bought together a diverse project team consisting of soil scientists, research agronomists, ag technologists, precision ag specialists, website designers, climatologists, extension, and communications experts to work together with local farmers and advisors to deliver this project through several avenues:

1. A group of trusted influencers (local farmers and advisors (called the Regional Innovators Group (RIG)) are collaborating with researchers ensuring the project will test decisions with rigour and provide real benefits to farmer decision making.
2. CSIRO and SARDI are reviewing the existing soil moisture probe collection and soil characterisations for coverage and effectiveness in the ability to provide real time landscape scale data on soil moisture status. Gaps in the landscape will be filled and technology updated to ensure a region wide coverage that can provide quality data for on farm decision making. CSIRO and SARDI will calibrate the soil moisture probes and apply geospatial modelling to interpolate the soil probe information at up to 44 locations in combination with other soil property data as a means of generating value from the soil probe data at both paddock and regional scale.
3. CSIRO researchers with the RIG are discussing which decisions may be enhanced using emerging and available digital tools. The top three to five decisions will be prioritised and analysed to determine their economic, production and sustainability levers which will lead to identification of suitable approaches for testing with digital data.
4. SARDI Climate Applications group (Peter Hayman) are working with the RIG to determine the influence of the combination of soil moisture and dynamic weather forecasting on farm decision making. A climate risk analysis will be conducted at key sites on Eyre Peninsula.
5. EPAG Research will establish a set of 24 field trials over the course of the project to validate and demonstrate practices that will take advantage of the new ability to make informed decisions on the soil/water interface across the region. In 2020 work was concentrated on eight focus paddocks aiming to understand how soil moisture varies across a paddock scale, its influence on crop production and possible interventions to improve productivity.
6. Square V (website and app developer) are enhancing the use of imagery, linking information to decision making through setting appropriate trigger points to be displayed on a user-friendly mobile application. The application will provide real time information to farmers and advisers of approaching critical decision points.
7. A comprehensive multi channelled communications and extension plan is being delivered to ensure farmers and advisors receive accurate information and support in decision making in an engaging way.

Yield-adjacent to soil moisture probe
Potential: 5.2 t/ha (W)
Actual: 4.2 t/ha Scepter
Paddock history
2020: Wheat
2019: Wheat
2018: Wheat
2017: Lentils
2016: Wheat
Soil type
Clay loam over clay
Soil test
Comprehensive, variety of testing over 19 points across the paddock to a depth of 110 cm
Yield limiting factors
Boron, calcium carbonate

Location
Pinkawillinie
Paul Schaefer
Buckleboo Farm Improvement Group
Rainfall
Av. Annual: 337 mm
Av. GSR: 227 mm
2020 Total: 372 mm
2020 GSR: 276 mm
Yield-adjacent to soil moisture probe
Potential: 4.4 t/ha (W)
Actual: 3.5 t/ha Scepter
Paddock history
2019: Pasture
2018: Barley
2017: Wheat
2016: Pasture
Soil type
Sandy loam over clay
Soil test
Comprehensive, variety of testing over 19 points across the paddock to a depth of 110 cm
Yield limiting factors
Boron, calcium carbonate

Location
Lock
Andrew Polkinghorne
Rainfall
Av. Annual: 385 mm
Av. GSR: 293 mm
2020 Total: 317 mm
2020 GSR: 251 mm
Yield-adjacent to soil moisture probe
Potential: 3.8 t/ha (W)
Actual: 3.1 t/ha Scepter
Paddock history
2019: Lentils
2018: Wheat
2017: Wheat
2016: Lentils
Soil type
Calcareous sandy loam
Soil test
Comprehensive, variety of testing over 19 points across the paddock to a depth of 110 cm
Yield limiting factors
Calcium carbonate

What happened?

In 2020 work focused on eight focus paddocks. The paddocks were selected to cover a wide geographical area, representing major soil types and to be sown with wheat in 2020. The focus paddocks were extensively soil sampled to determine if differences in crop production could be better understood through improving our knowledge of soil water (and its availability to plants) across the paddock, using the soil moisture probe as a reference point.

Summer rainfall and the ability of the soil to store any out of season rainfall proved to be a large driver of grain yield at the focus sites on upper EP in 2020. Wheat yields adjacent to the soil moisture probe generally yielded 3-3.5 t/ha in focus paddocks at Minnipa, Cootra, Pinkawillinie and Lock in decile 4-5 growing season rainfall. Rainfall recorded at each upper EP site between November 2019 and April 2020 was between 97-125 mm.

Another example of the value of stored soil moisture occurred at the Yeelanna focus paddock. This paddock had a large section cut to hay in 2019 (wheat crop planted over the entire paddock). 2020 wheat yields in the section of paddock that was cut for hay yielded 1.5 t/ha higher than where the crop was grown out to grain. While several other factors (such as a reduction in weed numbers) could have helped drive the 1.5 t/ha yield advantage, sampling found that storing extra moisture accounted for the majority of the extra wheat yield.

Another factor that needs some consideration when using soil moisture probes is how far the information they produce can be extrapolated. Yields varied between 1.4-3.6 t/ha across the landscape in the Minnipa focus paddock, where the variation in grain yield could largely be accounted for by differences in soil type and the ability of the soil to store and make that water available to the plant. Variation in yield wasn't quite that large in the other 2020 focus paddocks on Upper EP but was still considerable. The challenge from here is to work out if there are opportunities to raise yield in the poorer parts of the paddock (possibly through the addition of higher fertiliser rates) or if grain yield is capped at a low level by soil restrictions (leading to possible opportunities to limit spending on these parts of the paddock).

The further challenge is to determine how well these variations in grain yield, their underlying cause, and possibly real time soil water across a landscape can be determined through existing information, such as yield maps, satellite NDVI imagery, soil maps and plant modelling, so that intensive in paddock sampling isn't required. This will be explored in the next two years of this project.

What does this mean?

- The ability to make the best use possible out of rainfall and stored soil moisture continues to be the largest driver of crop and pasture production on Eyre Peninsula.
- Being able to measure what plant available soil moisture is present at any time of the year, not only at soil moisture probe points but across the landscape, offers the potential to improve productivity and limit risk.
- In the next 12 months, tools such as an improved platform (website/app) to display soil moisture probe information will be rolled out.

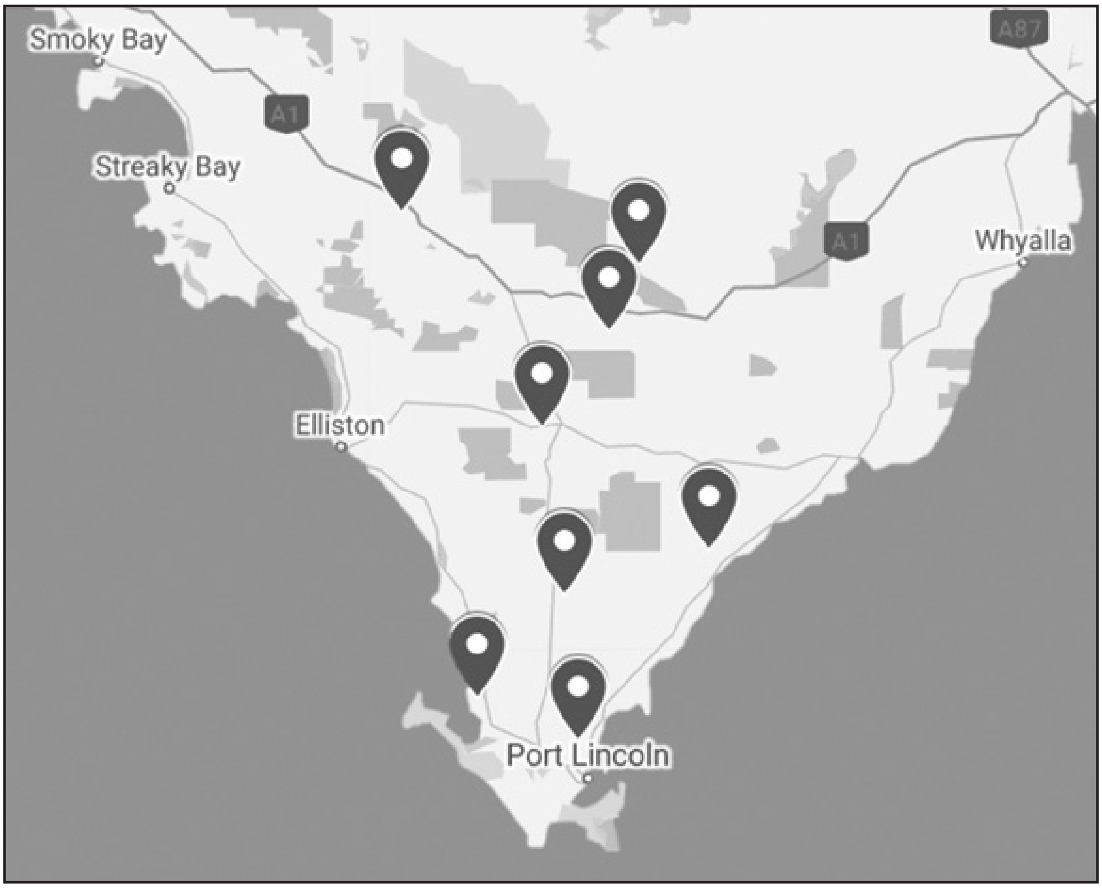

Figure 1. Location of eight focus paddocks in 2020.

Acknowledgements

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SARDI
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Regional Connections

SquareV

SARDI research centres are focusing on latest developments in agricultural technology

John Kelsh

AgTech Extension Officer, SARDI Minnipa Agricultural Centre

Why the new initiative?

In March 2020, the South Australian AgTech Advisory Group initiated an industry-wide survey to better understand the opportunities and challenges facing technology adopters within agriculture. More than 600 people responded and the following barriers to adoption were identified:

1. The value proposition of new technologies is not always clear:
   - Return on Investment (ROI) is not always well defined or attractive.
   - Technologies are not always sufficiently fit-for-purpose.
   - The capital expense is often prohibitive.
2. Lack of knowledge about new technologies:
   - Difficulties keeping up with new technology developments.
   - Farmers want to see the technology working and hear feedback from their peers before investing.
   - Tech companies often don't have the networks to connect with farmers who are willing to adopt early.
3. The deployment of new technologies can be a struggle:
   - Solutions need to be easy to use, seamlessly integrated and reliable.
   - Poor network connectivity limits adoption.
   - Readily available ongoing support and training is required.

In response to these barriers, and to help increase gross state product by an average of 3% per year, the South Australian government released the South Australian AgTech Strategic Plan. This plan facilitates adoption of more efficient production practices to increase on-farm productivity through the deployment of new technologies.

Through a state government partnership with Elders Ltd., the Best-Practice Demonstration Farm (BPDF) at Struan & Kybybolite research centres was established to showcase available technology solutions in the high rainfall zone. Similarly, a partnership with Adelaide University led to the establishment of ThincLab Loxton at the Loxton Research Centre - a business incubator with the opportunity to access high-tech farm and research centre facilities.

Subsequently, expressions of interest are now being sought from technology providers wishing to showcase their AgTech solutions at Struan & Kybybolite, Loxton, Nuriootpa, Turretfield and Minnipa research centres. These products need to meet certain criteria to be eligible, including being readily available to purchase by the South Australian agriculture industry.

What has happened?

Implementation of the AgTech Strategic Plan has already begun, with AgTech solutions being rolled out across the state at various SARDI sites. A range of activities designed to demonstrate how technology adoption can benefit your business will be developed and delivered over the coming seasons - keep an eye on the AIR EP (https://airep.com.au) events calendar for details as they arise.

A two-way digital marketplace will provide farmers with a resource to assist in purchasing decisions by publishing key information on technology solutions and performance in local farming systems, matching producers to the products that fit them best.

So, if you are a primary producer considering a new piece of technology but would like to get a hands-on demonstration and/or independent evaluation get in touch with John Kelsh at Minnipa Ag Centre. or, if you have an innovative AgTech product that you would like us to evaluate and demonstrate to farmers across the state, also please get in touch with John Kelsh.More information can be found on the PIRSA website: https://www.pir.sa.gov.au/primary_industry/agtech/agtech_eoi

Acknowledgements

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SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE

Mixed cover crops for sustainable farming

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

Location
Minnipa Ag Centre, paddock S8
Rainfall
Av. Annual: 324 mm
Av. GSR: 241 mm
2020 Total: 367 mm
2020 GSR: 255 mm
Paddock history
2019: Mixed Cover Crop species trial
2018: Medic pasture
2017: Scepter wheat
Soil type
Red sandy loam
Plot size
12 m x 1.5 m x 4 replicates

Key messages

- **Crop intensive farming systems are running down soil carbon.**
- **Mixed species cover cropping offers a new approach that may address the issue.**
- **The cover crop species grown in 2019 had no influence on the growth, yield and grain quality of the wheat over-sown in 2020.**

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.

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.

This article reports a trial at Minnipa which investigated mixed species cover crops grown over winter and their impact on wheat production the following year.

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 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 is a hay variety 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 sheep.

Mandy's Mix was included because oats and medic produced the most dry matter of the mixes included in a 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 the 2011 - 2014 'Crop Sequences' trial.

Fi's Mix was selected to represent a balance of species from cereals/grasses, legumes and brassicas.

Dry matter cuts were taken on 13 September 2019 at early grain fill as a measure of maximum biomass. The trial was terminated with glyphosate on 2 October 2019 to prevent seed set and further water use.

Table 2. Average yield (t/ha) for wheat sown at Minnipa, 9 November 2020.

Cover crop species	Wheat yield (t/ha)
PM-250 strand medic	2.21
Volga vetch	2.51
Field peas	2.29
Mulgara oats	2.48
Safeguard annual ryegrass	2.43
Cereal rye	2.33
Triticale	2.34
Stingray canola	2.64
Tillage radish	2.18
Narbon beans	2.45
Control (fallow)	1.84
Ten Species Mix	2.58
Jake's Party Mix (oats, vetch & canola)	2.72
Mandy's Mix (oats & medic)	2.66
Fluff's Mix (canola & field peas)	2.34
Fi's Mix (tillage radish, ryegrass, cereal rye, oats, field peas & vetch)	2.68
LSD (P=0.05)	*ns*

On 11 May 2020 the trial was sown to Scepter wheat to evaluate the impact of each cover crop option on crop performance. Plant emergence and crop vigour (estimated by a Green Seeker) were assessed. The wheat was harvested on 9 November 2020 and grain quality measured.

What happened?

In 2019 Mulgara oats produced the most dry matter of all treatments with 2.94 t/ha at early grain fill. Of the mixes Fi's Mix produced the most dry matter with 2.60 t/ha. The PM-250 strand medic produced the lowest amount of dry matter with 0.48 t/ha.

The cover crop species grown in 2019 had no influence on the growth of the wheat over-sown in 2020. The average wheat yield across the trial was 2.42 t/ha. The 2019 cover crop mixture of oats, vetch and canola (Jake's Party Mix) produced the highest wheat yield in 2020 with 2.72 t/ha and the wheat sown over the fallow the lowest with 1.84 t/ha, however no variation in wheat yield was statistically different. Grain quality of the harvested wheat was similar for all treatments.

What does this mean?

Whilst some cover crop species were shown to grow more vigorously and/or produce more biomass than some of the traditional break crop options, this had no influence on the growth, yield nor grain quality of the following wheat crop. Cover crops can potentially improve soil health, nutrient cycling, organic carbon, and soil moisture; decrease weed populations and increase the population of beneficial insects, however these aspects were not monitored in this trial.

Acknowledgements

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Overcoming increasing degradation from mallee seeps on Eyre Peninsula

Chris McDonough[1] and Sarah Voumard[2]

[1]Insight Extension for Agriculture, [2]Landscape Officer, Eyre Peninsula Landscape Board

Key messages

- **New trials demonstrate clear methods for farmers to identify, assess and rehabilitate mallee seeps land back to production.**
- **Farmers must differentiate between localised mallee seeps, highly saline stream systems and dry saline “magnesia” land, before applying management strategies.**
- **Strategic lucerne or Puccinellia establishment and pumping water for farm use are under investigation as management strategies within various farming systems**

Why do the trials?

The number and severity of mallee seeps have been increasing across the EP in recent years due to the removal of deep rooted summer weeds in modern farming systems, and exacerbated by very high rainfall periods such as experienced through 2010/11 and 2016. While wet periods drive the issue of excess water flowing into seep prone areas, it is often the drier periods with high evaporation that accelerate the capillary rise of salts and concentrate them in the surface soil layers, resulting in large, bare salt-scalded patches.

Trials in the SA Mallee have shown that seep areas can be restored to production if the flow of water from surrounding deep sands can be intercepted and utilised, and soil cover is re-established on bare scalded or water-logged areas.

This article summarises methods used to assess seeps and manage seeps. It describes the establishment of multiple demonstration sites across EP to improve our understanding of how seeps operate locally and which management strategies can be most effective.

How was it done?

Five sites were established in 2020 with consultant Chris McDonough, EP Landscape Board and AIR EP officers working with local farmers at Kimba, Lock and Rudall. The sites ranged from large, well established salt scalds to areas only very recently beginning to bare out. These areas were often surrounded by crop growing twice as well as the remainder of the paddock due to increased water availability.

At each site the area was first assessed to determine the:

1. **Recharge Zones** (where the water is coming from). This was achieved by looking for adjacent deep sand areas with poor water holding capacity, compaction or limited plant growth, and evaluating whether this is simply a direct flow out of a single sandhill, or part of a larger catchment system. NDVI imagery proved very useful for this purpose (see guide of how to do this at http://www.malleeseeps.msfp.org.au/).
2. **Discharge Zones** (surface areas being currently affected as well as the areas under future threat). An initial visual assessment noting types of any vegetation, surface saline crystals and increases in surrounding crop growth was made. Soil samples were taken from surface and deeper soil layers to determine salinity levels. Finding the depth and quality of the perched water table was vitally important. This was achieved at each site using a post hole digger and/or soil auger. The areas under threat of further degradation were also quantified using NDVI images of the site, as surrounding areas stay greener for longer where a perched water table exists.
3. **Potential Interception Zones** (where strategic management could be effectively applied to reduce water flows). These were determined after reviewing the information gained in steps 1 and 2 and after discussion with the farmers. In some cases a further auger hole was dug to assess the depth and quality of the perched water table in these zones.

What happened and what was done?

Kimba. Lucerne over sandhill to bring recent seep scalds back to cropping in mixed farming.

This site was established on the farm of Tola Ag near Kimba in May 2020. There were two bare scalds on either side of a sand hill that had suffered wind erosion following dry conditions early in the season. The north eastern scald was 0.3 ha in area with a perched water table at 55 cm below the surface and wet clay to 160 cm, underlain with a drier impervious clay layer. Soil salinity was slight at the surface (0.33 dS/m) but increased to 0.58 dS/m at 20-30 cm, and pH (water) increased from 9.8 to 10.2.

As livestock are an important part of the Tola Ag farming system, and this sandhill has presented many challenges for achieving consistent yields and has high susceptibility to wind erosion, it was decided to establish lucerne over most of this hill (approx. 1000 m x 50 m). This will provide valuable fodder and reduce water flow into the growing scald area. On the scald, *Puccinellia*, a salt tolerant grass, will be established to provide permanent soil cover and stop surface salt accumulation. After a few years it is hoped that the scalded area can be returned to normal cropping.

The lucerne was sown in July and suffered erosion due to strong winds and limited soil protection, so while there are patches of reasonable establishment, Tola Ag will look to re-establish the lucerne in 2021. A successful summer crop mix planted in October 2020 over the sides of this sandhill helped to utilise the spring and summer rainfall. *Puccinellia* was spread with a baitlayer in July 2020 with reasonable plant densities at establishment. This is expected to thicken up across the scald this season.

This site has piezometers placed within the scald and 30 m up the slope within the lucerne area, along with a soil moisture probe. All have continuous data logging to monitor the success of the lucerne in reducing the height of the water table. Ongoing soil measurements will be taken within the scald to estimate when the site may be restored to cropping, or whether an extra sand layer may be required to ensure successful crop establishment, once the extra flow of recharge water into the site has been halted.

On the south western side of the sandhill, the surface soil was a heavier clay loam, but no perched water table was detected. This scald did not have high soil salinity or pH at the surface or in deeper soil layers. It is thought that poor growth on this patch and other clay areas in the paddock, is not driven by a perched water table, but is more indicative of dry saline land often referred to as “magnesia patches”. So this site is not likely to be impacted by the strategic placement of deep rooted perennial vegetation to reduce water flows.

Kimba 2. Establish sump to pump out perched water for farm use and rehabilitate seep scald

This site is also at Tola Ag, with a 1 ha bare scald within a 5 ha area identified from NDVI images as being under threat of degradation (Figure 1). The water flows into this area are mainly from the north-west, through a larger basin of sandy catchment which appears to channel water into this seep area. The scald contained saturated sand to a depth of around 2.5 m filling right up to the surface after rainfall events. Surface soil salinity was at a level where crop growth might be impacted (0.5 dS/m). Fortunately, water quality is still reasonable at 2.8 dS/m (1700 ppm) and is suitable for stock water and farm use.

It was decided to install a lined sump filled with stone (Figure 2) with a solar pump to be attached in 2021 to move water to an existing tank for stock water and possible other farm uses. This sump will soon be covered, to avoid salinity increasing in the open dam water and becoming unsuitable for use. It is hoped that the removal of water will be enough to lower the perched water table, stop the scald spread and in time restore the scald back to cropping. *Puccinellia* was successfully established over much of the bare scald area to halt surface salt accumulation and help restore the soil back to conditions suitable for cropping.

Piezometers have been set at 20 m, 40 m and 80 m away from the sump with continuous data-loggers, as well as one in the sump itself. Rates of water removal will also be recorded which should lead to an excellent understanding as to how quickly water can be removed, how quickly it will refill, and how wide the impact on the water table will be. If successful, this could provide an innovative and effective method of not only draining seep areas but also enhancing farm water supplies.

Kimba south. Using NDVI to identify areas for lucerne to stop water flows through linked, developing seeps

This site is on Jericho’s farm, south of Kimba and is a large white saline scald that has been farmed around for many years but is expanding to the west. Further west is a recently formed but rapidly expanding scald area. Soil from the large scald is highly saline at 1.2-1.4 dS/m in the top 30 cm, with a pH (water) of 10.2. The salinity of the perched water in the centre of the scald measured 15 dS/m (9000 ppm), while edge areas were very shallow and less saline (3-6 dS/m).

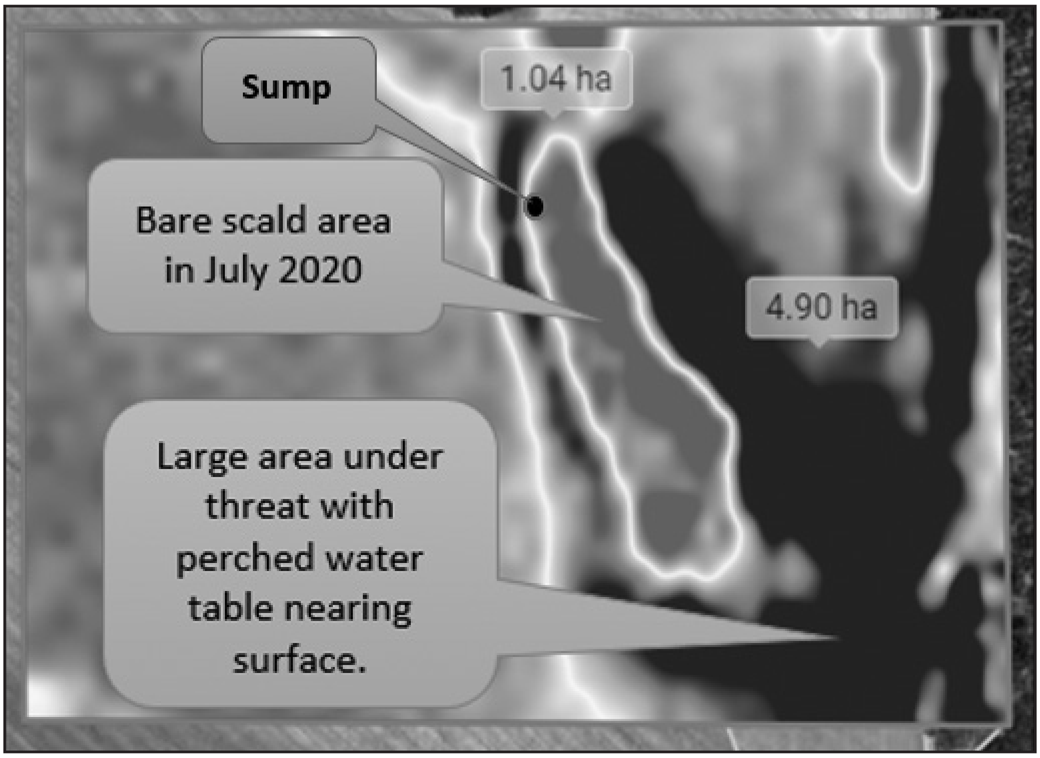

Figure 1. NDVI image of Kimba 2 scald, threatened area (dark).

Figure 2. Sump under construction at Kimba 2.

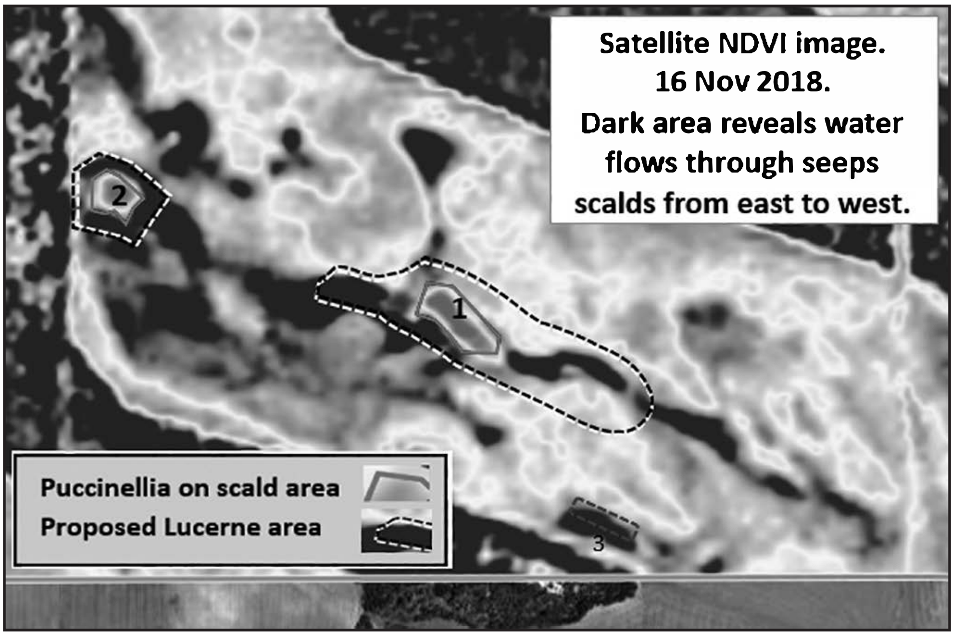

Figure 3. Satellite NDVI image at Kimba south showing water flow links between seeps and targeted Lucerne.

Figure 4. **Puccinellia** ***growing well on salt scald near piezometer at Kimba south.***

The second more recent seep (first observed in 2016) has toxic levels of salinity at the soil surface (0.8 dS/m) but very low salinity below this. Salinity of the perched water table at 30 cm was 4.5 dS/m (2700 ppm). Thirty metres from the scald edge in the adjacent sand hill there is a water table at 220 cm with salinity of 3.3 dS/m (2000 ppm).

By assessing the landscape along with the NDVI satellite images (Figure 3), it became clear that the 2 sites were linked, and there was a strong potential for them to expand towards each other. While recharge was coming from the sandy rises on the northern side, there are clear indications of water accumulating and flowing through the landscape from east to west through each seep. As the water table salinities were well within the lucerne tolerance levels, it was decided to establish lucerne along this zone and around each seep. This should be highly productive and limit the flow of water into these expanding seep scald areas (as shown in Figure 3). The Jericho's have sheep and were happy to utilise lucerne within this paddock. *Puccinellia* was also established on the scald areas by planting seedlings, throwing seed out by hand and machine sowing, with all methods providing reasonable results.

This site has 2 piezometers set in the lower and western seep, along with a soil moisture probe to monitor the impact from the lucerne. It is hoped that this seep will be restored to cropping once the water flow is stopped. Some sand amelioration may also be done. A good outcome for the highly saline main seep would be complete coverage with salt tolerant pasture and stopping the seep from spreading, then seeing what is possible at a later date.

Lock. Using a narrow Lucerne strip and sand amelioration to stop an early stage seep.

This site on Glover's focusses on 2 important seep management strategies. The first strategy is recognising and taking action whilst the area is still growing significantly more biomass due to the presence of the rising perched water table and before it becomes a major salt scald. The second strategy is sowing a narrow lucerne strip to lower the water table. Lucerne should lower the water table, despite being in a continuous cropping paddock, because it will also use water during summer. This should reverse the scalding trend and protect a far greater area of highly productive land.

This site has been set up with piezometers, a moisture probe and a rain gauge, ready for the 20-30 m wide lucerne strip to be established in 2021. The landholder will undertake some sandhill amelioration to improve root penetration, soil fertility and moisture retention for crop use. Previous mallee trials have shown this can greatly increase in-season water use and crop production in the recharge zone, but it is the deep rooted perennials in the interception zone that will have the largest and most likely impacts on mallee seep recovery.

Rudall. Aiming for rapid restoration of 4 year old seep scald back to cropping.

This site on the Wiess property has gone from a small waterlogged patch in late 2016 to a 0.6 ha bare scald in 2020. The water table is at 1 m from the surface, with salinity at 3.5-4.3 dS/m (2200-3000 ppm). The top half of the paddock is a gentle rise of coarse sand with poor water holding capacity. The scalded area has mid-range salinity in the surface soil (0.55 dS/m). This suggests that if the flow of water can be stopped with a lucerne strip between the sand and the scald and salt tolerant grass can be established to provide year round cover, then this site may return to cropping soon. The salt tolerant grass will reduce evaporation and allow leaching of surface salts in any future seasons which have high rainfall events. A return to cropping would depend on a consistent lowering of the water table below 2 m, and a reduction in surface soil salinity to around 0.2 dS/m. Adding sand to the surface may also be considered to accelerate topsoil rehabilitation.

What does this mean for farmers?

It is important farmers understand the 3 distinct types of saline land issues on EP (often appearing on the same farm) as they have different causes and management strategies:

1. Mallee seeps, driven by localised perched water tables, are able to be managed with high water use strategies as described within this article.
2. Highly saline stream soaks (water table induced salinity) that are driven by rising water tables associated with river systems of regional catchments. These need major district works to improve them.
3. Dry saline land or "magnesia patches" are often found on heavy clay areas and shallow stony ground, exacerbated by dry periods, but not driven by perched water tables. They can be improved through addition of organic matter. If one is located near a sandy rise and you are unsure if it is a mallee seep, it is worth auguring a posthole to 1-2 m. If you hit a sloppy layer of clay (perched water table), then this excess water should become your focus of remedial management.

Famers and consultants are advised to follow a similar method of identifying the key zones within their seep landscape. Management strategies centre on stopping the flow of water into the seep area and establishing cover over scalded areas. Digging holes to find the presence, depth and quality of perched water is critical to making informed and effective management decisions, and utilising NDVI imagery (follow the MSF guide) can guide where strategic action is most needed.

Establishing salt tolerant grasses on scalds is a vital step to break the spread of degradation. Lucerne strips have proven to lower water tables in the SA Mallee and can fit within farming systems to help bring land back to production. Mallee Seeps can be turned around, and early recognition and action is more effective and easier than just watching them grow.

If any farmer is interested to learn more about seep issues, contact the EP Landscape Board on 8688 3111 or Amy Wright 0467 004 555, AIR EP Regional Agricultural Landcare Facilitator.

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Australian Government

LANDSCAPE SOUTH AUSTRALIA EYRE PENINSULA

Section Editor:
Rhiannon Schilling
SARDI Waite

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

Nigel Wilhelm[1], Mel Fraser[2], David Davenport[3]
[1]SARDI Waite, [2]Rural Solutions SA Struan, [3]Davenport Soil Consulting

Location
Brooker, Lower EP
Challinger family
Rainfall
Av. Annual: 399 mm
Av. GSR: 315 mm
2019 Total: 320 mm
2019 GSR: 294 mm
2020 Total: 423 mm
2020 GSR: 330 mm
Yield
2019 Potential: Wheat - 3.7 t/ha
2019 Actual: 3.8 t/ha
2020 Potential: Canola - 3.3 t/ha
2020 Actual: 1.2 t/ha (in the best part of the trial).
Paddock History
2019: Wheat
2018: Wheat
Soil type
White siliceous deep sand
Soil test
Low levels of organic matter and K, Cu reserves. Very strong repellency.
Plot size
20 m x 6 rows x 1-3 replicates
Trial design
Partially randomised complete block
Yield limiting factors
Ryegrass (moderate), repellency (severe in un-spaded), low fertility (severe)

Key messages

- **Incorporating high rates of lucerne pellets into a poorly performing siliceous sand by spading caused a substantial boost in crop production over the first 2 years.**
- **A very cheap source of N-rich organic matter and mode of incorporation will be necessary before this approach will be profitable.**
- **Incorporating fertiliser which supplied N, P, K and S performed as well as an equivalent rate of incorporated lucerne for both crops.**

Why do the trial?

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

See the next article in this EP Farming Systems Summary for more details of the Murlong trial, “Ameliorating a deep repellent sand at Murlong increased vetch performance substantially in 2020”, p.70.

The aim of the trial reported here is to map the response of crops to increasing rates of incorporated lucerne pellets to better inform economic evaluation of the approach.

How was it done?

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

The trial was set up in 2019 by incorporating multiple rates of lucerne pellets with a spader prior to seeding. Lucerne pellets were spread evenly across the surface of 20 x 2 m wide plots prior to rotary spading to 30 cm in early May 2019. Nine rates of lucerne pellets were used ranging from 0 to 20 t/ha. There was also an unspaded treatment which received no lucerne (unspaded control) and a further treatment which had fertiliser broadcast evenly over the plot area prior to spading to supply the same amounts of N, P, K and S as in 4 t/ha of lucerne.

Potassium was surface applied in both years to half of every plot, in a randomised split plot design, to additionally test crop responses to applied K. In 2019, K was supplied mid-season and in 2020 prior to seeding, both as 100 kg/ha of muriate of potash.

Six of the main treatments were replicated three times to allow analysis with standard ANOVA models (both controls plus the 4, 8 and 15 t/ha of lucerne and fertiliser only treatments). Standard curve fitting models were used to investigate the effect of lucerne rate on crop production using all sub-plots.

Starter N and P fertiliser were used for all treatments at sowing to simulate commercial practice but extra N and P were applied to nil and low lucerne treatments in both years. A similar approach was taken for midseason applications of N; applications in both years as sulphate of ammonia were reduced as lucerne rate increased in recognition that high rates of lucerne also supply high rates of N.

Razor CL wheat was seeded on 11 May 2019 and the plots were re-sown with 44T02 TT canola on 20 May 2020.

Establishment, growth, grain yield and quality were assessed in both years.

What happened?

Crop establishment in both seasons was poor, especially in unspaded plots and in low lucerne rate treatments. For wheat in 2019, crop establishment only averaged 9 plants/m^2 in the unspaded control, increasing to 29 plants/m^2 with spading and varied between 68 and 93 plants/m^2 where lucerne had been incorporated. Incorporating fertiliser also boosted plant numbers compared to spading without lucerne. A similar pattern in establishment occurred with canola in 2020; only 9 plants/m^2 in the unspaded control to a range of 24-45 plants/m^2 with high rates of incorporated lucerne. However, in 2020, the incorporated fertiliser treatment had similar plant numbers to the spaded control. Water repellency has contributed to poor crop establishment but we suspect other factors have been at play as well, such as K deficiency and herbicide residues.

In 2020, severe wind erosion prevented any crop establishment in the first 4 plots on the western side of the trial; these plots have not been included in analyses of treatment effects. There was also a strong increase in crop growth in 2020 from west to east, regardless of treatment, so canola grain yields were adjusted for plot position before lines of best fit were estimated for response to increasing lucerne rates.

Ryegrass was severe in both years and competed heavily with the wheat crop in 2019 except in treatments where high rates of lucerne had been incorporated. In 2020, ryegrass was largely controlled in all plots by the middle of the season.

Growth of wheat and canola throughout each season was stronger with increasing rates of incorporated lucerne and grain yields followed a similar trend. Figure 1 shows that grain yield for both crops increased as the rate of lucerne increased. Wheat in 2019 only showed some sign of levelling out as rates exceeded 15 t/ha, but for canola, there was little increase in yields above 8 t/ha of lucerne, applied the year before. These increases in crop performance with incorporated lucerne occurred despite the treatments receiving lower rates of N and P over both seasons.

In 2019, wheat showed no clear response to K despite low reserves in the soil which may be due to wheat being tolerant to low soil K or because K was applied too late in the season to be fully effective. In 2020, fresh K was added to the same subplots prior to seeding and the plots were seeded with a more susceptible crop (canola). Grain yields increased on average by 0.16 t/ha with added K in 2020, regardless of lucerne rate.

The effect of lucerne on canola performance was analysed in the absence of added K because K is not widely used on lower EP and so better reflects the impact of incorporated lucerne in that environment.

The best fit for the impact of incorporated lucerne on the combined yields of wheat and canola, without applied K, was a quadratic curve described in the equation below:

$$Y = a + bx + cx^2 \text{ where,}$$

Y = combined yield, t/ha

a = 0.73

b = 0.31

c = -0.0043

This means that for every tonne increase in incorporated lucerne over the range of 0 - 5 t/ha, there was an increase in combined grain yield over the 2 seasons of approximately 0.25 t/ha.

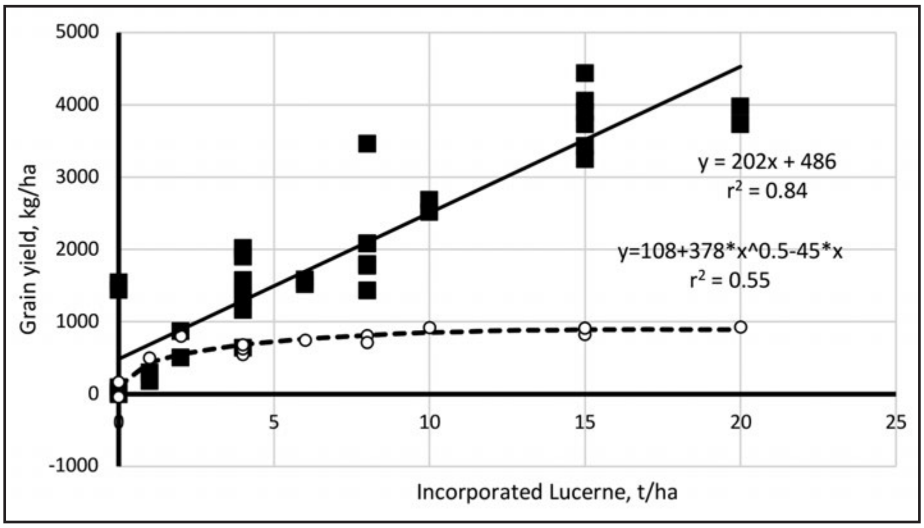

Figure 1. Increasing rates of incorporated lucerne increased grain yield of wheat in 2019 and in canola in 2020 at Brooker, lower EP. Solid squares are wheat in 2019 (all sub-plots used because there was no clear K response), hollow circles are canola in 2020 (only no K sub plots used because there was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

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

Treatment	Wheat yield (t/ha)	Canola yield (t/ha)
Unspaded Control	0.03	0.07
Spaded control	0.50	0.19
Incorporated fertiliser[1]	1.44	0.31
Incorporated lucerne at 4 t/ha	1.33	0.51
Incorporated lucerne at 15 t/ha	3.90	0.73
LSD (P=0.05)	*0.81*	*0.35*

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

For the approach to break even, the cost of the lucerne (or another source of OM which provided the same benefits) would need to be 25% of the $ value of the extra yield gained over the 2 years, ignoring the costs of incorporation and the savings in fertiliser. However, this comparison will change if additional yield gains occur in subsequent years.

Incorporating fertiliser which supplied the same amounts of N, P, K and S as 4 t/ha of lucerne produced similar crop benefits in both years (see Table 1). Neither treatment produced crops near the levels achieved with a much higher rate of incorporated lucerne. However, due to the much lower cost of incorporated fertiliser compared to lucerne, it is a more financially attractive option at this stage. This may change if the benefits of lucerne persist longer than the fertiliser.

What does this mean?

- Incorporated lucerne resulted in substantially increased grain yields for at least 2 years after application into a poorly performing siliceous sand at Brooker on the lower EP. An important component of this increase was that both the mode of incorporation (rotary spading) and lucerne itself, improved crop establishment on this severely repellent sand.
- This trial has shown that the benefits of incorporated lucerne increase with rate of application over a wide range. However, this rate of increase in yield is low compared to the cost of lucerne.
- The rates of incorporated lucerne used in many trials in recent research (10 - 20 t/ha) have been in the upper range of effectiveness. This suggests that if lower rates of lucerne had been used in those trials, benefits to crop performance may have been smaller.
- Based on the results of this trial so far, a very cheap source of OM which provides the same benefits of lucerne to crop performance needs to be found before this approach will be cost effective.
- The trial will be managed for one more season to monitor the persistence of treatments into a third crop.

Acknowledgements

Farmer Cooperator: Challinger family.

This work is funded under the GRDC project “Increasing production on Sandy Soils in low and medium rainfall areas of the Southern region” (CSP00203); a collaboration between the CSIRO, the University of South Australia, the South Australian Government Department of Primary Industries and Regions, Mallee Sustainable Farming Inc., Frontier Farming Systems and Trengove Consulting.

Ameliorating a deep repellent sand at Murlong in 2018 increased vetch performance in 2020

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

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Location
Murlong
Mark Siviour and family
Rainfall
Av. Annual: 332 mm
Av. GSR: 248 mm
2020 Total: 231 mm
2020 GSR: 200 mm
Yield
Potential: Vetch - 1.1 t/ha (French/Schultz based on the pea model)
Actual: 0.8 t/ha in best treatments
Paddock History
2019: Barley
2018: Wheat
2017: Barley
Soil type
Deep white siliceous sand over clay
Soil test
Low fertility throughout for P, N and trace elements. Severely water repellent and compacted.
Plot size
25 m x 6 row x 4 replicates
Trial design
Completely randomised block
Yield limiting factors
Poor start and winter (moderate), repellency (moderate)

Key messages

- **Woolly pod vetch performed very well on a water repellent sand.**
- **Physical intervention has improved yields in all three crops grown so far.**
- **Incorporated organic and nutrient amendments will have to be very cheap to pay their way.**

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 2019 for more details of results from this trial in 2019 ("Ameliorating a deep repellent sand at Murlong in 2018 increased barley performance in 2019," p 71). This article summarises the impact of treatments on the third crop post amelioration and on the accumulated benefits in grain yields over the three years.

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.

Crop performance in 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). All amelioration treatments were applied in 2018 and have not been re-applied.

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

Data was analysed using standard ANOVA models in Statistix 8.

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

19 April 2018	Amendments applied	Organic Matter: Lucerne pellets at 5 t/ha Nutrient Package: nutrients applied to match lucerne (N 167, P 14, K 105, S 12, Cu 0.03, Zn 17, Mn 0.18 kg/ha). NPKS applied as granular and trace elements as fluids. Treatments were applied evenly across the surface on spaded plots or in bands to align with ripper tine spacings, immediately prior to spading and ripping.
	Soil treatments imposed	• Spading to 30 cm at 5 km/hr • Ripped: 4 times at 64 cm spacings, with inclusion plates positioned 10 cm below the soil surface and operated at 5 km/hr. • Shallow ripped (corresponding to the depth of spading) to 30 cm with 20 cm tall inclusion plates. • Deep ripped to 41 cm with 30 cm tall inclusion plates.
20 May 2020	Sowing, inter-row on 2019 crop rows	50 kg/ha RM4 vetch at 25.4 cm row spacing + MAP at 60 kg/ha (all treatments).

What happened?

In 2020, vetch was seeded into a completely dry seedbed but 5 mm of rain fell that night. The vetch established well on physically amended plots despite the poor conditions, averaging 45 plants/m^2 in spaded treatments, whereas only 26 plants/m^2 were present in the untreated controls at that time. Ripping resulted in plant numbers intermediate between the controls and spading. Amendments had no impact on vetch establishment, unlike 2018 when they were beneficial in the first crop of wheat. In all years, severe water repellence resulted in low plant numbers where there was no physical soil disturbance.

RM4 is a woolly pod vetch and this type of vetch has a good reputation amongst eastern EP growers for performing well on poor sands. RM4 did a very good job in 2020 despite below average rainfall in the period May to August (124 mm versus the long-term average of 165 mm) and put on good growth in spring as a result of very high rainfall in October (50 mm above average).

At flowering, the highest vetch dry matter (DM) of 2.53 t/ha occurred with spading, which is a reasonable estimate of a likely hay cut. Deep ripping resulted in 2.09 t/ha of DM while shallow ripping only produced 1.50 t/ha which was still much better than the 0.97 t/ha of DM produced in the untreated soil. Organic and nutrient amendments had no impact on DM at flowering.

Grain production of vetch in 2020 was low compared to DM at flowering with spading only resulting in 0.77 t/ha. However, this was still substantially better than yields in unamended soils which only averaged 0.19 t/ha. Ripping resulted in grain yields intermediate between controls and spading at approximately 0.50 t/ha. Amendments had no impact.

The cumulative impact of amelioration strategies on three years of crop yields is summarised in Table 2. Any physical disturbance resulted in much better production overall, partly because the performance in the unamended soil was very poor in every year. Spading produced the highest grain totals but deep ripping is proving a competitive alternative given its cheaper implementation cost and lower erosion risk, with grain yield benefits ranging from 2.2 to 2.8 t/ha. Shallow ripping resulted in an average 1 t/ha lower grain totals than deep ripping, which was still much better than no disturbance (cumulative 1.4 t/ha). Both amendments only increased grain totals with the two most vigorous disturbance options and almost all these benefits occurred in the first crop.

What does this mean?

Physical interventions on this deep, water repellent sand at Murlong continue to deliver large production responses in crop biomass and grain yield. Three consecutive crops have now been monitored. Even with deep ripping typically costing between $50 and $80/ha and spading at least double that cost, these physical interventions have made a good return on their investment. There are also good prospects for benefits continuing beyond the third season.

Spading has proven to be the most effective type of disturbance so far from a grain yield perspective but ripping to 40 cm with inclusion plates and wide rows (60 cm) is proving very competitive in terms of economic return. Ripping has the additional benefit that it does not leave the soil as vulnerable to wind erosion as deep soil mixing and inversion can. Increased erosion risk is a critical factor to consider when physically disturbing deep fragile sandy soils.

Table 2. Cumulative grain yield of crops (t/ha) with various amelioration strategies at Murlong from 2018 to 2020.

Physical intervention	Amendment	Wheat in 2018	Barley in 2019	Vetch in 2020	Cumulative grain yield
None	None	0.48	0.72	0.19	**1.38**
Shallow Ripping	None	0.99	1.33	0.47	**2.79**
	Nutrients	1.20	1.37	0.52	**3.08**
	Lucerne pellets	1.19	1.25	0.48	**2.92**
Deep Ripping	None	1.41	1.62	0.56	**3.59**
	Nutrients	1.90	1.52	0.49	**3.91**
	Lucerne pellets	1.80	1.74	0.66	**4.20**
Spading	None	1.90	1.64	0.76	**4.30**
	Nutrients	3.22	1.83	0.72	**5.76**
	Lucerne pellets	3.12	1.81	0.84	**5.77**
LSD (P=0.05)					*0.55*

Physical disturbance has improved early crop establishment at Murlong by diluting and disturbing surface repellent layers, leading to better crop biomass and grain production; spading is more effective than ripping in this aspect. However, seeder strategy trials conducted by the University of SA (see their articles in the previous 2 editions of 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 without major physical disturbance.

A combination of those approaches with deep ripping could improve outcomes even further.

While incorporating lucerne hay or a multi-nutrient fertiliser package increased crop performance in 2018, the cost of these amendments will have to come down substantially to be economically attractive. They have not produced any benefits to grain yields in the second two crops.

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

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Constraints to barley production highlighted in a very calcareous grey sand at Poochera

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Location
Poochera
Gosling family
Rainfall
Av. Annual: 326 mm
Av. GSR: 247 mm
2020 Total: 328 mm
2020 GSR: 214 mm
Yield
Potential: Barley - 2.5 t/ha
Actual: 1.4 t/ha in best treatment.
Paddock History
2019: Volunteer pasture
2018: Cereal
Soil type
Grey highly calcareous sandy loam
Soil test
Notable features: very high pH and carbonate throughout profile, poor P reserves, high N reserves, moderate boron toxicity and salinity lower in the profile.
Plot size
50 m x 6 row x 3 replicates
Trial design
Randomised complete block
Yield limiting factors
Delayed sowing (moderate), dry winter (moderate), rhizoctonia (severe in non-ripped treatments)

Key messages

- **Barley on a grey highly calcareous sand grew poorly with severe rhizoctonia unless deep ripping had occurred prior to seeding.**
- **Packages to reduce rhizoctonia and to cause fertiliser toxicity in seed rows did not reduce rhizoctonia nor result in obvious toxicity.**
- **Cropping on grey highly calcareous sands continues to be a challenge but some opportunities were identified in this trial. These and other treatments are to be investigated in a new research initiative funded by GRDC and the Soils CRC.**

Why do the trial?

A trial was conducted in 2020 to showcase a new research initiative aiming to produce more profitable crops on highly calcareous soils by improving early vigour and overcoming soil constraints. The initiative will run for the next three years and is funded by GRDC and the CRC for High Performance Soils. It involves teams from SARDI, Rural Solutions SA, CSIRO and NSW DPI with support from AIR EP and MacKillop Farm Management Group.

The 2020 trial was conducted on the Gosling family farm at Poochera and included treatments addressing some of the major issues facing cropping on highly calcareous sands of the upper EP.

How was it done?

Seven treatments were applied in 50 x 4 m plots in a randomised complete block design:

- Control - typical management strategy for the district
- Anti-rhizoctonia - high rates of MAP and SOA with fungicides and extra trace elements at seeding
- Fertiliser toxicity - high rate of DAP with the seed
- Deep ripping with inclusion plates (D.Rip + IP)
- Deep rip + IP with animal manure (D.Rip + IP + Manure)
- Deep rip + IP with biochar enriched with nutrients (D.Rip+IP + Biochar).

Deep ripping treatments were imposed to 40 cm in early May using a Yeoman's plough on 64 cm spacings with inclusion plates. The animal manure (Neutrog pellets at 10 t/ha) and nutrient enriched biochar (at 1.5 t/ha) were applied in bands on the soil surface to align with the ripper tines to aid incorporation in the ripping pass.

The trial was treated with knockdown and soil-active herbicides immediately prior to seeding and subsequent weeds controlled with an Intervix® application mid-season. Spartacus CL barley was seeded in all plots at 60 kg/ha with a DBS seeder using ribbon seeding boots on 19 May 2020. All plots received banded liquid trace elements at seeding of 2 kg Zn, 3 kg Mn and 1 kg Cu/ha as sulphates, except for the anti-rhizoctonia treatment which received a double rate.

The fertiliser package for the control and all deep ripping treatments was the same; 25 kg DAP/ha with the seed and 50 kg DAP/ha plus 36 kg urea/ha banded under the seed rows. The fertiliser toxicity treatment received a package of fertilisers at seeding that was designed to reduce germination and establishment; 75 kg DAP/ha plus 36 kg urea/ha with the seed.

The anti-rhizoctonia treatment received 45 kg MAP/ha plus 4 kg SOA/ha with the seed and 68 kg MAP/ha plus 137 kg SOA/ha banded under the seed rows. Seed was treated with Vibrance® at 360 mL/100 kg seed and Uniform® was added to the trace element mix banded under the seed rows at 300 mL/ha.

Crop establishment, rhizoctonia infection, crop growth during the season and grain yield plus quality were monitored during the season.

Data from quantitative assessments were analysed with ANOVA models using Statistix 8.

What happened?

Seedbed conditions at seeding were marginal for germination but emergence occurred slowly and evenly despite seed being placed at 40 mm below the surface in ripped treatments, which was twice as deep as in non-ripped treatments. Establishment averaged 120 plants/m^2 with little impact of treatments.

Despite the dry seeding conditions, the fertiliser toxicity treatment had no impact on emergence or establishment. Using ribbon seeding boots which split the fertiliser into two seed rows per tine may have reduced the risk of fertiliser toxicity which is common in this soil type.

Ripping (regardless of amendment) increased dry matter of shoots at late tillering by nearly 50% compared to all non-ripped treatments (Table 1). By flowering, shoot dry matter was still 40% higher than without ripping but the highest shoot weights were in ripping with biochar. All non-ripped treatments had similar shoot weights.

The barley crop struggled to finish and all non-ripped treatments yielded similarly but poorly, only 1 t/ha regardless of treatment (Table 1). Deep ripping increased yields by 30% but amendments had no impact. Grain proteins averaged nearly 18% with deep ripping and over 16% without ripping (Table 1).

Rhizoctonia patches appeared early in crop growth in all non-ripped treatments but did not appear in any ripped treatments which remained even and vigorous for the whole season (Table 2). Rhizoctonia infection on seminal roots at late tillering decreased from an average severity score of 3.1 in non-ripped treatments to 2.3 with ripping (Table 2). The percentage of infected crown roots in ripped treatments averaged 49% but was 65% in non-ripped treatments (Table 2). The anti-rhizoctonia treatment had no impact on rhizoctonia or crop growth.

What does this mean?

The growth of barley in this trial showcased many of the issues that farmers face when cropping on highly calcareous sands and which will be investigated by the new initiative funded by GRDC and the CRC for High Performance soils.

Rhizoctonia was severe in all treatments not ripped and the anti-rhizoctonia package which has shown good benefits in other environments had no impact in this trial. While there were issues with the application of Uniform® which would have reduced its effectiveness, Vibrance® plus extra fertiliser should have suppressed the disease but did not in this trial. Ripping prior to seeding reduced rhizoctonia infection and no patches developed in these treatments which was an unexpected bonus from this strategy.

Table 1. Effect of treatments on growth of barley at Poochera in 2020.

Treatment	**Shoot dry weight at tillering (t/ha)**	**Shoot dry weight at flowering (t/ha)**	**Grain yield (t/ha)**	**Grain protein (%)**
Control	0.38	2.55	1.0	16.1
Anti-Rhizo	0.37	2.32	1.0	16.7
Fert toxicity	0.29	2.13	1.1	16.7
D.Rip+IP	0.47	3.03	1.3	17.5
D.Rip+IP + Manure	0.49	3.04	1.3	17.6
D.Rip+IP + Biochar	0.56	3.80	1.4	18.1
LSD (P=0.05)	*0.09*	*0.67*	*0.2*	*0.8*
Treatments clustered into two groups				
Non ripped	0.35	2.33	1.0	16.5
Ripped	0.51	3.29	1.3	17.7
LSD (P=0.05)	*0.06*	*0.46*	*0.1*	*0.7*

Table 2. Effect of treatments on rhizoctonia in barley at late tillering, Poochera 2020.

Treatment	Area of patch (% of the plot)	Disease score on seminal roots[1]	Crown roots infected (%)
Control	25	3.1	64
Anti-Rhizo	27	3.1	63
Fert toxicity	27	3.1	67
D.Rip+IP	0	2.3	51
D.Rip+IP + Manure	0	2.1	46
D.Rip+IP + Biochar	0	2.6	50
LSD (P=0.05)	*19*	*0.7*	*15*
Treatments clustered into two groups			
Non ripped	26	3.1	65
Ripped	0	2.3	49
LSD (P=0.05)	*9*	*0.4*	*7*

[1]0 = healthy and 5 = severe disease

Many previous attempts with deep ripping on highly calcareous sands have produced no benefits to crop production and often have had negative impacts. However, in this trial deep ripping caused a substantial boost to barley performance. It seems likely the use of inclusion plates during the ripping operation, which increases the amount of mixing of topsoil into the subsoil, improved the impact of deep ripping. Adding nutrient-enriched biochar with the deep ripping operation improved the vigour of barley during the season but did not result in any major gains in grain yield.

Incorporating animal manure is a technique which has produced spectacular increases in crop performance in other environments but had no impact in this trial. The field of incorporating organic and nutrient amendments into the subsoils of highly calcareous sands is largely uncharted territory but will be investigated in this new initiative.

Barley in non-ripped treatments showed the slow and weak growth typical of crops on these soils and characteristic of P and N deficiencies. However, increasing the rate of fertilisers and changing to more acidic formulations in the anti-rhizoctonia treatment did not increase crop vigour. This is another common issue with cropping on these soils - improving the nutrition of the crop is difficult.

The fertiliser toxicity treatment was supposed to show the vulnerability of crops grown on highly calcareous sands to toxicity from fertilisers in the seed row. However, no reduction in crop establishment occurred which might have been partly due to the use of ribbon seeding boots which split the fertiliser into two bands with the seed. The lack of damage was still a surprise given the very marginal moisture conditions at seeding.

The lack of impacts from the anti-rhizoctonia and fertiliser toxicity treatments but strong benefits from deep ripping highlight the uncertainty and difficulty of managing crops on highly calcareous sands and the challenges which the new research initiative faces, but also the opportunities for improved crop production.

Acknowledgements

Many thanks to the Gosling family for making a paddock available to research again and to the MAC farm team for implementing the deep ripping treatments.

Thank you to MAC staff Ian Richter, Katrina Brands and Steve Jeffs for managing the trial, sampling and processing samples.

GRDC GRAINS RESEARCH & DEVELOPMENT CORPORATION

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SARDI SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE

SOIL CRC Performance through collaboration

Increasing reliability of lentil production on sandy soils

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[1]Trengove Consulting

Paper presented at GRDC Update, 2021

Key messages

- **Four key steps to improving lentil productivity on underperforming sandy soils are: soil amelioration, variety selection, herbicide choice and nutrient management.**
- **Ameliorating soil constraints increased lentil grain yields up to 347%, with an average 0.31 t/ha (85%) yield response to deep ripping.**
- **The highest yielding varieties on loamy soil types may not be the highest yielding on underperforming sandy soils.**
- **Weed control methods on sandy soil types should be carefully planned to minimise yield loss due to the heightened risk of herbicide damage from soil residual herbicides.**
- **Nutrient requirements on sandy soil types can vary across locations and seasons. Application of molybdenum on acidic sands were shown to increase grain yields.**
- **Lentil growth and biomass, as measured by NDVI, was positively correlated with grain yield on sandy soils.**

Why do the trial?

Lentil production in South Australia has expanded significantly over the last 20 years. It is valued for its agronomic rotational benefits and its ability to generate high economic returns. The expansion in lentil area now sees the crop produced on a diverse range of soil types across the state. Observations of lentil growth and productivity has indicated that on some sandy soils' performance has been sub optimal, with significant scope for improvement.

This was particularly notable in the dune swale landscape of the northern Yorke Peninsula. Two SAGIT projects (TC116, TC119) have investigated opportunities for increasing lentil productivity on the sandy soil types of this region. These sands are typically red sandy dunes with low organic carbon (0.4-0.8%). Constraints on these sands can include compaction, non-wetting, pH (both acidic and alkaline), nutrition and low biological activity. The heavy reliance on herbicides with residual soil activity for broadleaf weed control in lentil also presents challenges on these soils. However, these sandy dune soil types are not typically constrained by the subsoil toxicities of sodicity, salinity or boron that limit production on many of the heavier textured soils in the region. Thus, significant production improvement in lentil is expected if these known constraints can be overcome. This paper details the results of SAGIT and GRDC funded amelioration, variety selection, herbicide choice and nutrition trials conducted on these sandy soils.

How did we do it?

General trial information

Yield data from specific treatments from a range of soil amelioration trials have been summarised for the purpose of this paper. For detailed methodology of each trial contact Trengove Consulting or refer to the relevant project listed.

Soil types - Trials occurred in 2015 and from 2017 to 2020 and were located on poor performing sandy soils across the upper northern Yorke Peninsula. Soils ranged from grey alkaline sands near Alford to red/orange sands around Bute and Port Broughton. Organic carbon level was typically low with 0.94 % the highest, pH values ranged from acidic sites (0-10 cm pH 5.3 $CaCl_2$) to highly alkaline (0-10 cm pH 8.6 $CaCl_2$) and nutrition levels also varied with Colwell P values ranging from 26 - 44.

Trial sowing dates were typical for lentil crops in the region and were sown between May 11 and May 22. Standard seeding fertiliser was applied as MAP at 60 - 80 kg/ha.

Herbicides treatments were applied using a 2 m hand boom. Pre-emergent herbicides were applied pre seeding or split with ⅔ applied pre seeding and ⅓ post seeding pre-emergent. Plots were sown using knife points and press wheels on 250 mm spacing and all plots were rolled using a steel roller, either pre-emergent or early post emergent. Early post emergent diflufenican herbicide treatments were applied (June 14 - July 28) approximately 10 days prior to Intercept® herbicide treatments (July 2 - August 8). Varieties for the herbicide tolerance and nutrition trials were either PBA Hurricane XT^A or PBA Hallmark XT^A.

All trials in these projects were randomized complete block designs with three replicates and plot dimensions were 1.5 x 10m.

Early growing season rainfall during the herbicide trial years was generally average, with the exception being one day in June 2019 where 47 mm was recorded at Bute (Figure 1).

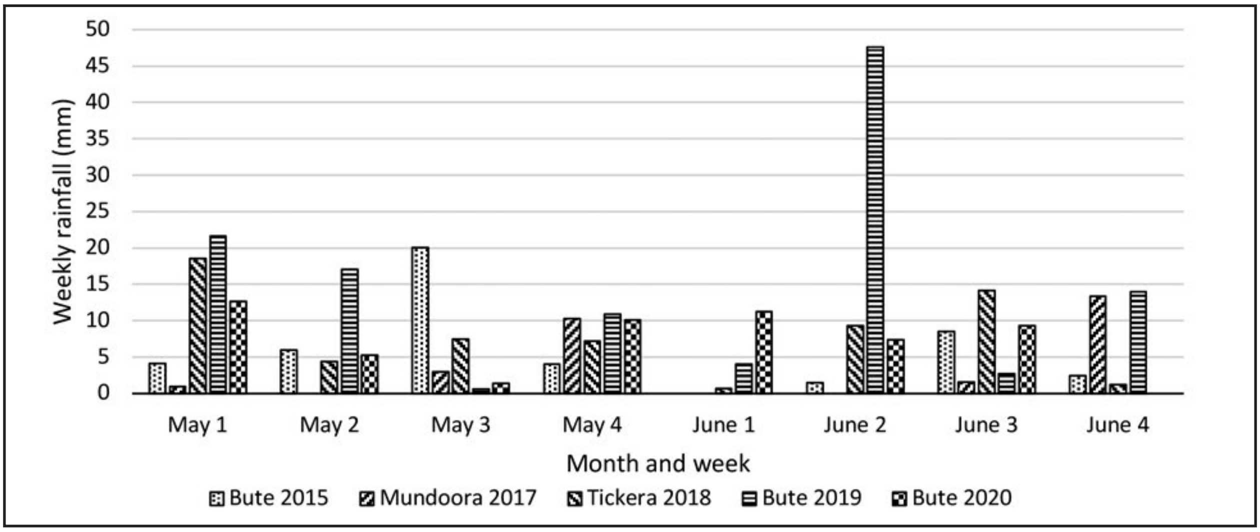

Figure 1. Weekly rainfall (mm) for the period leading up to seeding and early post emergent for all trials 2017 - 2020.

What happened

Amelioration

Compaction is a common physical constraint of crop growth on sandy soils in the northern YP region, it inhibits plant root exploration beyond compacted depths. Results from amelioration trials conducted in the northern YP and Mallee regions show an average lentil response to ripping of 0.31 t/ha, or 85% yield increase (Table 1). In some instances, the scale of response is much larger in lentil than for cereals at the same site. For example, a long-term trial site at Bute (Table 1, site 6) has averaged 0.51 t/ha (109%) yield increase in lentil over two seasons, whereas cereal response has averaged 0.6 t/ha (19%) over four seasons at the same site. The lentil responses, as measured by percent increase over the control treatment, are much greater than those measured in cereal due to the lower baseline yields in lentil. In this example the lentil response provides a much greater economic response when compared with cereals, due to their inherent higher grain price.

Penetrometer resistance measurements down the soil profile (data not shown) were characterised for sites five and six (Table 1). At site five soil resistance to a cone penetrometer never exceeded 2500 kPa. However, at site six the untreated control exceeded 2500 kPa from a depth of 17 cm to the limit of measurement (at 60 cm), with a peak of 4300 kPa between 30-35 cm. These differences help to explain the grain yield response to ripping at site six. It also highlights the need for diagnosing the presence of the constraint prior to undertaking soil amelioration works.

Other constraints identified include low fertility, low organic matter and soil acidity. Four trials testing the response to chicken litter applied at rates of 5 or 7.5 t/ha as a once off application averaged 0.26 t/ha (41%) yield increase in lentil (Table 1). As found with the ripping response, at site six (Table 1) the application of 5 t/ha chicken litter has a greater effect in lentil than for cereals with the cereal yield increasing by an average 10.6% (0.32 t/ha) compared to 37% (0.18 t/ha) for lentil. Grain yield responses were measured six years after application in this trial. However, responses of this scale have not been observed in separate nutrition trials during the same period, where chicken litter has been included as a treatment at 5 t/ha. The latter trials differ in that the chicken litter was applied to the surface immediately pre-seeding and incorporated by sowing, where in the amelioration trials the chicken litter was mostly incorporated in some way, either by ripping or offset disc, and was applied at least two years prior to lentils in three of the four trials. This method of incorporation and time period from application to lentil season may be important in explaining the differences in results observed. The findings suggest that earlier application and incorporation provided an improved environment for lentil plants to uptake mineralised nutrients from the chicken litter application than when applied and incorporated with the lentil crop.

Three trials assessing options for management of soil acidity on sandy soils in the Bute region were established recently in 2019. These trials were all lentil in 2020. Only small increases in grain yield were achieved in response to lime treatments averaging 0.08 t/ha, or 4% (Table2). Without the application of lime, soil acidity will continue to increase, and it is expected that these responses will increase over time. One trial included an elemental sulphur treatment applied to reduce soil pH to demonstrate effects of increased soil acidity. Plant biomass as measured by NDVI on 15 September was lowest in this treatment, with the best treatments (PenLime Plus and Spalding lime) having a 5% higher NDVI value (data not shown).

Table 1. Lentil grain yield response for a range of sandy soil amelioration trials.

Location	Project Code (GRDC or SAGIT)	Year trial established	Lentil crop year	Response to deep rip ~50cm	Response to spading ~30cm	Response to chicken litter in addition to district practice fertiliser
1. SARDI pulse agronomy - Bute	DAV00168BA: southern pulse agronomy	2019	2019	0.7 t/ha (127%)	NA	5 t/ha app 2019 = 0.19 t/ha (63%) Nil background fertiliser applied.
2. Validation trial - Warnertown	CSP00203: southern region sandy soils	2019	2020	Rip: 0.06 t/ha (7%) Rip + IP: 0.15 t/ha (16%)	0.35 t/ha (38%)	NA
3. Soil acidity lime incorporation trial - Bute	DAS 1905-011TRX: addressing soil acidity in SA	2019	2020	Rip: 0.53 t/ha (29%) Rip + IP: 0.74t/ha (41%)	0.63 t/ha (35%)	NA
4. UniSA soil acidity fellowship trial - Bute	USA103-002RTX: mixing uniformity and crop response	2019	2020	0.07 t/ha (8%)	2 km/h (multi-pass): -0.09 t/ha (-10%) 5 km/h: 0.04 t/ha (4%) 9 km/h: -0.01 t/ha (-2%)	NA
5. CSIRO soil amelioration - Bute Boundary Rd	CSP00203: southern region sandy soil	2018	2020	-0.05 t/ha (-3%)	NA	7.5 t/ha = 0.48 t/ha (25%)
6. Long term soil amelioration - Bute	TC116: Increasing lentil productivity on dune and swale soils	2015	2017	0.58 t/ha (149%)	NA	5 t/ha app = 0.18 t/ha (47%) 20 t/ha app = 0.293 t/ha (75%) 5 t/ha app + rip = 0.84 t/ha (216%)
6. Long term soil amelioration - Bute	CSP00203: southern region sandy soils	2015	2020	0.44 t/ha (69%)	NA	5 t/ha app = 0.17 t/ha (27%) 20 t/ha app = 0.22 t/ha (35%) 5 t/ha app + rip = 0.67 t/ha (106%)
7. Lameroo 2020	SA MDBNRM	2020	2020	0.69 t/ha (179%)	0.66 t/ha (172%)	NA
8. Lameroo 2019		2019	2019	0.19 t/ha (171%)	NA	NA
9. Kooloonong 2020	SPA (DAV00150)	2020	2020	0.71 t/ha (97%)	NA	NA
10. Kooloonong 2019	SPA (DAV00150) / CSP00203	2019	2019	0.38 t/ha (337%)	NA	NA
11. Carwarp	CSP00203: southern region sandy soil	2018	2018	-0.05 t/ha (-12%)	NA	NA
		2018	2019	0.04 t/ha (19%)	NA	NA
		2018	2020	0.09 (13%)	NA	NA

Table 2. Lentil grain yield response to lime application in a range of acidic sandy soil amelioration trials.

Location	GRDC Project	Year trial established	Lentil crop year	Starting pHca by depth increments of - 5 cm from 0-30 cm	Grain yield response to lime
Soil acidity lime product trial - Bute	DAS 1905-011TRX: addressing soil acidity in SA	2019	2020	6.1, 5.0, 4.8, 5.2, 5.6, 6.0	0.1 t/ha (4%)
Soil acidity lime incorporation trial - Bute	DAS 1905-011TRX: addressing soil acidity in SA	2019	2020	6.1, 5.0, 4.8, 5.2, 5.6, 6.0	0.14 t/ha (6%)
UniSA soil acidity fellowship trial - Bute	USA103-002RTX: mixing uniformity and crop response	2019	2020	5.5, 5.0, 4.4, 4.6, 5.0, 5.6	0.02 t/ha (2%)

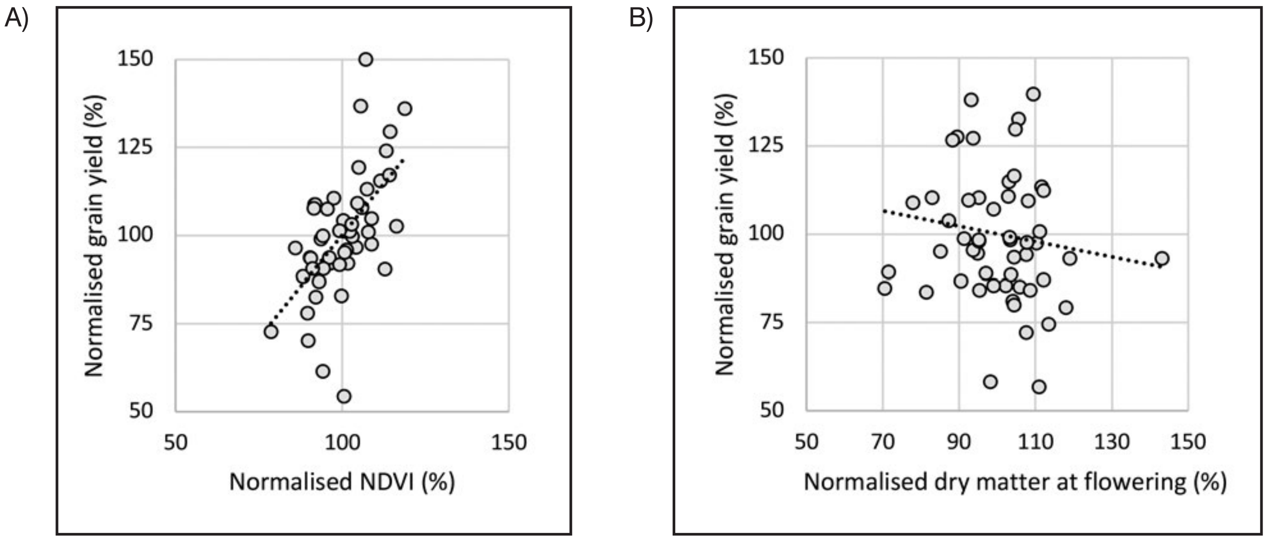

Figure 2. A) Normalised grain yield and NDVI at flowering data from lentil variety trials located on sandhills of the northern Yorke Peninsula from 2017-2020 (y = 1.1674x - 16.642, R^2 = 0.329). B) Normalised grain yield and biomass at flowering data from PBA breeding program located on loamy soils near Melton from 2012-2014 (source: PBA) (y = 0.2176x + 121.82, R^2 = 0.0143).

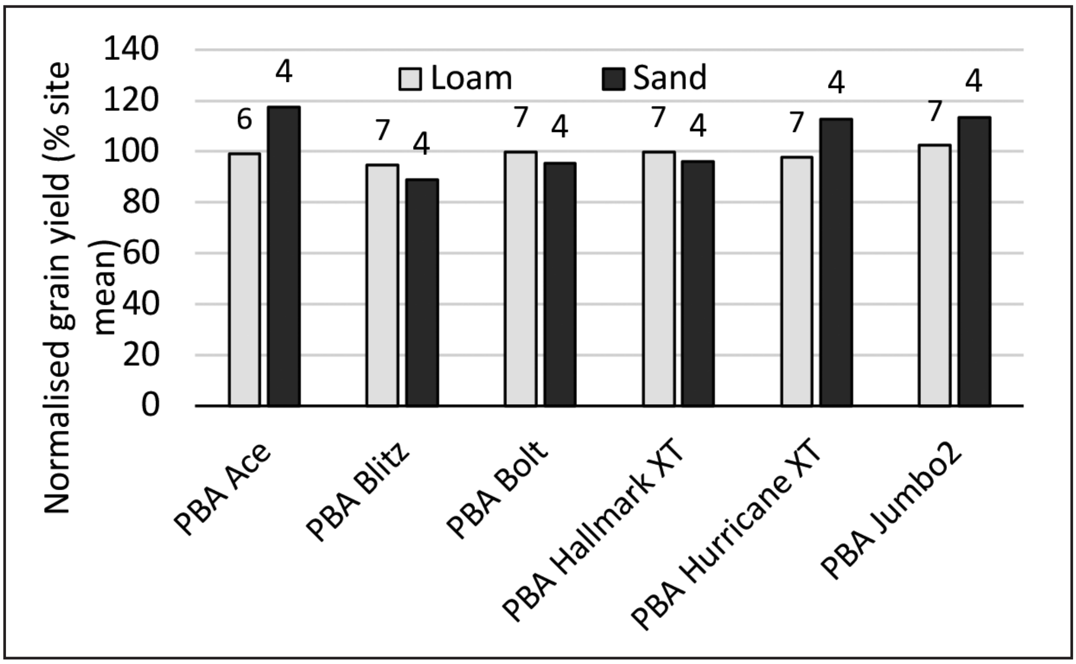

Figure 3. Average grain yield for selected commercial varieties as clustered by soil type for years 2017-2020 (Source: NVT Online, Willamulka NVT and Melton PBA yields used for loam cluster, sandy soil cluster yields from Trengove Consulting trials), number above bar shows number of trials variety is present.

Varieties

Across a range of lentil agronomic trials, treatments that increased crop growth on sandy soils of the northern Yorke Peninsula also increased lentil grain yield. This finding was confirmed in variety trials, where varieties with higher NDVI values at the flowering growth stage produced higher grain yield (Figure 2A), even though no other site-specific constraints were addressed. This contrasts with results from trials conducted on more loamy soils (Figure 2B) where increasing biomass was not correlated with increased grain yield. This finding suggests that the highest yielding variety on a heavier textured flat may be different to the highest yielding variety on a sand hill in the same paddock. The Willamulka NVT site is considered one of the lighter textured soil types within the suite of SA NVT lentil trials, yet by district standards it is a medium textured sandy loam flat. A four-year relative comparison of yield results from lentil variety trials on sandy soils across the northern Yorke Peninsula, to those from the Willamulka NVT and Melton PBA (loamy clay) lentil trials found that the highest yielding variety varies between the two groups (Figure 3). The high biomass later maturing variety PBA Ace was the highest yielding line from the sandy soils cluster of trials, some 4% higher than PBA Jumbo2[A]. Whereas in the loamy soil cluster, PBA Ace[A] was 3% lower yielding than PBA Jumbo2[A].

Herbicides

Herbicide tolerance

Yield losses associated with herbicide damage in lentil trials on these sandy soil types have ranged from 0 - 58% for individual products and up to 75% for herbicide combinations over 8 trials conducted in 2015 and from 2017 to 2020. This has been measured in the absence of weeds, with any weeds surviving the herbicide applications controlled by hand weeding from mid-winter onwards.

The herbicide products used in these trials all have different chemical properties. However, the residual soil applied herbicides were particularly sensitive to rainfall patterns post application (Table 3). The solubility value of each herbicide affects the way it moves in the soil profile with low solubility herbicides such as diuron requiring higher amounts of rainfall to move them through the soil. However, highly soluble herbicides such as metribuzin move rapidly through the soil profile after relatively smaller rainfall events. The adsorption coefficient (how tightly the herbicide binds to organic matter) and the DT50 value (days of time for 50% of the herbicide to dissipate) also have impacts on how these herbicides respond in each season and soil type. The herbicide diuron has a high adsorption coefficient and relatively low solubility and was found to often be the safest group C herbicide at the rates applied (Table 4). The seasons in which these trials were conducted generally did not have large rainfall events post seeding and in different seasons results may vary.

The products and ranges of rates that were used in these trials were selected as they were found to be representative of use patterns on sandy soils in the region, and typically at the low end of the rate range recommended for group C herbicides on sands (Table 4). Despite the low use rates crop damage and yield loss was still observed at these sandy soil trial sites in some seasons. Various group C herbicides were trialled in combination with other group B and F herbicides across different trials (Figure 4, Table 6). To summarise the effect of these group C interactions, results have been bulked across group C products and referred to as Group C plus companion herbicide. Chlorsulfuron was applied at 5 g/ha IBS to simulate residual carryover from the previous season. However, it still caused significant yield loss in XT lentil varieties at these sites (Figure 4), therefore it is important for growers to recognise the heightened risk of SU residue effects on these soil types and avoid this use.

Herbicide products applied individually generally only showed low levels of crop damage and associated grain yield loss. In this series of trials, average yield loss for individually applied products was 9% compared to the untreated control (Figure 4). However, when multiple products were applied, greater levels of crop damage were observed. This is particularly the case with the soil residual herbicide chlorsulfuron where the application of group C herbicides in conjunction increased the yield loss to 50% on average. Similarly, the additional effect of Intercept where chlorsulfuron residues were present significantly increased damage with yield loss averaging 50%, whereas on its own at the rates applied Intercept® did not reduce grain yield (Figure 4).

Table 3. Pre-emergent herbicide properties for products used in the herbicide tolerance trials 2015 and 2017-2020 (Source: GRDC pre-emergent herbicide fact sheet).

Herbicide	Solubility (mg/L @ 20C)	Adsorption coefficient, Koc value	DT50 value (range in reported value)
Diuron	36	680	90
Terbuthylazine	7	130	22 (6-149)
Metribuzin	1100	60	19 (14-28)
Chlorsulfuron	12500	40	36 (10-185)

Table 4. Herbicide products used and rate ranges used in trials in 2015 and 2017-2020.

Product name	Herbicide active constituent	Herbicide group	Concentration	Rate range (mL or g/ha)	Application Timing
Chlorsulfuron	Chlorsulfuron	B	750 g/kg	5	IBS #
Intercept	Imazamox + imazapyr	B	33 g/L + 15 g/L	500	Post-emergent
Diuron	Diuron	C	900 g/kg	550 - 825	IBS or PSPE
Metribuzin	Metribuzin	C	750 g/kg	150 - 180	IBS or PSPE
Terbyne	Terbuthylazine	C	750 g/kg	500 - 750	IBS
Brodal Options	Diflufenican	F	500 g/L	150	Post-emergent

 # Chlorsulfuron was applied IBS at 5 g/ha to simulate residual carryover from application in the previous season.

Weed control

Individual herbicides

- Metribuzin at the range of rates applied produced the poorest weed control of the group C herbicides across all weeds assessed (Table 5).
- Control of Indian Hedge Mustard (IHM) with Intercept was highly variable, and likely represents the presence of imidazolinone herbicide resistance in some IHM populations across the region. Despite imidazolinone resistance now reported in sow thistle in the district, average control of 79% was seen as a relatively good result.
- Diflufenican (DFF) provided good control of the brassica weeds IHM and wild turnip.

Herbicide combinations

- Combinations of herbicides improved weed control compared to the same herbicides applied alone.
- Group C herbicides followed by DFF gave 100% control of IHM and wild turnip and good control of medic (82%) and sow thistle (94%).
- Group C herbicides followed by Intercept® provided 85% or better weed control of all four weed species.
- Group C herbicides followed by DFF followed by Intercept® averaged greater than 94% control of all weeds.

Nutrition

Chicken litter increased yield in four amelioration trial years (Table 1), as discussed previously. Tissue testing at site six (Table 1) in 2017 revealed elevated levels of phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulphur (S), copper (Cu), manganese (Mn) and molybdenum (Mo), in lentil whole tops compared with the control treatment, indicating chicken litter was supplying a broad range of nutrients. A trial with matched application rates of the macronutrients N, P, K, S and micronutrients Zn, Cu & Mn as synthetic fertiliser sources also elevated tissue test levels of P, K, S, Cu, and Mn but did not increase yields. Due to the differences in Mo levels between chicken litter and synthetic fertiliser treatments it was hypothesised that this may have been a significant deficiency on the acidic sand at this site (0-10 cm pH 5.2 $CaCl_2$). Nutrition trials were run from 2017-2020 on both alkaline and acidic sands in the region. These trials included the addition and omission of a range of essential plant nutrients. While elevated levels of some nutrients were again measured in tissue tests, no unique nutrition constraints were identified that led to improved yield.

Molybdenum on acidic sands

In 2019 and 2020 post-emergent molybdenum trials on slightly acidic sands were conducted with pH of 5.8 $CaCl_2$ and pH of 5.9 $CaCl_2$ at 0-10cm, respectively. Nine treatments ranging from 0 - 400 g/ha sodium molybdate, applied over two timings, early July and mid-August were evaluated. In both seasons strong visual plant growth responses were observed within two weeks of treatment and resulted in increased NDVI values. This also resulted in increased grain yields of 43% and 21% for 2019 and 2020, respectively. In both seasons there was no benefit from increasing the rate of sodium molybdate above 25 g/ha and timing had no impact (data not presented).

Soil

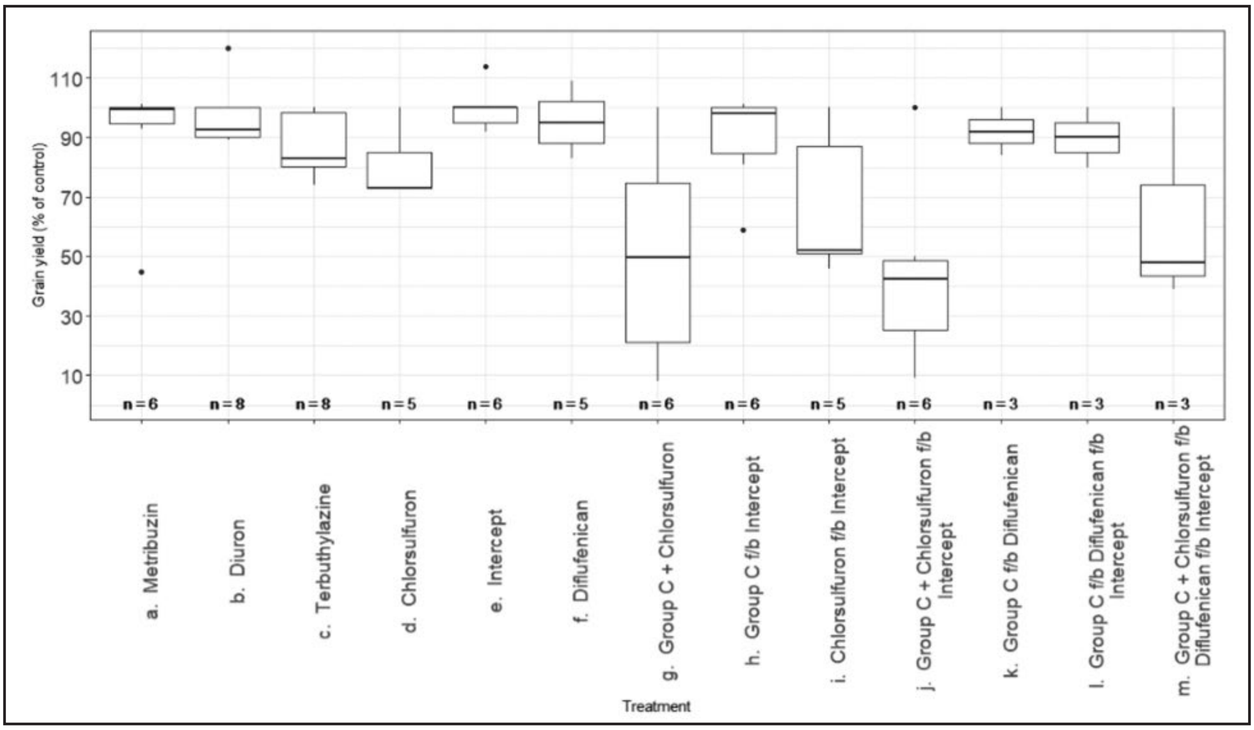

Figure 4. Grain yield presented as percent of control treatments for individual and product mixtures/sequences in the herbicide tolerance trials from 2015 and 2017-2020 on sandy soils.

Table 5. Weed control of Indian hedge mustard (Sisymbrium orientale), burr medic (Medicago polymorpha), common sow thistle (Sonchus oleraceus), and wild turnip (Brassica tournefortii) for different herbicide products and sequences in lentil herbicide trials on sandy soils across the northern Yorke Peninsula.

Herbicide product(s)	**% weed control (# samples) range**											
	IHM			Medic			Sow thistle			Wild turnip		
Metribuzin	58	(4)	29-82	28	(5)	0-76	45	(6)	16-69	62	(5)	50-83
Diuron	85	(4)	74-97	40	(5)	0-70	76	(6)	50-94	70	(5)	52-94
Terbuthylazine	92	(4)	83-100	63	(5)	36-82	81	(5)	61-96	85	(5)	78-100
Intercept	59	(3)	0-91	56*	(4)	0-88	79	(5)	61-88	96	(4)	88-100
Diflufenican (DFF)	97	(2)	95-100	56	(2)	34-78	59	(3)	0-94	80	(2)	63-97
Group C f/b Intercept	85	(3)	62-97	86*	(4)	71-94	92	(5)	63-100	87	(4)	74-100
Group C f/b DFF	100	(2)	100-100	82	(2)	74-90	94	(3)	88-100	100	(2)	100-100
Group C f/b DFF f/b Intercept	99	(2)	99-100	94*	(2)	92-96	95	(3)	84-100	100	(2)	100-100

**in most cases surviving medic plants were severely stunted and not competitive.*

Biomass and yield

Across a suite of 24 trials on sandy soils of the northern Yorke Peninsula a consistent positive linear relationship between biomass at flowering (using Greenseeker NDVI as a biomass surrogate) and grain yield has been established. This is consistent with work by Lake and Sadras (2021) experimenting with 20 lentil lines varying in seed type and phenology in eight environments. They found yield correlated with biomass and crop growth rate in more stressful conditions, where yields were less than 1.07 t/ha. However, they also found this relationship decoupled in more favourable conditions where yields exceeded 1.7 t/ha. In these favourable conditions' excessive vegetative growth can lead to self-shading, reduced pod and seed set, low harvest index and higher risk of disease and lodging (Lake and Sadras, 2021). The results presented in this update paper suggest the physical and chemical constrained sandy soils of the northern YP are also plant biomass constrained, where any treatment that overcomes some or all these constraints, increases both biomass and yield. However, it is also possible that this relationship decouples on the heavier textured soils within the same paddocks where biomass is not a constraint to yield.

What does this mean?

There are four main steps and considerations when planning to increase the reliability of lentil production on sandy soils identified in this study. The first step is to identify and overcome any soil physical and chemical constraints that limit crop growth and biomass, through the use of soil amelioration techniques. The second step is selecting a suitable high biomass variety such as PBA Ace^{A}, PBA Hurricane XT^{A} or PBA Jumbo2^{A}. This decision needs to factor in the presence of any other soil types within the paddock. The third step is the selection of appropriate herbicides for the situation which should be based on the variety to be grown, soil types, soil moisture content and probable three day forecast at the time of application, the main weed targets and the level of escapes that are deemed acceptable as 100% control may come at a cost in yield reduction. The final step is correcting any nutritional deficiencies that may be present. Further gains on these soils are realistic through breeding improvements in varieties with higher plant biomass and improved Group C herbicide tolerance.

Acknowledgements

The research undertaken as part of this project is made possible by the significant contributions of growers through both trial cooperation and the support of the SAGIT (Project TC116 and TC119), the author would like to thank them for their continued support. The authors also acknowledge the valuable input from Larn McMurray during these projects.

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Trengove Consulting

SAGIT

Treating production constraints on the sandy soils of upper and lower Eyre Peninsula - Year 2

Brett Masters

PIRSA Rural Solutions SA, Port Lincoln

Location
Kimba, Mt Damper, Karkoo, Cummins

Graeme & Heather, Tristan & Lisa Baldock, Nigel Oswald, Reece Modra, Scott & Maryanne Mickan.

Rainfall

Av. GSR/2020 GSR

Kimba: 215/251 mm

Mt Damper: 218/110 mm

Karkoo: 334/366 mm

Cummins: 361/336 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 x 12-18 m x 3 replicates

Yield limiting factors

Below average growing season rainfall resulting in very low moisture levels.

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

Key messages

- **Production constraints on sandy soils can be overcome by mechanical intervention and the application of soil amendments, however, the response can vary between sites and years.**
- **Knowledge of soil characteristics throughout the profile is vital for identifying key production constraints and determining an appropriate and effective management strategy.**

Why do the trial?

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 production including water repellence, soil acidity, compaction and low organic carbon levels leading to poor biological cycling and nitrogen mineralisation. Estimates of the yield gap (the difference between water limiting potential and average actual crop yield) are between 1.8 and 2.1 t/ha on Upper Eyre Peninsula and as much as 2.3 t/ha on Lower Eyre Peninsula (http://yieldgapaustralia.com.au/maps/).

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 EPARF and LEADA grower groups (now AIR EP), four replicated validation trials were established in 2019 at Kimba, Mt Damper, Karkoo and Cummins (EPFS 2019, p 99). Soil analysis 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 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.

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

In 2019, the sites were all sown with wheat. Plant density was evaluated 3 weeks post sowing and only the Karkoo site showed significant differences in crop establishment between treatments, with the clayed control and the clay+rip treatment recording between 14 and 19% more wheat plants than where inclusion plates were used. Opportunistic biomass at flowering was assesed at Kimba, Mt Damper and Karkoo with ripping with inclusion plates resulting in biomass increases of at least 33% compared to the control at Kimba, and at Mt Damper the spading ripping+IP, and rip+IP+nutrient treatments producing more spring biomass than the control.

Table 1. Summary of replicated trial sites.

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

2019 grain yield at Kimba saw increases of 25 to 30% from ripping+IP+nutrients compared to the control, and at Mt Damper whilst physical interventions saw a doubling of grain yields over the control, high variability across the site meant that only the rip+IP+nutrients gave a significant yield increase. Ripping at Karkoo gave an 18% increase in grain yield compared to 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 and at Cummins there were no improvements in grain yield from treatments.

What happened in 2020?

In 2020 all sites were sown by the landholders and managed as per the rest of the paddock. The upper EP sites were sown with cereals (Scepter wheat at Mt Damper and Compass barley at Kimba) with both of the lower EP trial sites sown to 44Y90 canola. Good opening rains of 25 to 43 mm were received in all districts at the end of April with a further 20 to 40 mm in early May. All sites except Mt Damper were sown by the end of the first week in May and germinated quickly. However, Mt Damper wasn't sown until 24 May and cool dry conditions had slowed growth when crop establishment was assessed in June.

There was some evidence of soil drift at crop emergence on the ripped plots at Cummins and Karkoo and the spaded plots at Mt Damper. A fifth trial was intended to be established at Wharminda to validate the use of modified tyne designs and wetting agents to mitigate production impacts from water repellent surface soils. However, continued low rainfall and very dry soil profiles (<2% gravimetric moisture to 20 cm) into late June made the risk of wind erosion and crop failure too high so the trial was postponed until 2021.

Plant density

Plant density was evaluated 4 to 6 weeks after sowing. There was no difference in plant density between the control or treated plots at any of the sites at this time. Very much below average rainfall was received at all sites from May to the end of July, with average August rainfall. Good rainfall in late winter and spring saw improved crop growth at Cummins, Karkoo and Mt Damper, but very dry conditions combined with poor subsoil moisture saw the crop at Kimba struggle during spring for a second year.

Biomass

Opportunistic biomass cuts were taken at Kimba and Mt Damper in August. At Kimba deeper ripping (45 cm) yielded 0.5 to 0.9 t/ha more biomass than the control (which yielded 2.4 t/ha), however, there was no additional biomass response from the use of inclusion plates or extra nutrition in 2020. Only the rip+IP with APP or high cost nutrient package gave increased August biomass compared to ripping at 35 cm in 2020 (Figure 1).

August biomass at Mt Damper was generally low (<1.0 t/ha), with rip+IP+spading the only treatment to produce more biomass than the control (which yielded 0.6 t/ha) (Figure 2).

Soil

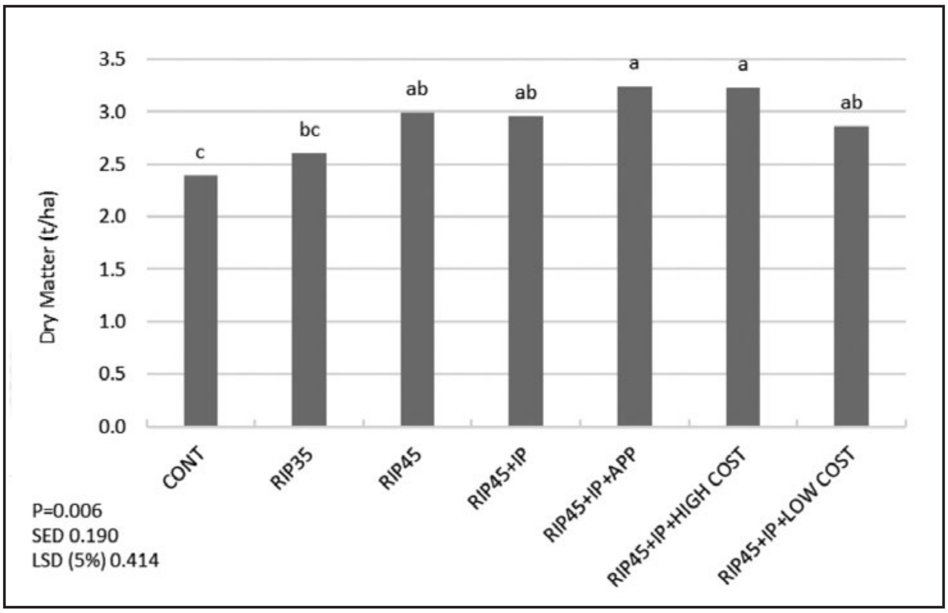

Figure 1. Winter biomass (t/ha) at Kimba. A different letter indicates a signficant difference at P<0.05.

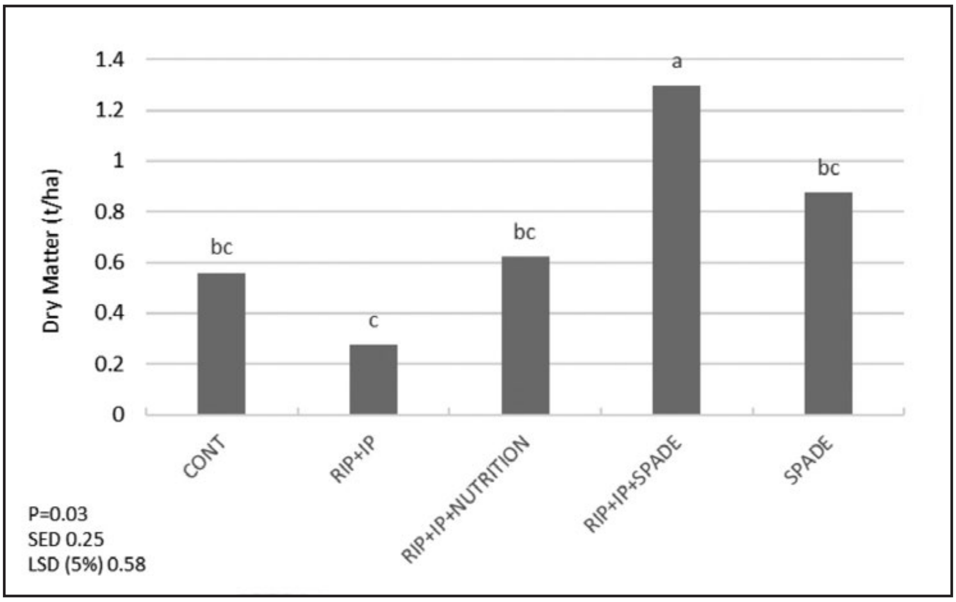

Figure 2. Winter biomass (t/ha) at Mt Damper. A different letter indicates a signficant difference at P<0.05.

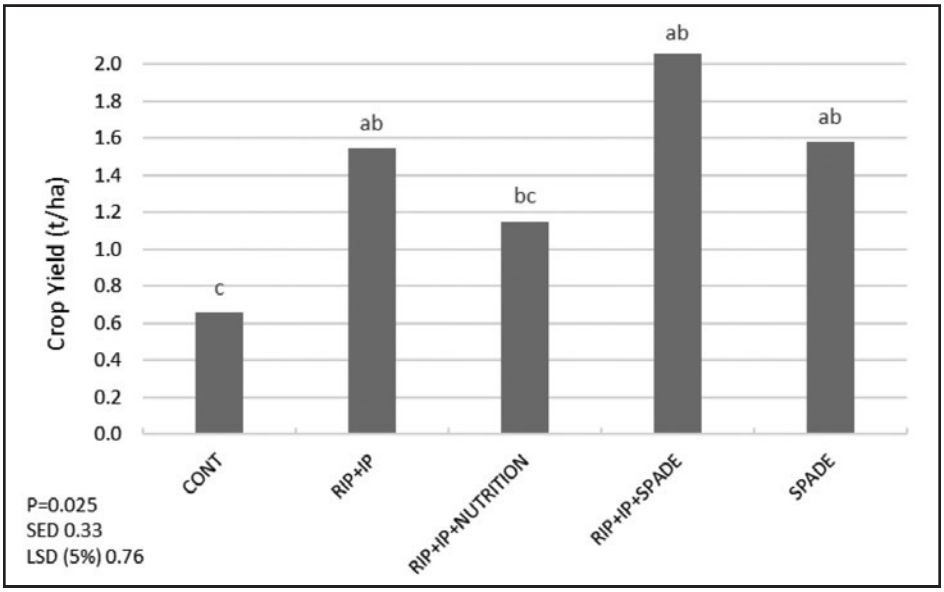

Figure 3. Wheat yield (t/ha) at Mt Damper. A different letter indicates a signficant difference at P<0.05.

Grain yield

At Kimba, Cummins and Karkoo the trials were harvested by the landholders in late October/ early November, yielding an average 1.7 t/ha, 2.7 t/ha and 2.3 t/ha respectively. There was no additional yield response from any of the treatments at any of these sites in 2020.

Harvest cuts were taken at Mt Damper on December 14. The heads were cut from 4 x 1 m rows, threshed and grain weights extrapolated to yield in t/ha. Grain yields varied greatly from 0.7 t/ha on the control to 2.1 t/ha on the rip+IP+Spade treatment. Whilst all treatments at this site except rip+IP+nutrients yielded more grain than the control there was no difference between the spaded plots and the ripping+IP (Figure 3).

What does this mean?

As in 2019 it is hypothesised that rainfall timing and distribution was the major factor in the results seen in 2020. All sites had good opening rainfall and the Kimba, Cummins and Karkoo sites which were sown by the first week of May, germinated well and had rapid early growth. Germination and early growth was slow at Mt Damper which wasn't sown until the end of May, and biomass growth at all sites was hindered by dry conditions between May and the end of July. Although April to October rainfall was more than 2019, much of it fell in October (ranging from 60 mm at Karkoo to 105 mm at Kimba) and was too late to improve grain fill in the barley at Kimba or canola on lower Eyre Peninsula.

Despite improved biomass at Kimba from ripping to 45 cm, this did not translate to improved grain yield this season. There are a number of factors which might have contributed to this, including:

- Hot drying winds in early September which caused some damage to flowering barley.
- Dry conditions throughout the growing season causing moisture stress.
- Below average rainfall to the end of September resulting in little subsoil moisture at grain fill.

In contrast, the crop at Mt Damper was able to better utilise the late spring rain on plots that had been physically altered (rip+IP and Spaded), resulting in substantial grain yield gains, even where spring biomass was not different to the control (Figures 2 and 3).

On Lower Eyre Peninsula good opening rains might have reduced the expression of water repellence at Cummins, with warm conditions providing ideal conditions for early canola growth. Meanwhile below average rainfall from May to August meant that waterlogging, which is common at the site, was not expressed in 2020 and might explain the lack of response from treatments.

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

Key questions that remain unanswered include:

- How long before responses from soil applied amendments 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 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, Nigel Oswald, Reece Modra and Scott and Mary-Anne Mickan as well as AIR EP and the Buckleboo Farm Improvement Group (BigFIG) for their support of these trials.

Deep ripping improves crop yields on compacted Mallee sands

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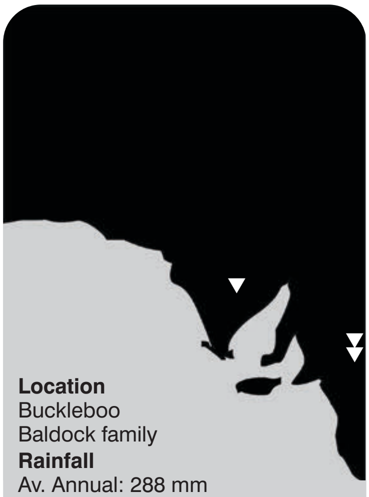

Location
Buckleboo
Baldock family
Rainfall
Av. Annual: 288 mm
Av. GSR: 197 mm
2020 Total: 325 mm
2020 GSR: 251 mm
2019 Total: 161 mm
209 GSR: 143 mm
Paddock history
2020: Barley
2019: Wheat
Soil type
Sand
Soil test
pH (water): 7.13
Plot size
15 m x 2 m x 3 reps
Trial design
RCBD with 3 replicates
Yield limiting factors
Moisture, nitrogen

Location
Peebinga
George Gum and family
Rainfall
Av. Annual: 319 mm
Av. GSR: 210 mm
2020 Total: 309 mm
2020 GSR: 230 mm
Paddock history
2019: Fallow
2018: Scope barley
2017: Fallow
2016: Fallow
Soil type
Sand
Soil test
pH (water): 7.3
Plot size
15 m x 2 m x 4 reps
Trial design
Randomised complete block design (RCBD) with 4 replicates and two treatment factors
Yield limiting factors
Moisture

Key messages

- **Deep ripping of compacted sands resulted in improved grain yields when the ripping reached beyond the compacted layer.**
- **Wider tine spacings are still effective and should improve overall profitability.**
- **In the mid to long-term, overcoming multiple soil constraints should improve the longevity of benefits and overall return on investment.**

Why do the trials?

Soil compaction occurs in many cropping soils of southern Australia and may be due to frequent trafficking of heavy vehicles, livestock-induced or naturally occurring. 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. By breaking up the soil, deep ripping can free the way for roots to penetrate the soil and access extra water and nutrients, leading to yield increases. This article reports on results from the 2020 cropping season and also multiple years (2-3) of conducting trials on the Eyre Peninsula and in the SA Mallee. These trials investigated how deep ripping can impact crop performance and how to refine this amelioration strategy on different soil types in order to achieve sustainable and improved crop yields and good returns for invested dollars.

How was it done?

Three replicated field trials (Table 1) were conducted during the 2018, 2019 and 2020 cropping seasons on sandy soils across the northern and southern Australian Mallee, and on the upper Eyre Peninsula (UEP). Trial 1 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 years after amelioration. Trial 2 (depth x spacing) was conducted at Peebinga (2018, 2019, 2020) and at Buckleboo (2019, 2020) 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.

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 at all 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.

Location
Location Loxton Robin Schaeffer **Rainfall** Av. Annual: 282 mm Av. GSR: 290 mm 2020 Total: 260 mm 2020 GSR: 194 mm 2019 Total: 136 mm 209 GSR: 103 mm **Paddock history** 2020: Barley 2019: Peas 2018: Wheat **Soil type** Sand **Soil test** pH (water): 7.3 **Plot size** 15 m x 2 m x 6 reps **Trial design** Randomised complete block design (RCBD) with 6 replicates **Yield limiting factors** Moisture, nitrogen

What happened?

Loxton

No grain yield was achieved in field peas for 2018 and 2019 because of severe frost which resulted in pod damage. As a result, field peas were excluded from the experiment, and only wheat and barley responses were investigated. Deep ripping resulted in better barley and wheat flowering shoot DM and grain yield than the unripped control (Table 2). Wheat grain protein and post-harvest soil nitrogen (N) in the 0-50 cm zone were the same for both treatments. Barley grain protein was higher in the unripped control when compared to the ripped treatment.

Peebinga and Buckleboo

Averaged over all ripping depths, deep ripping with tines spaced at 30 cm or 60 cm resulted in similar plants/m^2, flowering shoot DM, grain yield, grain protein, and post-harvest soil N at both sites in 2020, so all data presented for these two sites are as an average of both tine spacings. At Peebinga, deep ripping beyond 60 cm resulted in higher plants/m^2 and flowering shoot DM than the unripped control, and lower grain protein (Table 3). Post-harvest soil mineral N was not impacted by deep ripping. At Buckleboo, only grain protein was affected by ripping, with the control having better protein than all of the ripped treatments (Table 3). There was no response to deep ripping in soil N, plants/m^2 or flowering shoot DM. At both Peebinga and Buckleboo, deep ripping beyond 40 cm resulted in higher grain yields than the control (Figure 1). The highest grain yield was achieved by ripping to 70 cm; however, this was not statistically different from ripping to 40 cm or 60 cm in 2020. The highest yielding treatment (70 cm) produced 0.37 t grain/ha (Peebinga) and 0.50 t grain/ha (Buckleboo) more than the unripped control, respectively.

Soil

Table 1. Deep ripping locations and treatment details for 2018, 2019 and 2020 cropping seasons.

Trial	Location	Year (crop)	Treatments
1	Loxton	2018, 2019 (barley, wheat, peas), 2020 (barley, wheat)	Ripped (50 cm) vs compacted (control), Tine spacing = 50 cm
2	Peebinga	2018 (barley), 2019 (Wheat), 2020 (wheat)	Ripping depths (0, 20, 40, 60, 70 cm), Tine spacings (Narrow = 30 cm and wide = 60 cm)
	Buckleboo	2019 (barley), 2020 (wheat)	

Table 2. Flowering shoot dry matter, grain yield and protein, and post-harvest soil N for wheat and barley at the Loxton site, 2020.

	Flowering shoot DM (t/ha)	Grain yield (t/ha)	Grain protein (%)	0–50 cm Post-harvest soil N (kg N/ha)
Wheat				
Ripped	3.57	2.01	11.7	47
Control	2.31	1.59	11.7	35
LSD (5%)	*1.17*	*0.27*	*ns*	*ns*
Barley				
Ripped	3.73	2.27	12.9	30
Control	2.33	1.76	13.4	44
LSD (5%)	*0.87*	*0.39*	*0.56*	*ns*

Table 3. Crop establishment, flowering shoot dry matter, grain protein, and post-harvest soil N for wheat at the Peebinga and Buckleboo site, 2020 (averaged over both tine spacings). Means followed by the same letter are not statistically significant.

Site	Depth (cm)	Plants/m²	Flowering shoot DM (t/ha)	Grain protein (%)	0 - 50cm Post-harvest soil N (kg N/ha)
Peebinga	0	65 a	1.66 a	13.9 b	34 a
	20	74 ab	2.21 ab	14.0 b	20 a
	40	102 abc	2.22 ab	13.6 ab	30 a
	60	124 bc	2.58 b	13.0 a	21 a
	70	128 c	2.53 b	13.0 a	18 a
	LSD (5%)	37	0.60	0.5	ns
Buckleboo	0	94 a	3.07 a	12.5 b	31 a
	20	87 a	3.26 a	11.7 a	18 a
	40	87 a	3.45 a	11.3 a	26 a
	60	89 a	3.52 a	11.5 a	26 a
	70	88 a	3.48 a	11.2 a	21 a
	LSD (5%)	ns	ns	0.5	ns

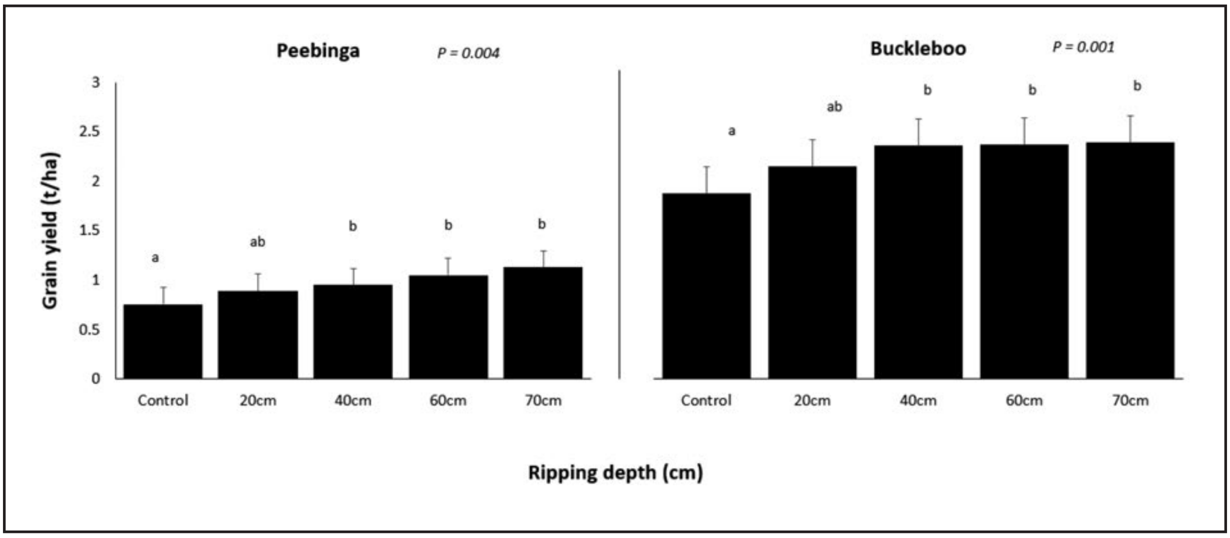

Figure 1. Grain yield at Peebinga and Buckleboo, 2020.

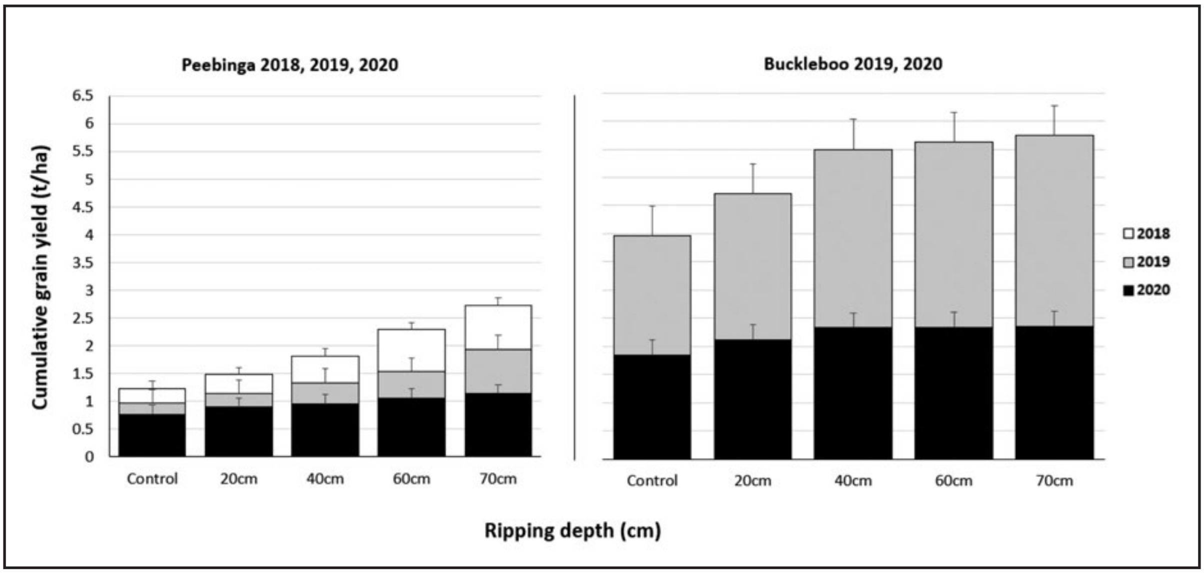

Figure 2. Cumulative grain yield for Peebinga (2018, 2019, 2020) and Buckleboo (2019, 2020).

Table 4. Summary of marginal benefits from deep ripping at Peebinga (2018, 2019, 2020) and Buckleboo (2019, 2020).

		Tine spacing (30cm)				Tine spacing (60cm)			
Peebinga	**Depth (cm)**	**20**	**40**	**60**	**70**	**20**	**40**	**60**	**70**
	Estimated cost ($/ha)*	40	60	90	100	30	50	70	80
	2018 Marginal benefit ($/ha)	8	3	50	20	-40	-10	35	63
	2019 Marginal benefit ($/ha)	0	78	90	180	23	26	75	165
	2020 Marginal benefit ($/ha)	9	70	93	99	73	44	81	119
	3 year Marginal benefit ($/ha)	**16**	**150**	**233**	**298**	**56**	**60**	**192**	**347**
Buckleboo	2019 Marginal benefit ($/ha)	125	128	265	155	33	283	155	295
	2020 Marginal benefit ($/ha)	87	128	154	145	70	151	128	151
	2 year Marginal benefit ($/ha)	**212**	**255**	**419**	**300**	**102**	**433**	**283**	**446**

**Estimated cost of deep ripping extrapolated from Davies et al., 2017. Assumptions. Prices of wheat @ $290/t and barley @ $250/t https://www.awb.com.au/daily-grain-prices.*

Cumulative grain yields for the 2018, 2019, 2020 cropping seasons, show a clear trend of increasing grain yield with increasing ripping depth at both sites. Ripping beyond the “standard” depth of 40 cm further increased grain yields (Figure 2). Penetration resistance at each site (data not shown) indicated that the compacted soil layer started at about 20 cm from the surface and continued with depth. Deep ripping well into this zone has proven worthwhile, especially at Peebinga.

Economics are an important factor when evaluating the merits of an amelioration strategy. Three years (Table 4) of conducting the “ripping depth x tine spacing” trials showed that the greatest returns were achieved with deep ripping below 60 cm. At the 70 cm ripping depth and 60 cm tine spacing, the returns were $346/ha at Peebinga and $445/ha at Buckleboo. This result also implies that when tine spacing is considered, it is cost effective to rip on wider tine spacings than narrow to increase returns. There is no evidence in our data that the benefits of deep ripping are diminishing, which implies that the benefits of deep ripping could possibly extend into year 4 and beyond, improving economic returns even more.

What does this mean?

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. Our trials have shown that ameliorating compacted sandy soils by deep ripping, in low rainfall environments, can lead to improved grain yields and is very cost effective. Ripping on narrow (30 cm) tine spacings or wide (60 cm) gave similar outcomes in terms of grain yield, therefore wider tine spacing should be considered because less machinery horsepower will be required. When there is not enough ground cover, i.e. stubble, legumes may be more prone to frost, and the risk of wind erosion when a legume phase follows after deep ripping increases. The response of wheat and barley to deep ripping seem similar so either cereal is a reasonable choice following ripping. Central to cost effective soil amelioration is how long these benefits last, therefore it is important to further monitor these trials and document if continued responses are achieved. This will, in the long run, help in developing the most appropriate, cost effective practices that improve soil condition, crop yields and dollar returns over multiple seasons while still keeping the paddock trafficable and minimising risk to erosion.

Acknowledgements

This research was made possible by the significant contributions of Robin Schaefer; and George Gum and family and through both trial cooperation and the support of the GRDC (Project code: UOA2008-008RTX: Developing more informed decisions for management of infertile sandy soils in the southern Mallee region), the author would like to thank them for their continued support. We also thank SAGI for statistical analysis and support.

Improving crop performance on Mallee sands through subsoil injection of animal manure

Brian Dzoma[1], Nigel Wilhelm[2], Hugh Drum[2] and Kym Zeppel[1]
[1]SARDI Loxton, [2]SARDI Waite

Location
Loxton
Paul Rudiger and family
Rainfall
Av. Annual: 282 mm
Av. GSR: 190 mm
2020 Total: 260 mm
2020 GSR: 194 mm
2019 Total: 136 mm
209 GSR: 103 mm
Paddock history
2020: Wheat
2019: Barley
2018: Wheat
Soil type
Sand
Soil test
pH (water): 7.3
Plot size
15 m x 2 m x 3 reps
Trial design
Randomised complete block design (RCBD) with 3 replicates
Yield limiting factors
Moisture, nitrogen

Key messages

- **Deep ripping to ameliorate soil compaction had larger benefits than subsoil injection of animal manure.**
- **Applying animal manure on the surface is not as effective at increasing grain yields as applying in the subsoil.**

Why do the trial?

Soil organic matter is agronomically important because it improves soil physical, chemical and biological properties. Organic amendments such as manures, composts and plant residues can be used in broadacre production systems as alternatives or supplements to inorganic fertilisers, to restore degraded soils and ameliorate physicochemical constraints. The main aim of the trial reported here 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 in 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. This process, which is also known as subsoil manuring, has resulted in large grain yield increases, relative to nil or low-nutrient application, for several years. Nutrient-rich materials such as poultry manure or Lucerne pellets have been the most successful.

How was it done?

This trial was established in April 2019 with 3 animal manures placed in the subsoil or on the surface on the midslope of a sandhill or on its crest. Treatment details and results from the first season of the trial are reported in a previous article in the EPFS summary, 2019: Improving crop performance on Mallee sands through subsoil injection of organic matter, p 93. Soil sampling for mineral nitrogen and moisture was carried out on 30 April 2020. The trial was sown to Scepter wheat at 60 kg/ha and with 100 kg DAP/ha on 1 May 2020. Biomass was estimated at the start of stem elongation and at flowering. Plots were machine harvested for grain yield at maturity.

What happened?

Crop responses to manure and deep ripping on the crest appeared to be small during the growing season but the crop was more vigorous than that on the midslope. Flowering shoot dry matter (DM) and grain yields with organic amendments or ripping were similar to the control on the crest (Table 1). However, cattle and sheep manure in the subsoil resulted in higher whole shoot nitrogen (N) than the control (Table 1). Average grain yield on the sandhill crest (2.84 t/ha) was higher than on the midslope (2.13 t/ha).

Flowering shoot DM and grain yield increased with manures and deep ripping on the midslope. There was a 66% increase in grain yield in response to deep ripping compared to the control, and the biggest yield response of 70% was achieved through the use of pig manure in the subsoil (Table 1).

Table 1: Wheat responses to surface and subsoil manure, and deep ripping on the crest and midslope of a sandhill at Loxton in 2020.

Location	Treatment	Flowering shoot DM (t/ha)	Shoot N (%)	Grain yield (t/ha)
Sandhill crest	Rip only	4.37	3.17	2.63
	Cattle - surface	4.57	3.07	2.79
	Chicken - surface	5.07	3.39	2.87
	Pig - surface	5.06	3.36	2.81
	Chicken - subsoil	5.38	3.67	2.87
	Cattle - subsoil	4.85	3.78*	3.07
	Sheep - subsoil	5.09	3.97*	3.10
	Pig - subsoil	4.75	3.34	2.96
	Control	4.02	3.09	2.42
	LSD (5%)	-	*0.59*	-
	P value	*ns*	*0.05*	*ns*
Midslope	Rip only	3.99	3.10	2.31*
	Cattle - surface	3.42	3.05	1.99
	Chicken - surface	4.94*	3.35	2.25*
	Pig - surface	3.58	2.98	1.91
	Chicken - subsoil	4.07	3.43	2.36*
	Cattle - subsoil	4.60*	3.55	2.31*
	Sheep - subsoil	4.04	3.42	2.25*
	Pig - subsoil	4.90*	3.43	2.37*
	Control	3.13	3.17	1.39
	LSD (5%)	*1.19*	-	*0.56*
	P value	*0.05*	*ns*	*0.03*

**Significantly different from the control.*

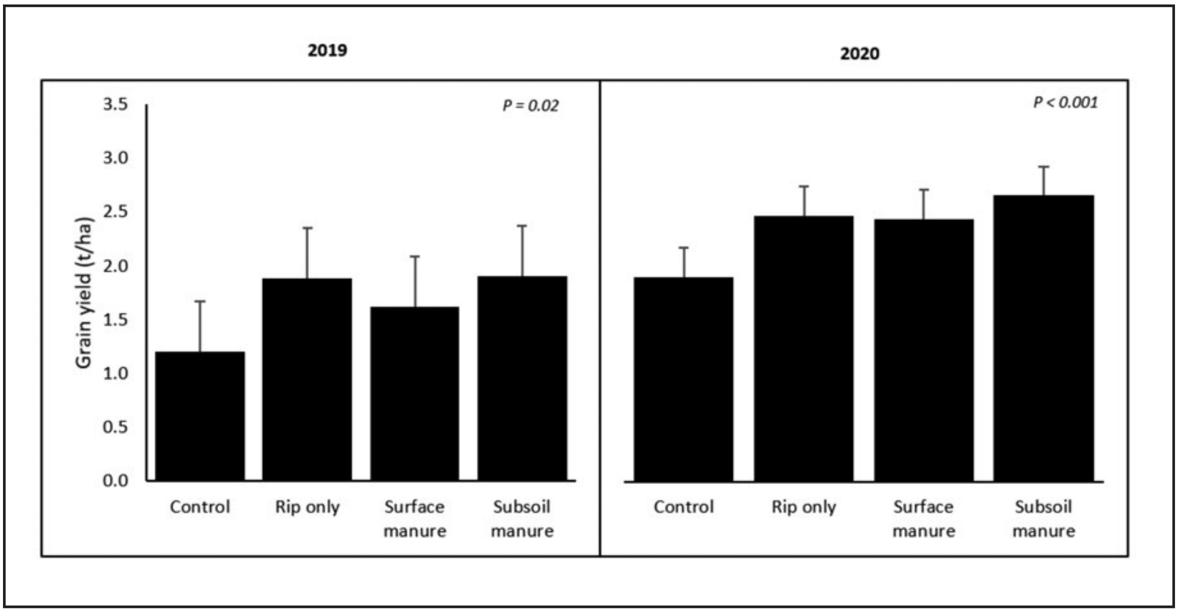

Figure 1: Cereal grain yield responses to deep ripping, and surface and subsoil manures in 2019 and 2020.

Soils

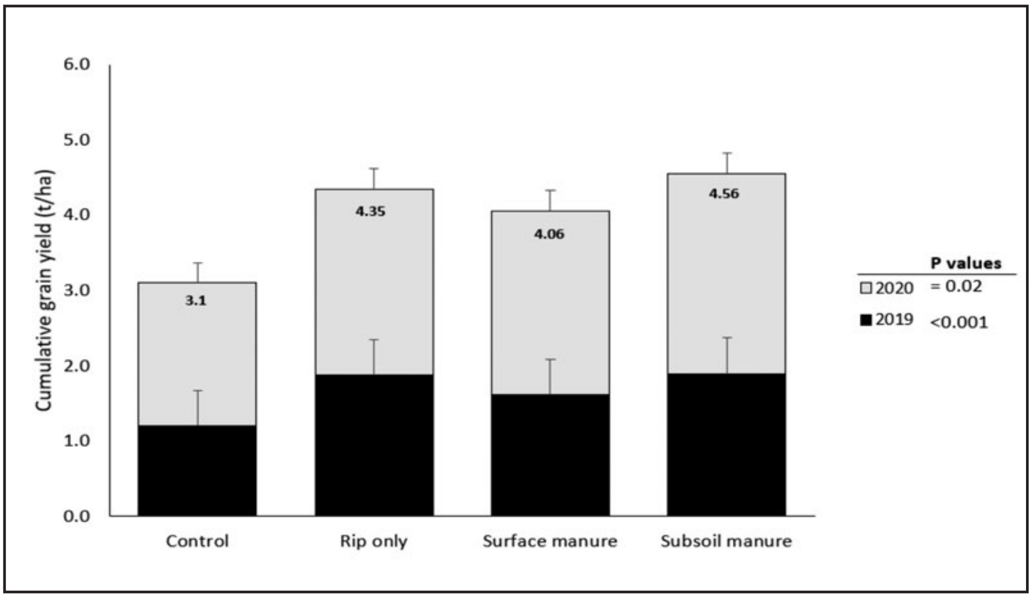

Figure 2: Cumulative grain yield (t/ha) for 2019 and 2020, in response to ripping, surface and subsoil manures. Figures shown in treatment bars indicate the total grain yield for the two seasons. 2019 crop (barley), 2020 crop (wheat).

To get a clearer overall picture of the responses, we analysed the data for both years by grouping the manures into surface and subsoil application (ignoring manure type), and also ignoring the trial location (sandhill crest, midslope). Figure 1 shows that in 2019, deep ripping and subsoil animal manures resulted in yield responses significantly better than the usual "district practice" (control), but that there was no benefit in spreading animal manures on the surface in 2019 which was a decile 1. In 2020, deep ripping and addition of animal manure resulted in increases in grain yield when compared to the control. Subsoil manures as a strategy resulted in the highest yield increase, 40%, when compared to the control last year (Figure 1).

Figure 2 shows that when grain yields are combined for the two growing seasons, all three interventions of deep ripping and adding surface or subsoil manure, resulted in higher grain yields than the control. Overall, for 2019 and 2020, grain yield responses were 31% (surface manure), 40% (deep ripping) and 47% (subsoil manure) better than the control (Figure 2).

What does this mean?

Crop yield responses to the application of organic amendments can be due to the amelioration of soil constraints, increased water use or improved nutrient supply, or all factors jointly acting together. This trial was conducted to evaluate if locally available manure can be used as a cost-effective soil ameliorant by the method of injecting slurry into the subsoil. Our results for work conducted over two growing seasons, have shown that there is a small complementary benefit to deep ripping with nutrient-rich organic matter into the subsoil of poor performing sands. A yield gain of 1.25 t/ha was achieved by ameliorating subsoil compaction using a deep ripper over 2 years, and a gain of 1.46 t/ha was achieved by deep ripping with the addition of animal manure placed in the subsoil. However, the benefit of improving subsoil nutrition by the addition of animal manure in the subsoil are far less (0.2 t/ha) than the benefit of ameliorating compaction by physical soil disturbance alone (1.25 t/ha). Soil amelioration is slow and costly; therefore, it is vital to continue to monitor the trial to assess longer-term responses.

Acknowledgements

This research was made possible by the significant contributions of Paul Rudiger and family and through both trial cooperation and the support of the GRDC (Project code: UOA2008-008RTX

Developing more informed decisions for management of infertile sandy soils in the southern Mallee region), the author would like to thank them for their continued support. We also thank SAGI for statistical analysis and support and Wayne and Genevieve Philips (Alpha Engineering) for their technical support with use of their machine; NuLeaf Organics for supplying chicken manure, Paul Rudiger for supplying cattle manure; Westbrook Feedlot - Loxton for supplying sheep manure; and Andrew Falting for supplying pig manure.

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Residual responses to ripping in the Mallee

Therese McBeath, Lynne Macdonald, Rick Llewellyn, Bill Davoren, Willie Shoobridge
CSIRO Agriculture & Food, Waite

Location
Waikerie
Schmidt family
Rainfall
Av. Annual: 253 mm
Av. GSR: 164 mm
2020 Total: 323 mm
2020 GSR: 210 mm
Yield
Potential: Wheat (Yield Prophet®) 4.0 t/ha
Actual: 2.5 t/ha
Paddock history
2019: Barley
2018: Wheat
2017: Vetch/oats
Soil type
Red alkaline sand
Plot size
1.68 m x 25 m x 4 reps
Trial design
Experimental: randomised complete block
Yield limiting factors
Soil compaction at 40-60 cm depth
Soil fertility (marginal soil test phosphorus

Location
Lowaldie
Loller family
Rainfall
Av. Annual: 337 mm
Av. GSR: 237 mm
2020 Total: 363 mm
2020 GSR: 255 mm
Paddock history
2019: Wheat
2018: Canola
2017: Wheat
Soil type
Deep neutral pH sand
Plot size
20 m x 2 m x 4 reps
Trial design
Experimental: randomised complete block
Yield limiting factors
Non-wetting, nitrogen, soil compaction at 30-50 cm, root disease

Key messages

- **Physical constraints to crop water use are present at many of our Mallee Sandy Soils (CSP00203) project sites.**
- **Across the Sandy Soils project the average yield gain from the residual (after the first year) ripping response has been 0.3 t/ha, with a range of -0.6 to +1.1 t/ha.**
- **Lowaldie had wheat yield gains of up to 1.1 t/ha, 1 year after ripping.**
- **At Waikerie there were barley yield gains of 0.4 t/ha 2 years after ripping with a 0.4 t/ha benefit from the addition of chicken litter. The benefits of ripping and chicken litter combined were 0.7 t/ha.**
- **Conventional fertiliser treatments did not deliver consistent benefits.**

Why do the trial?

The aim of this work is to increase crop water use in underperforming sandy soils in the Southern cropping region by improving diagnosis and management of constraints. Water-use and yields on sandy soils are commonly limited by a range of soil constraints that reduce root growth. Constraints can include a non-wetting topsoil-layer causing poor crop establishment, soil pH issues (both acidity and alkalinity), poor nutrient supply or 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), through to high soil disturbance interventions (deep ripping, spading, deep ploughing) that require specialised machinery. Here we discuss the 2020 results from our sites at Lowaldie (near Karoonda) and Waikerie.

How was it done?

Waikerie

A range of intensive interventions were implemented at Waikerie in 2018 to evaluate the value of increasing the depth of ripping with or without amendments (chicken litter (manure) at 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 2020 we measured the residual (3rd crop after ripping) responses to these treatments. Adjacent to the intensive treatments was an experiment testing nutrient packages applied with a seeder including combinations of nitrogen (20 kg N/ha) and phosphorus (10 kg P/ha) supplied on the surface, 3, 6 or 10 cm deep. The trials were sown with Compass barley on 6 May with 20 kg N/ha and 10 kg P/ha as urea and MAP across all treatments. 2020 was an above average rainfall season with 210 mm growing season rainfall (164 mm average) and 323 mm annual rainfall (253 mm average). There was however a dry period in June-July.

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

Site (Year)	Treatment (depth cm)	Amendment Type	Amendment Placement
Waikerie 1 (2018)	Rip (30), Rip (60)	Chicken Litter (2.5 t/ha), fertiliser matched at ripping time	deep, surface
Waikerie 2 (2018)	Seeder (8,15)	Fertiliser (N, P)	At furrow depth
Lowaldie (2019)	Rip (40), Rip (60)	Nil	

Table 2. Barley yields at Waikerie in response to fertiliser treatments. Results with a different letter are significantly different from each other (P=0.05).

Treatment	GS31 biomass (t/ha)	GS65 biomass (t/ha)	Grain Yield (t/ha)
Nil	0.71 b	3.34	1.73
MAP broadcast	0.79 ab	3.25	1.82
MAP with seed	0.88 ab	3.94	2.08
MAP @ 6 cm	0.99 ab	3.32	1.87
MAP @ 10 cm	0.89 ab	3.52	1.82
MAP + Urea @ 10 cm	1.07 ab	3.63	1.90
MAP @ 6 cm + Urea topdress early	0.88 ab	3.71	1.93
MAP with seed + Urea @ 6 cm	1.02 ab	3.91	1.91
MAP @ 10 cm + Urea topdress early	1.00 ab	3.74	1.94
MAP with seed + Urea @10 cm	1.10 a	4.41	1.86
LSD (P=0.05)	*0.24*	*ns*	*ns*

Lowaldie

A trial was established on two soil types (dune crest and deep sand) at Lowaldie in 2019 testing the response to nil, 40 cm or 60 cm ripping depth (Table 1). The plots were sown in 2020 with Vixen wheat on 14 May. Soil moisture was good at the time of sowing with 175 mm water in the top metre in all treatments. Ten kg P/ha was applied at sowing and a total of 65 kg N/ha was applied through the season (40 kg N/ha at sowing, 15 kg N/ha on 1 July and 20 kg N/ha on 7 July). 2020 was an average rainfall season with 254 mm growing season rainfall (237 mm average) and 363 mm annual rainfall (337 mm average). Rainfall in June-July was below average.

What happened?

Waikerie

At the time of sowing there was good moisture throughout the profile with an average of 113 mm water to 1 m depth, and strong carryover of N from the dry season of 2019 with 89 kg mineral N/ha/m depth in control plots.

The fertiliser experiment was affected by rhizoctonia pruning of crown roots early in the season and showed some small responses to fertiliser addition early in the season, despite high levels of variability, but this did not translate to a grain yield benefit.

In the ripping experiment, the 2020 response to ripping alone averaged 0.38 t/ha and ripping to 60 cm was similar to ripping to 30 cm (Figure 2). The response to chicken litter averaged 0.4 t/ha but the effects of ripping and chicken litter combined were not additive with the best treatment (rip 60 cm with chicken litter deep) yielding about 0.7 t/ha greater than the control (Figure 2).

These responses follow no or negative responses (to 60 cm rip treatments in 2019) and small positive responses (+0.3 t/ha) in the year of ripping (2018), (Figure 2). The experiment will continue for a further 2 years to evaluate the longevity of physical and nutrient carry-over effects.

Lowaldie

At the time of sowing there was good soil moisture in the profile (175 mm/m) but mineral N tests indicated low N availability with 17 to 22 kg N/ha/m. Ripping in 2019 generated substantial wheat yield benefits in 2020 with 0.53 to 0.85 t/ha increases with ripping to 40cm and 0.67 to 1.09 t/ha increases with ripping to 60 cm depending on the soil type (crest shallower sand vs. dune deep sand) (Figure 2). There was no difference in response according to soil type in 2020, but we will continue to monitor to inform the question of which soil types are most responsive to ripping.

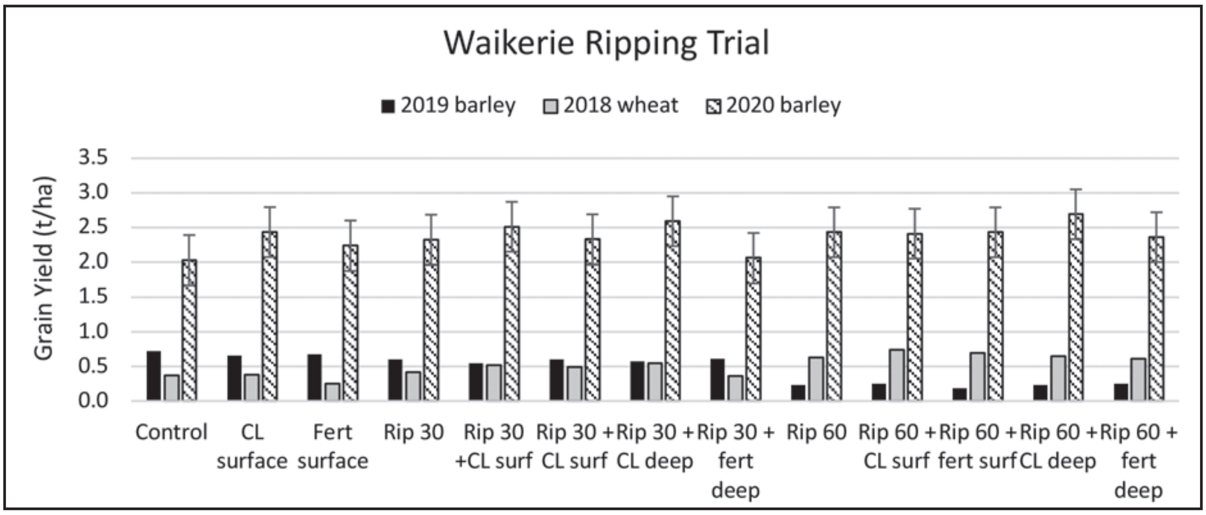

Figure 1. 2020 Barley yields (t/ha) (green columns) presented alongside 2018 and 2019 responses (grey and black) at Waikerie in response to treatments implemented in 2018; ripping (Rip30, Rip60) with and without 2.5 t/ha chicken litter (CL) or matched nutrients from fertiliser (fert) applied at the surface (surf) or deep. The error bars represent least significant difference (P=0.05, LSD 0.36 t/ha in 2020).

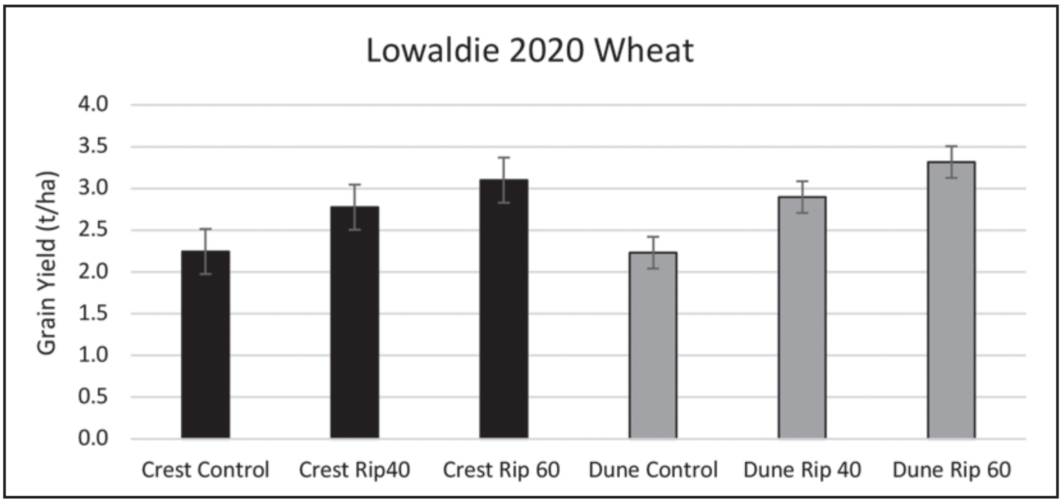

Figure 2. Wheat yields at Lowaldie in response to ripping treatments. Error bars represent least significant difference (P=0.05, LSD 0.27 crest and 0.19 dune t/ha).

What does this mean?

Large physical interventions (ripping, spading, deep cultivation) can improve crop productivity in compacted sandy soils, but there are risks of small yield benefits or even yield loss in very low rainfall seasons which can be difficult to recover from. At a cost of $100/ha for ripping, the Waikerie and Lowaldie sites have strongly contrasting risk vs. reward outcomes (Waikerie 3-year yield response +0 to 0.2 t/ha and Lowaldie 2-year yield response +1.7 t/ha). The ability to further increase yield gains by incorporating amendments (fertilisers, litter or manure, hay or straw) is not as well understood but can generate benefits in above average rainfall conditions.

Acknowledgements

The research undertaken as part of this project is made possible by the significant contributions of growers through both trial cooperation (Schmidt and Loller families) and the support of the GRDC. The broader Sandy Soils Project team is gratefully acknowledged for valuable input. CSP00203 acknowledges industry collaboration with Groocock Soil Improvement, Peats Soils & Garden supplies and Neutrog.

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Mitigation options to increase crop establishment on water repellent sands

Jack Desbiolles[1], Melissa Fraser[2], Nigel Wilhelm[3] and Hugh Drum[3]

[1]The University of South Australia, [2]Rural Solutions SA Straun, [3]SARDI Waite

Location
Coombe
Rodney and Jeremy Lush
Hyfield Pastoral
Rainfall
Av. Annual: 460 mm
Av. GSR: 342 mm
2020 Total: 389 mm
2020 GSR: 308 mm
Soil type
Deep non-wetting sand
Plot size
1.68 m x 25 m x 4 reps
Paddock history
Lucerne long term pasture (last 10 years)
Plot
3.6 m x 30 m x 3 reps (main plots)
1.2 m x 30 m x 3 reps (sub-plots)

Key messages

- **Low-cost, low risk seeder-based strategies increased barley establishment on a severely water repellent sand at Coombe in the Upper South East.**
- **A seed-zone wetter and a seed-zone+furrow-surface split soil wetter increased establishment on a sandy rise and a sandy flat, while a wetter applied to the furrow-surface benefited on the flat only. The greatest improvements (+27-34 plants/m^2) occurred by combining soil wetters with 110 mm wide press-wheel tyres.**
- **The limited crop establishment benefits overall may have been due to furrow in-filling from strong winds experienced the day after sowing.**
- **The seed zone and split soil wetters achieved yield gains of 0.2-0.25 t/ha while no measurable impacts of press-wheel type could be detected.**
- **Along with a broader suite of trials, this work highlights the importance of stable furrows along with appropriate placement of wetting agents to maximise establishment benefits in repellent sands.**

Why do the trial?

Water repellent sands prevail throughout the upper South East, impacting crop establishment and subsequent grain yields. Clay application has been widely adopted as an amelioration strategy for water repellence in the region, but there are large areas extending from east of Keith to Coomandook that do not have suitable/any clay for spreading. Mitigation options, such as wetting agents and seeder-based strategies, have shown promising results in recent research trials on the Eyre Peninsula (Desbiolles *et al*. 2020). This trial aimed to validate those results in the Upper South East, testing the hypothesis that cereal crop establishment can be improved on water repellent sands using low cost, low risk approaches.

How was it done?

The host farm lies in a 340 mm GSR rainfall zone and is mostly non-wetting sands. The trial paddock has a soil with a dark grey 0-11 cm top layer, highly repellent with MED 4-4.5, above non-wetting white sand transitioning to wettable yellow sand patches in the range of 20-35 cm depth, with orange loam at depths of 70-90 cm. The paddock had been a lucerne pasture over the last 10 years, under rotational grazing (4-4.5 DSE/ha) with 100 kg/ha of single super phosphate annual input. DNA soil testing of the 0-10 cm layer prior to testing showed high risks of rhizoctonia and common root rot. Table 1 summarises the chemical analysis of the upper soil layers.

Two identical trials with 3 replications were established on two nearby sites in the same paddock, namely a heavier flat and deeper sandy rise. The trials were sown using a 24 row John Shearer combine direct drill equipped with inverted T points (50 mm wide, level lift wings) set at 20 cm row spacing for single shoot seeding and with 80 mm wedge press wheels. Five different seeder treatments (Table 2) were evaluated. Within each seeder run, 3 sections of 6 rows each had different press-wheels (Figure 1). The wider press-wheel tyres were expected to improve furrow stability and water harvesting potential. All press wheels were set under a constant 2 kg/cm tyre width of down pressure.

Table 1. Initial 0-30 cm soil chemical analysis.

Depth	pH ($CaCl_2$)	OC %	CEC cmol+/kg	EC dS/m	Colwell P mg/kg	DTPA Zn mg/kg	DTPA Cu mg/kg	DTPA Mn mg/kg
0-10	5.9	1.15	3.9	0.065	18	1.8	0.35	2.6
10-30	5.6	0.3	1.65	0.045	10	0.25	0.17	0.5

Table 2. Details of the seeder main treatments and associated agronomy.

Seeder Main Treatments	Details	Soil Wetter (100 L/ha volume)	Notes
Farmer practice	9 km/h, single shoot fertiliser+seeds, 3-4 cm sowing depth, low tine break-out (35 kgf)	1 L/ha on furrow surface (*Soak n Wet* from Vic Chemicals)	Knockdown (Glyphosate 540 2.5L/ha +Dicamba 500 0/5L/ha +Goal 100mL/ha +SoA 1.5%) spray pre-sowing, no-till seeding with 1.5L/ha trifluralin 480 incorporated by sowing; 5L/ha TE blend (5.8% Zinc, 8.6% Manganese, 0.9% Copper) in 100 L/ha applied together with soil wetters or in the seed zone where no wetter was used, MAP/SoA fertiliser mix applied at 85 kg/ha (= 12N+18P+6S+0.8Zn)
Improved seeder baseline* (NB: no wetter)	6km/h**, surface-applied fertiliser prior to seeding, 4-5 cm sowing depth, higher tine break-out setting (80 kgf)	N/A	
Improved seeder baseline plus furrow-surface wetter		4 L/ha on furrow surface (*Soak n Wet* from Vic Chemicals)	
Improved seeder baseline plus seed-zone wetter		3 L/ha in the seed zone (*SE14* from SACOA)	
Improved seeder baseline plus split wetter[¥] (50:50 seed-zone and furrow-surface)		Split 1.5+1.5 L/ha (*Bi-Agra Band* from SST Australia)	

**Improved seeder baseline was set-up and operated to reduce risks of crop establishment losses; **controlled speed for minimal furrow ridging and a lesser risk of pre-emergence crop damage; [¥]Split zone wetter applied at 2 x 100 L/ha Keys: SoA: Sulphate of Ammonia; MAP: Mono-Ammonium Phosphate.*

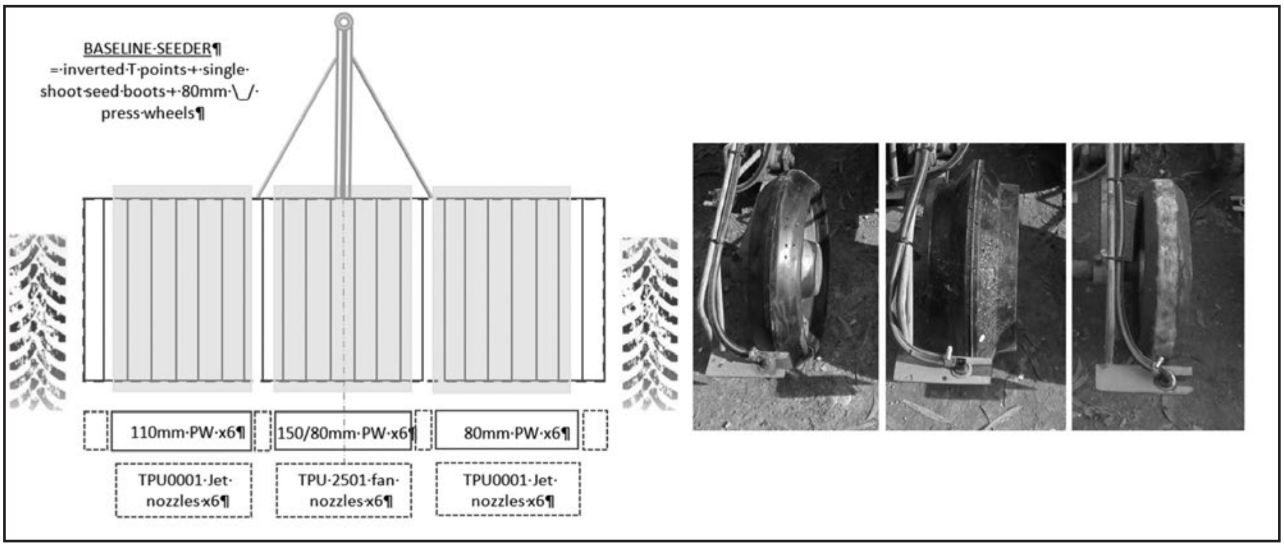

Figure 1. Seeder configuration showing 6 row wide sections contrasting 3 press-wheel types. Pictures from L to R: 110 mm, 150/80 mm and 80 mm wide tyres.

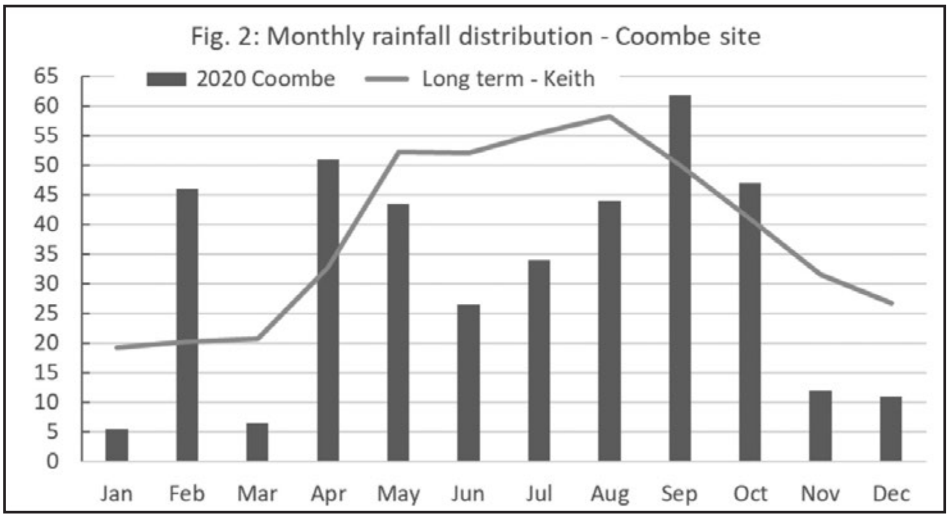

Figure 2. Monthly rainfall (mm) at Coombe, SA in 2020 (shown in bars) and long term average at Keith, SA (shown as line).

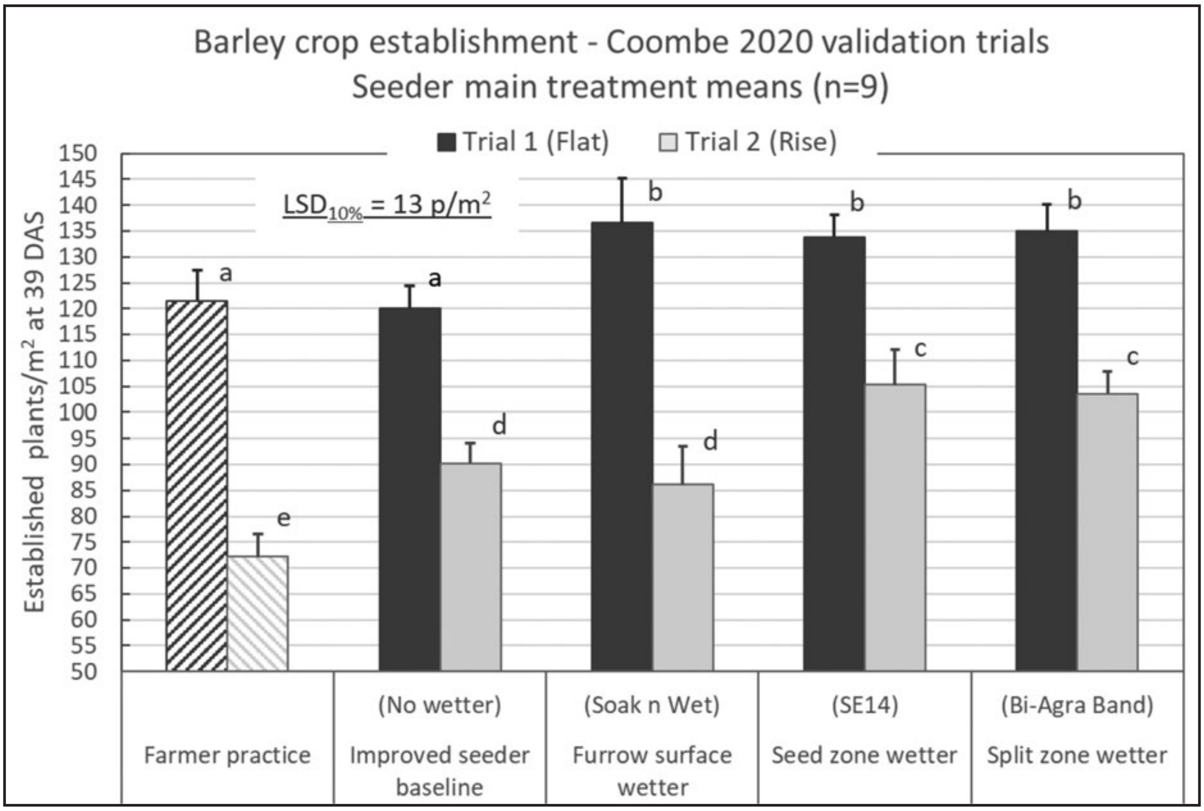

Figure 3. Barley crop establishment overview at the 2 sites (Error bars represent 1 std error of the mean).

Spartacus CL® barley (33.5 g/1000 grains and 94% germination) were treated with Rancona Dimension (3.2 L/t), Zincflow Plus - Thiamethoxam (3 L/t) and Cruiser (1 L/t) and sown at 63.8 kg/ha (=176 seeds/m^2, targeting 140 established plants/m^2) on 29 May 2020. Following 48 mm rainfall in 4 events over the month prior to seeding, soil moisture at seeding was a dry 3-5 cm top layer over good moisture at depth. Post-sowing rainfall was favourable with 18 mm (2-3 DAS), 13 mm (16-17 DAS), and 25 mm (34-36 DAS). A very strong wind event the day after sowing induced significant erosion which resulted in furrow in-fill cancelling press-wheel furrow differences. SoA at 100 kg/ha (21N+24S) was applied at 85 DAS. The growing season was slightly below average with a 61 mm deficit over June-August period followed by an above average spring finish (See monthly rainfall distribution in Figure 2).

What happened?

Trial 1 on the flat established best at 129 plants/m^2 on average (74% establishment), while the exposed Trial 2 on the rise established at 92 plants/m^2 (52% establishment).

The seeder main treatments ranked as follows:

Trial 1: all three soil wetter treatment improved crop establishment similarly, relative to both the improved baseline seeder and farmer practice, which did not differ.

Trial 2: the farmer practice performed worse than the improved seeder baseline. While the furrow-surface wetter did not result in any gain over the improved seeder baseline, both the seed zone wetter and the split wetter treatments significantly improved crop establishment.

Overall, the seed zone wetter and split wetter increased crop establishment by 14-15 plants/m^2 (or 12-17%) at both sites, while the furrow-surface wetter only produced a benefit on the flat. (Figure 3).

The farmer practice had lower establishment in the drier soil conditions on the rise. This treatment included combined fertiliser placement, shallower seeding with low (35 kgf) tine break out (=greater seed placement scatter) and a low rate (1 L/ha) of the furrow surface soil wetter. In contrast, the improved seeder baseline applied fertiliser separate from the seeds (on the surface in a prior pass), targeted slightly deeper sowing with high (80 kgf) break-out, and was a no soil wetter control.

The impact of press wheels ranked as follows: 110 mm >(150/80 mm =80 mm). A consistent benefit (extra 14-17 plants/m^2 or 14-21%) was measured at both sites under the 110 mm (widest) water harvesting tyre (Table 3). The 150/80 mm shouldered tyre, has a similar water harvesting furrow width to the 80 mm reference tyre and showed no improvement (Note: This tyre design consolidates the furrow shoulders to help with furrow stability and could be combined with a wider V tyre).

The above results show moderate but consistent benefits from the use of soil wetters and wider press wheel tyre technology at the site this season. Their combined benefits on crop establishment achieved an extra 25-34 plants/m^2 (29-38%) on the rise and an extra 25 plants/m^2 (22%) on the flat (see Table 4).

Harvesting was conducted on 30 Nov 2020 under favourable conditions, with the sites on the flat and on the rise averaging 4.37 t/ha and 2.48 t/ha, respectively. Grain yield was the same for all press-wheel types at both sites. The seed zone applied soil wetters (SE14), or the 50:50 split applied soil wetter (Bi-Agra Band) increased grain yields on the rise by 0.23 t/ha (9.3%) and 0.2 t/ha (8%), respectively, relative to the no wetter seeder baseline. Differences were less reliable on the sandy flat where the split applied wetter performed best (0.22 t/ha or 5% gain) relative to the no wetter control (Table 5).

Soil

Table 3. Mean effects of press wheel tyre type on established plants/m^2 at the 2 sites.

Press wheels / Trial site	Flat	Rise
100 mm tyre	140^a	103^c
150/80 mm tyre	126^b	88^d
80 mm tyre	123^b	85^d
LSD (5%) = 12.1		

Table 4. Plants/m^2 gains from a 110 mm wide press wheel tyre combined with soil wetters, over the no-wetter seeder baseline crop establishment.

Treatments (*LSD (10%) = 22 planst/m^2*)	Press wheel tyre	Trial sites	
		Flat	Rise
Reference seeder baseline (no wetter) establishment	80 mm	120	88
+ *Soak n Wet* 4 L/ha on furrow surface		+27	+12 ns
+ *SE14* 3 L/ha in seed zone	110 mm	+25	+34
+ *Bi-Agra Band* 1.5+1.5 L/ha at both locations		+25	+26

Table 5. Effect of main factors on grain yield (t/ha) at Coombe in 2020.

Main seeder treatments	Grain Yield t/ha	
	Trail 1 (FLAT)	Trial 2 (RISE)
Farmer practice	4.27 a	2.48 ab
Improved seeder baseline (no wetter)	4.38 ab	2.37 a
Furrow surface wetter (Soak n Wet)	4.34 a	2.40 a
Seed zone wetter (SE14)	4.26 a	2.60 b
Split zone wetter (Bi-Agra Band)	4.60 b	2.57 b
LSD (10%)	*0.26*	*0.14*
110 mm tyre	4.33 a	2.50 b
150/80 mm tyre	4.42 a	2.51 b
80 mm tyre	4.36 a	2.44 b
LSD (10%)	*0.26*	*0.14*

What does this mean?

This trial was conducted to validate some of the better performing seeder strategies identified over 2 years of trials in a strongly water-repellent sand at Murlong on Eyre Peninsula. While treatment benefits were small in 2020 at Coombe, they were probably compromised by press-wheel furrow in-filling from the strong winds experienced after sowing. The results are consistent with prior experience that soil wetters perform best when combined with stable and large water harvesting press wheel furrows. The best-practice advice for seeder strategies to improve crop establishment in non-wetting sands remains that the use of soil wetters be combined with stable and functional water-harvesting furrows.

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J Desbiolles, N Wilhelm, M Fraser, L Macdonald, T McBeath and J Barr (2020). Seeder-based approaches to reduce the impact of water repellence on crop productivity. GRDC research update, 10-11 Feb 2020, Adelaide Convention Centre (see https://grdc.com.au/resources-and-publications/grdc-update-papers?result_236771_result_page=4)

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Increasing adoption of new techniques combining physical, chemical and plant-based interventions to improve soil function on Eyre Peninsula

David Davenport[1] and George Pedler[2]

[1]Davenport Soil Consulting, [2]George Pedler Ag

Location
Brooker: Jason Challinger
Wharminda: Evan & Ed Hunt
Koongawa: Todd Matthews
Elbow Hill: Jon Hills
Greenpatch: Mark Modra
North Shields: Mark Modra
Mt Dutton: Bruce Morgan
Streaky Bay: Phil Wheaton
Buckleboo: Brett Zibell

BOM av. rainfall / 2020 rainfall
Brooker: 398 mm / 380 mm
Wharminda: 338 mm / 311 mm
Elbow Hill: 281 mm / 285 mm
Greenpatch: 522 mm / 525 mm
North Shields: 389 mm / 485 mm
Mt Dutton: 519 mm / 487 mm
Streaky Bay: 377 mm / 312 mm
Buckleboo: 291 mm / 325 mm

Soil type
Brooker: Deep sand over clay
Wharminda: Sand over clay
Koongawa: Sand over clay
Elbow Hill: Brown calcareous sandy loam
Greenpatch: Gravelly fine sandy loam
North Shields: Gravelly sandy loam
Mt Dutton: Sodic sandy clay loam
Streaky Bay: Grey calcareous loamy sand
Buckleboo: Red calcareous sandy loam

Plot size
2 m x 25-30 m x 3 reps

Trial design
Farmer managed demonstration (randomised)

Key messages

- **Deep ripping with inclusion plates generally resulted in lower plant numbers than unripped plots.**
- **Yield increases to ripping were observed mainly in sandy and calcareous soils.**
- **Treatments including the incorporation of mineral nutrients and organic amendments delivered mixed results but were generally the highest yielding treatments.**

Background

Trials and demonstrations involving soil mixing either with a spader or ripping with inclusion plates have been shown to increase yields on sandy soils on Eyre Peninsula (EP). Many of these trials have included the addition of organic material incorporated at rates of 5-10 t/ha. Whilst generally these treatments have provided yield increases for a number of years post application, the rates applied have proven to be uneconomic (EPFS 2019, p 71).

This project was originally developed by the Lower Eyre Ag Development Association (LEADA) with two major objectives being:

1. To test ripping with inclusion plates on a wider range of soils.
2. To trial rates and sources of organic matter that are practical for broadacre use.

How was it done?

The project steering committee selected 5 sites in both Lower and Upper EP.

Sites were chosen to represent a range of soils with constraints and included:

- 4 sands ranging from shallow to deep sand over clay - Treloar, Matthews, Hunt and Challinger.
- 3 calcareous soils - Wheaton, Zibell and Mills.
- 3 Ironstone / poorly structured soils - Modra (2 different locations) and Morgan.

The Modra Greenpatch site aimed to improve the outcome of ripping with foliar treatments whilst the other nine sites compared an unripped control to ripping and to ripping with amendments (Table 1). Treatments were replicated three times at all sites but not every site received the same suite of treatments. Amendments and soil mixing were applied during March to April 2020. Amendments included an animal manure and a nutrient package with similar elemental rates of N, P and trace elements to the manure application. The package was applied either directly to the soils or pre-sorbed to "Biogro" Biochar and wheat straw pellets (Table 1). Amendments were spread across the whole plot (Matthews, Hunt, Mills) or along furrows corresponding with ripper tyne spacings.

Following application of the product all sites were ripped to 25-40 cm deep using either a ripper with inclusion plates or a spader (Matthews site only). Inclusion plates were set at approximately 100 cm below the soil surface, except for the Treloar site where the shallow clay meant the top of the plates were level with the soil surface. The Modra GP site included a calcium foliar spray with/without ripping and foliar chelated trace elements compared to sulphates. Sowing and in-crop management was undertaken by the landholder with all plots receiving the same basal fertiliser application.

Biogro biochar is a low-grade, relatively cheap ($270/tonne at the source) biochar made from forestry waste. It was selected as it has low nutrient value allowing for assessment of a carbon only benefit

What happened?

Seasonal conditions ranged from good in the south with the Treloar and Morgan sites delivering historically high yields. The Wheaton and Mills sites were impacted by low growing season rainfall and weed competition (particularly on the Wheaton site).

Production monitoring included plant numbers, biomass and yield. Plant numbers were generally more variable and lower on ripped treatments than the nil. This is not unusual following ripping due to the uneven soil surface created. Also, the use of farmer seeding equipment that crossed a number of plots resulted in some rows being buried. This variation may have contributed to the large error bars observed in biomass and yield data. Full data analyses are yet to be completed and cannot be covered in detail in this article.

While the data needs to be treated with caution initial observations include:

- No significant biomass or yield differences in treatments observed on the Treloar and Zibell sites.
- On the Morgan site there were no significant differences between treatments. However, all ripped treatments recorded higher yields than the nil with the rip treatment 127% of the control. The Modra sites showed strong visual responses to ripping with some visual differences between amendments. However, there were no significant yield differences between treatments.
- On sandy soils spading/rip treatments delivered yields ranging from 117-137% of the nil. The addition of amendments further increased yield with the best performing treatment (biochar + nutrient + rip) delivering yields ranging from 124-214% of the nil.
- Of the highly calcareous soils low yields and large error bars have added to the difficulty in interpreting the data. At the Mills site the yield of the rip treatment was 133% of the nil, the biochar + nutrient + rip treatment was 160% of the nil. Despite some early visual differences ripping alone resulted in no yield increase on the Wheaton site. The best performing treatment on this site was the low rate biochar + nutrient + rip that delivered 124% yield of the nil treatment.

Table 1. Treatments applied at EP sites in March and April 2020.

Treatment	Product	Amount of product (kg/ha)
Nil		N/A
Ripping		N/A
Biochar + Rip	Biochar	680*
Biochar LR + Nutrient + Rip	Biochar, + P, UAN, Cu Zn, Mn	200
Biochar HR + Nutrient + Rip	Biochar, + P, UAN, Cu Zn, Mn	680
Wheat stubble + Nutrient + Rip	Wheat straw pellets + P, UAN, Cu Zn, Mn	1000
Manure + Rip	Neutrog animal manure	1000
Nutrient + Rip	Phosphoric acid, UAN, Cu Zn, Mn	**P 20, N 30, Cu 2, Zn 5, Mn 7

**Mills site applied at 1200 kg/ha, ** Elemental rates.*

Table 2. Soil monitoring activities.

Analyses	When taken	Sites	Treatments
Mineral N and water	Germination	All except Modra GP	All
Soil enzymes	Germination	Challinger, Hunt, Modra NS, Mills, Wheaton	Various (Table 3)
Soil chemistry	Post-harvest	All	Nil, Nutrition + Rip, Biochar + nutrition + Rip
Bulk density	Post-harvest	All	Nil, ripped

Table 3. Soil enzyme activity (mmol/g/h) 10-30 cm layer. NAG - carbon and nitrogen; P - phosphorus; S - sulphur; GLC - carbon; LEU - nitrogen; ACE - non-specific.

Site	Treatment	NAG	P	S	GLC	LEU	ACE
Challinger	Nil	0.07	0.56	0.01	0.11	0.07	0.49
Challinger	Neutrog	0.62	1.42	0.02	0.57	0.15	2.21
Hunt	Nil	0.07	0.46	0.01	0.09	0.04	0.30
Hunt	Nutrition	0.66	2.19	0.02	1.03	0.18	5.85
Hunt	Neutrog	0.61	1.78	0.02	0.63	0.20	4.20
Hunt	Biochar	0.40	1.24	0.02	0.54	0.13	3.24
Hunt	Biochar + Nutrition	0.53	1.47	0.02	1.12	0.20	4.75
Mills	Nil	0.16	0.06	0.01	0.75	0.72	7.50
Mills	Nutrition	0.15	0.41	0.02	0.95	1.43	20.64
Mills	Wheat straw + Nutrition	0.13	0.46	0.03	1.33	1.79	19.63
Mills	Biochar + Nutrition	0.09	0.39	0.02	0.74	1.39	20.21
Modra NS	Nil	0.24	0.93	0.02	0.32	0.06	7.79
Modra NS	Nutrition	0.51	1.31	0.03	0.81	0.12	7.65
Modra NS	Neutrog	0.25	1.12	0.03	0.55	0.15	7.89
Modra NS	Biochar + Nutrition	0.52	2.19	0.04	1.36	0.26	10.80
Wheaton	Nil	0.36	0.27	0.01	0.35	0.97	16.12
Wheaton	Nutrition	0.37	1.40	0.03	2.63	2.25	27.66
Wheaton	Wheat straw + Nutrition	0.59	1.20	0.03	3.04	1.95	22.53
Wheaton	Biochar + Nutrition	0.46	0.17	0.01	0.31	1.10	14.03

Table 4. Post-harvest soil Colwell P (mg/kg) at 5 sites.

Treatment	Sample Depth (cm)	Hunt	Matthews	Mills	Zibell	Morgan
Nil	0-10	32	13	26	27	63
Nil	10-30	8	<5*	<5*	<5*	15
Nutrition + Rip	0-10	27	12	31	23	68
Nutrition + Rip	10-30	20	9	<5*	<5*	23
Biochar + Nutrition + Rip	0-10	34	16	50	33	27
Biochar + Nutrition + Rip	10-30	20	12	12	6	12

** levels of <5 are considered below detectable limits*

Soil Impacts

Due to budget limitations soil monitoring was targeted to reflect the different treatments, soil types and site responses (Table 2).

There were minor differences in soil water levels between treatments. Soil mineralised nitrogen at germination was highly variable at each site with no clear trends obvious. With support from the Soil CRC and NSW DPI bioassays of soil enzymes were conducted on targeted treatments on some sites. This form of analysis is providing further understanding of changes to soil biology under different management systems. The enzymes measured are representative of nutrients cycled including: NAG - carbon and nitrogen; P - phosphorus; S - sulphur; GLC - carbon; LEU - nitrogen; ACE - non-specific. Results showed little difference in enzyme numbers in the 0-10cm layer but major differences in enzyme numbers on the rip lines in the 10-30 cm layer (Table 3).

Whilst statistical analysis has not been conducted there appears to be some interesting results in Colwell phosphorus (Colwell P). This analytical method has been used to provide an indication of "plant available" phosphorus in the soil. While there are questions on validity of this test in some soils the analyses received to date (Table 4) suggests:

- On sands (Hunt, Matthews) the nutrition treatment has had limited impact on Colwell P in the 0-10 cm layer but has increased P in the 10-30 cm layer. However, the biochar + nutrient treatment has delivered even larger increases in both layers.
- In calcareous soils (Mills, Zibell) the treatment differences are even greater with only the biochar + nutrition treatment providing any Colwell P in the 10-30 cm layer.
- On an acidic soil (Morgan) the biochar + nutrition treatment has resulted in a decline in Colwell P levels.

What does this mean?

- Practices and/or crop selection options to deliver more even plant germination on recently ripped areas need to be developed.
- Ripping on shallow sand over clay soils (i.e. Treloar) where inclusion plates were ineffective may not deliver production responses.
- The responses to biochar + nutrients on some sites require further research and raises the question: can a fertiliser product including carbon be produced to deliver similar results?
- In calcareous soils the difference in Colwell P levels in the biochar + nutrient treatment compared to the nil are greater than the amount of P applied. Phosphorus levels need to be validated and further research on biochar and the influence on plant available P needs to be conducted.
- To properly evaluate the cost effectiveness of treatments a number of sites will need further monitoring to determine if responses are maintained.

Acknowledgements

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Persistence of the herbicide clopyralid in Eyre Peninsula soils

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Location
Minnipa
Rainfall
Av. Annual: 325 mm
Av. GSR: 241 mm
2020 Total: 255 mm
2020 GSR: 367 mm
Soil type
Red loam
Paddock history
2020: Self-regenerating medic pasture
2019: Spartacus barley CL
2018: CL Chief wheat
Plot size
12 m x 1.7 m x 3 replicates

Key messages

- **Clopyralid herbicide carryover may harm some legumes - a sensitivity ranking of species to the herbicide has been established.**
- **Clopyralid persistence and crop toxicity is affected by soil type, rainfall and their interaction.**
- **Clopyralid can be released from stubble, so stubble management needs to be considered for managing potential carryover damage.**

Why do the trial?

The overall aims of this work are to determine the persistence of clopyralid herbicides over multiple seasons in different soil types and whether 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. However, damage was avoided in most cases by growing crops tolerant to the herbicides (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 predict 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 measured the persistence of clopyralid at several different sites in the 2019 and 2020 seasons. This article is an update on work presented in the 2019 EP Farming Systems Summary, p 105. Here we present data from four sites for the 2019 season and carryover into the 2020 season.

How was it done?

The persistence of clopyralid was measured at four field sites during the 2019 growing season through until mid-2020. Site details, including soil characteristics and herbicide application details, are provided in Table 1.

Four soil samples comprising of homogenised sub-samples each were taken from quarter grids within a 100 m by 100 m georeferenced grid at participating farmer paddocks prior to sowing the 2019 winter crop (Mar-April 2019), at two depths: 0-10 cm and 10-30 cm. Repeated soil sampling occurred throughout 2019 and 2020 after the application of the clopyralid according to the following schedule: 1, 7, 21, 42, 84, 168, 364 days (d) after herbicide application. Soil samples were refrigerated and transported to NSW DPI, where they were dried at 40°C and then stored frozen until analysis for herbicide residues. Herbicides were extracted from soils, derivatized and analysed via GC-MS, with spike-recoveries for each soil type to ensure satisfactory sensitivity, accuracy and precision.

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

Site	Location	Soil type	Crop	Product	Date of application	Product Rate (L/ha)
SA1	Minnipa	Red loam	Barley (cv Spartacus)	Lontrel Advanced 600	25 June 2019	0.075
SA2	Poochera	Grey alkaline sandy loam	Wheat (cv Scepter)	Lontrel Advanced 600	25 June 2019	0.05
SA3	Minnipa	Sand	Self-regenerating medic pasture	Lontrel Advanced 600	23 July 2019	0.045
SA5	Mt Cooper	Red loam	Wheat (cv Scepter)	Lontrel Advanced 600	4 July 2019	0.04

In conjunction with the field trials, dose-response bioassays were conducted for clopyralid in washed pool sand or soil taken from the trial site at Minnipa Agricultural Centre, paddock N7 (SA1). Large volume topsoil samples taken in 2019 prior to herbicide application were transported to NSW DPI Wollongbar, air dried, homogenised and sieved to <2mm. Subsamples (20 kg) were then spiked with increasing concentrations of either herbicide, with six levels ranging from 0 - 100 ng/g (with ~50 ng/g equivalent to an application rate of 0.125 L/ha of Lontrel Advanced 600, distributed in top 0-10 cm profile). Residue levels were confirmed by liquid chromatography/ mass spectrometry. Wheat (cv Scepter), barley (cv La Trobe), canola (cv Diamond), lupin (cv PBA Batemen), field pea (cv PBA Butler), chickpea (cv PBA Slasher), faba bean (cv Nasma) or lentil (cv PBA Bolt) were sown into pots (dimensions 65 mm by 65 mm and 160 mm depth, filled with 140 mm soil kept moist to 80% field capacity by mass). Plants were harvested 21 d after sowing by cutting shoots at the soil surface, drying them at 60°C for 2 days and weighing to determine dry weight. Dose-response thresholds were determined for sand or soil by fitting shoot dry weight data to sand/soil clopyralid concentrations using 4 parameter log-logistic curves and the 'effective dose' for 20% shoot biomass reduction (ED20) was calculated, using the package 'drc' (Ritz *et al*., 2015) in the R statistical soft-ware environment (R Core Team, 2019).

What happened?

As expected, bioassays showed that wheat, barley and canola were all tolerant to soil residues of clopyralid at rates representative of label rates (Table 2). The legumes tested were all sensitive, with the order of tolerance (from least to most sensitive in terms of shoot biomass at 21 d) being lentil ~ field pea <chickpea <faba bean <lupin (Table 2). Toxicity thresholds in the Minnipa soil (6% clay) were approximately 5 times higher than when the crops were grown in pure (washed pool) sand, showing the role that soil type can have on the bioavailability and hence toxicity of herbicide residues (Figure 1). This type of information is currently not widely available but is necessary to be able to interpret results from soil testing for herbicide residues.

Figure 1. Phytotoxicity dose-response of clopyralid residues toward field peas in (Left) sand and (Right) soil (sandy loam, Minnipa, SA). Within each photo, the clopyralid dose increases from control (no clopyralid) on the far left, to label rate (~ 50 µg/kg) on the far right.

Table 2. Preliminary phytotoxicity dose thresholds (ng/g) for 20% shoot biomass reduction (ED_{20}) for different crop species growing in sand or soil spiked with clopyralid. Note that these data have not yet been finalised and may be slightly different depending on best model fits.

Species	Sand	Minnipa Soil (6% clay)
Lentil	0.5	3.4
Field pea	0.6	1.9
Lupin	8.8	54
Chickpea	0.5	6.2
Faba bean	3.2	25
Wheat	>100	>100
Barley	>100	>100
Canola	>100	>100

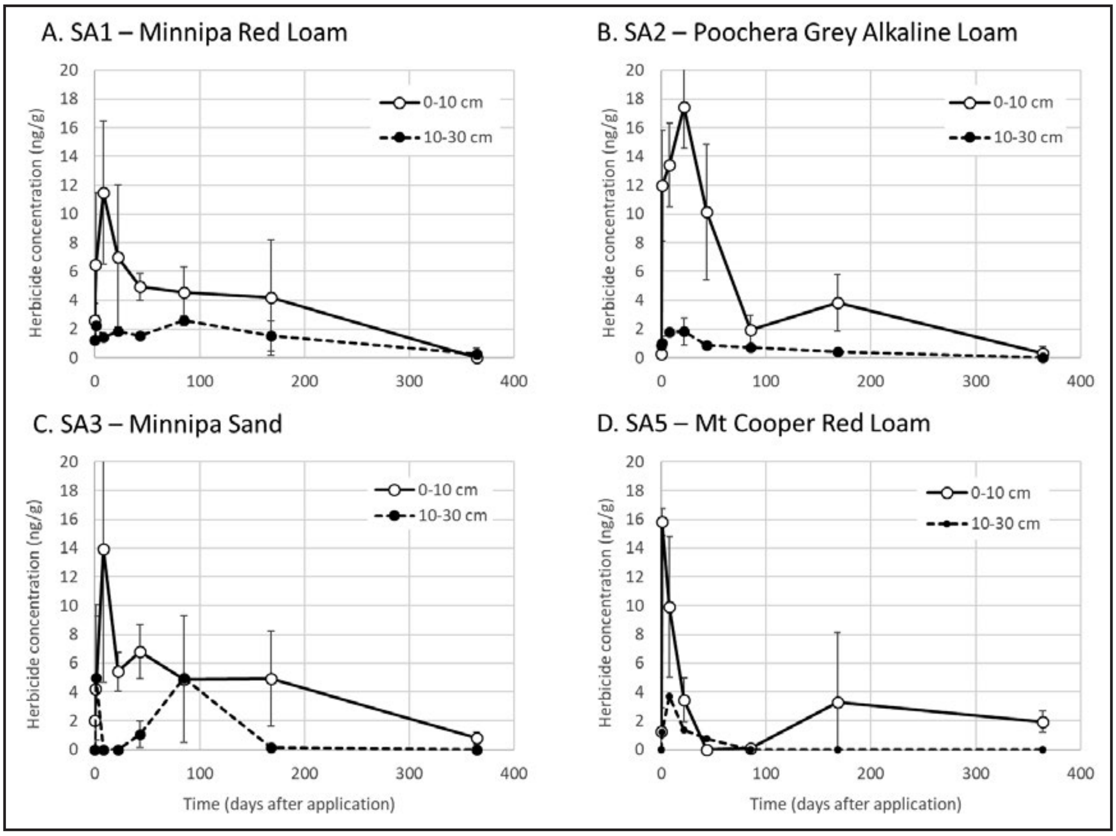

Figure 2. Clopyralid residue concentrations in 0-10 cm layer (white points, solid line) and 10-30 cm layer (black points, dashed line) at four EP monitoring sites. Points represent average residue levels of three field replicates, error bars are standard deviations. Line are a visual guide and are not statistical model fits.

Table 3. Soil properties, clopyralid application date and clopyralid dissipation at four monitoring sites (SA1, SA2, SA3, SA5).

Location	Soil Clay (%)	Soil pH	Soil OC (%)	Precipitation 0-180 d post-spray (mm)
SA1	6	7.8	1.0	120
SA2	6	7.9	1.0	75
SA3	<1	7.0	0.2	108
SA5	10	7.1	1.7	117

There was some variation in the persistence of clopyralid at the four different sites monitored from mid-2019 to mid-2020 (Figure 2). At all sites except Poochera, baseline residues of clopyralid were detected at 1-2 ng/g prior to the application of clopyralid in-crop in 2019. After clopyralid application, concentrations in topsoil (0-10 cm) increased to maximum levels of 12-18 ng/g, depending on the site. At the Minnipa sites, there was a steady decline in clopyralid over the 364 d after application, with approximately 30% of the clopyralid remaining at the 6-month sampling in January 2020. In contrast, at the Poochera and especially the Mt Cooper sites, dissipation was faster in the initial 3 months to day 84, to the point where clopyralid could no longer be detected in topsoil at Mt Cooper. However, clopyralid residues increased again at both sites at the 6-month sampling date and remained detectable (but low) at 1-2 ng/g by 364 d.

This pattern fits field observations (and product labels) that clopyralid can be released from crop stubble where clopyralid herbicides have been applied in crop. Thus, even though clopyralid breakdown/dissipation from soil can be rapid in some soils where rainfall and organic matter is sufficient (e.g. Mt Cooper, SA5), clopyralid residues may still be present in soil at sowing of the following crop (Table 3).

Another important point to note is the high variation in clopyralid concentrations at each time point, particularly at 168 d after spraying. Repeat analysis of the same soil sample (i.e. lab replicate) showed that analytical variation was low, suggesting that there is high variation across field replicates. This means that although the average concentration in one paddock could be 3.5 ng/g (i.e. Mt Cooper SA5 at 168 d), the actual concentrations at different points across that paddock could vary from 0 - 10 ng/g or more.

What does this mean?

This project has generated seedling toxicity thresholds for the effect of soilborne clopyralid residues on different legume species. Although there will be variation in these thresholds across different soil types, the values can give an indication as to when seedling injury may occur if soil clopyralid testing is conducted.

For the sites monitored in this project, residue levels would likely have been, on average between 2-5 ng/g at the different sites, but concentrations at particular points within a paddock show variation and could have been greater. It is unlikely that any of the crops planted in 2020 in these paddocks would have suffered damage from clopyralid residues, but alternative legumes like field peas or lentils could have been injured. The data from this project also confirm field observations that remobilisation of clopyralid from senescing crops or crop stubble occurs, and more research is required to determine where and when this may cause issues.

This research is currently being repeated for the 2020 cropping season and samples will be taken in April 2021 to determine clopyralid carryover. Additional research aims to predict how toxicity thresholds and persistence might vary from soil to soil, depending on clay content, pH, organic matter or other soil properties. Finally, the project is examining whether injured plants can be analysed to determine if a herbicide residue is responsible for causing the injury, as a diagnostic tool to help growers avoid herbicide residue damage in future. It is hoped that through a better understanding of factors that contribute to persistence combined with modelling, growers will have greater confidence in decisions relating to plant-back periods provided on product labels and be better able to consider the potential impacts of current herbicide use on future rotations.

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Impact of herbicide residues on conventional and Clearfield canola in the SA Mallee

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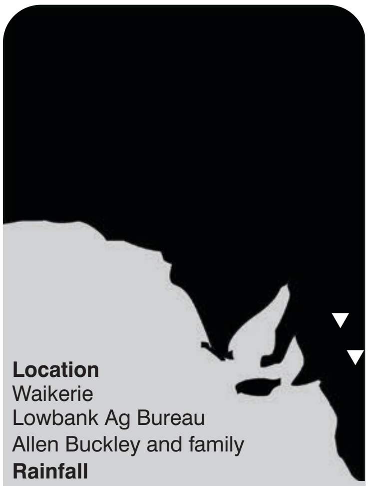

Location
Waikerie
Lowbank Ag Bureau
Allen Buckley and family
Rainfall
Av. Annual: 280 mm
Av. GSR: 173 mm
2020 Total: 257 mm
2020 GSR: 199 mm
Paddock history
2019: Wheat
2018: Scope barley
2017: Cereal rye
2016: Fallow
Soil type
Sand
Soil test
pH (water): 6.9
Plot size
15 m x 2 m x 3 reps
Trial design
RCBD with 3 replicates and 2 treatment factors.
Yield limiting factors
Moisture

Location
Peebinga
George Gum and family
Rainfall
Av. Annual: 319 mm
Av. GSR: 210 mm
2020 Total: 309 mm
2020 GSR: 230 mm
Paddock history
2019: Fallow
2018: Scope barley
2017: Fallow
2016: Fallow
Soil type
Sand
Soil test
pH (water): 7.3
Plot size
15 m x 2 m x 3 reps
Trial design
RCBD with 3 replicates and 2 treatment factors.
Yield limiting factors
Moisture

Key messages

- **Logran, Lontrel and Intervix herbicide residues did not affect canola grain yield, 24 months after the initial application.**
- **Adhering to label recommendations on plant back period is key to minimise the risk of crop damage from Logran, Lontrel and Intervix residues.**

Why do the trial?

Resilient Australian farming systems are aiming to not only improve productivity and profitability but also striving for sustainability. 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 soil longer than desired and in sufficient quantities that they may damage sensitive crop or pasture species sown in subsequent years. Herbicide breakdown can be greatly reduced in low rainfall farming environments that are characterised by soils low in organic matter and high in pH. The carryover of herbicides is posing a new challenge to growers, particularly in low to medium rainfall farming systems. It reduces management flexibility by imposing restrictions on the types of crops that can be grown. The main aim of the trials reported here was to evaluate if Lontrel(clopyralid), Intervix (imazamox/imazapyr) or Logran (triasulfuron) residues affect growth and productivity of conventional and Clearfield canola in a typical SA mallee situation.

How was it done?

Herbicide treatments (Table 1) were applied on 26 July 2018 on plots sown to Scope barley, simulating typical commercial applications using the protocol described in the article "Impact of herbicide residues on crop and pasture productivity in alkaline sandy soils" in the EPFS summary, 2019, p 108. Prior to sowing in 2019 and 2020, 0-10 cm soil cores were taken to determine the level of herbicides still present. Samples were prepared and analysed with liquid chromatography and mass spectrometry at CSIRO (Waite). In 2019, the Lontrel block was sown to field peas and vetch, Intervix block to wheat and lentils, and Logran to lentils and medic. On 28 April at Waikerie and 4 May 2020 at Peebinga, conventional "Diamond" and Clearfield "43Y92CL" canola varieties were sown at 5 kg/ha with 60 kg/ha of DAP. In August, sulphate of ammonia was applied at 80 kg/ha, and clethodim at 500 ml/ha plus Uptake oil to control grasses.

Table 1: Herbicide treatments.

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

RFR = recommended field rate

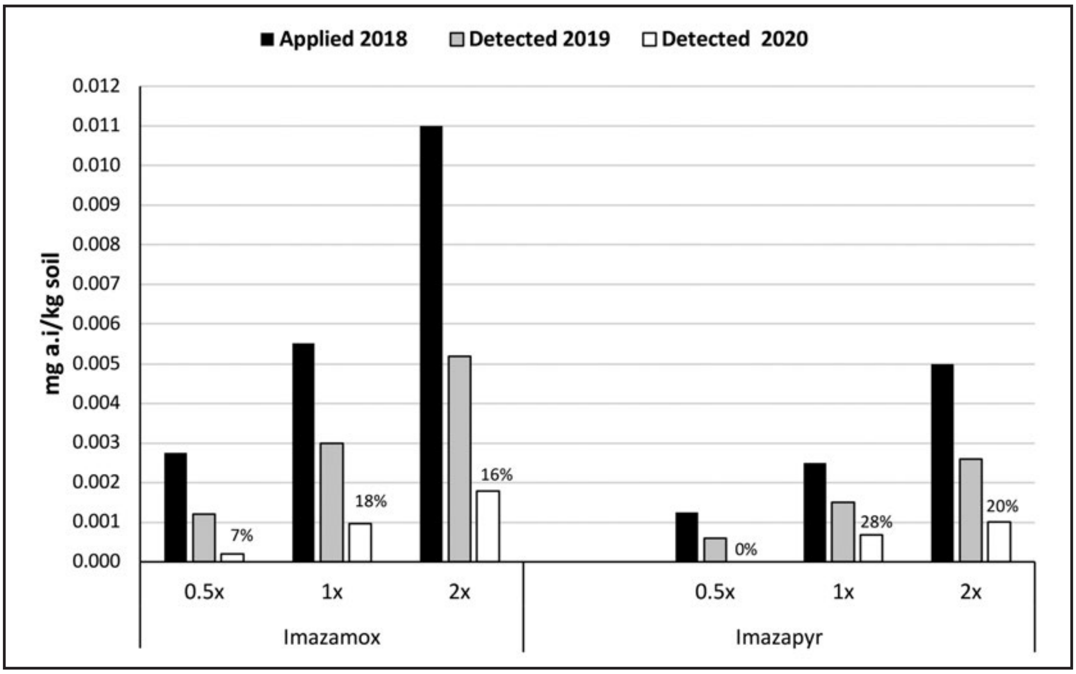

Figure 1. Applied and detected imazamox and imazapyr residues at Waikerie. Values indicate the percentage of remaining residues relative to the initial application in 2018.

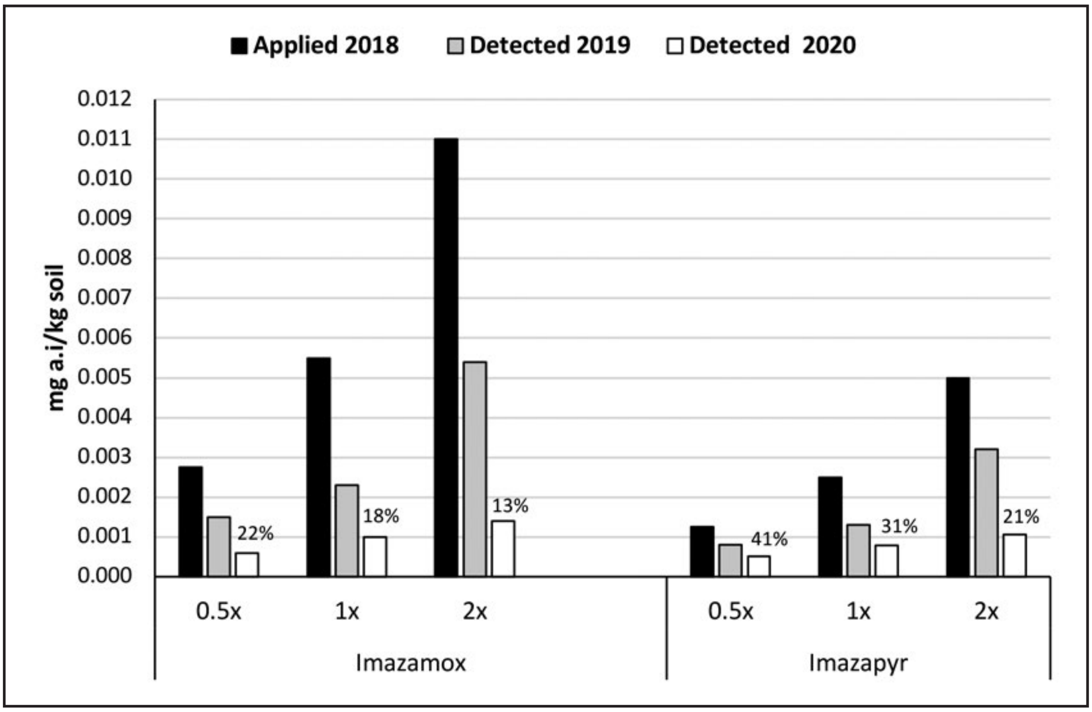

Figure 2. Applied and detected imazamox and imazapyr residues at Peebinga. Values indicate the percentage of remaining residues relative to the initial application in 2018.

What happened?

No Lontrel or Logran residues were detected in the 0-10 cm sampling zone 20 months after the initial application. Imazapyr and imazamox were the only active ingredients detected at both sites in 2020. From the Intervix applied at Waikerie at the recommended field rate (RFR (1x), 500 mL/ha), 18% of the imazamox and 28% of the imazapyr residues were detected in the top 10 cm of soil prior to sowing in 2020 (Figure 1). Similarly, at Peebinga, 18% of the imazamox and a higher level of imazapyr (31%) residues were detected in 2020 (Figure 2). Imazapyr is considered more persistent with a half-life ranging from 3 to 24 months depending on soil type, environmental conditions and the rate of application (Mangels, 1991).

Impact on crop growth and productivity

At both sites neither establishment nor grain yield of canola was affected by Logran, Lontrel or Intervix residues. The only impact on growth was by Intervix residues on flowering shoot dry matter at Peebinga. Shoot DM for the highest residue level (2x) was 2.06 t/ha, much lower than the untreated control at 2.64 t/ha.

What does this mean?

Zero detection of Logran in the 0-10 cm zone can be attributed to the fact that sulfonylurea herbicides are very mobile in water under high pH conditions. Field work conducted over the last 5 years indicate that small amounts of SU herbicides can move rapidly down alkaline soil profiles to levels deep in the profile, and this movement can occur under relatively low rainfall conditions (Hollaway *et al*., 2005). Following labelled plantback periods normally ensures adequate safety, but predicting herbicide persistence can be complex, particularly when conditions are much drier than usual. The plantback periods for conventional canola following Lontrel application is 1 week (Dow AgroSciences, APVMA Approval No: 31365/0306); 22 months for Logran (Syngenta, APVMA Approval No: 46511/1/1209); and 34 months for Intervix (BASF, APVMA Approval No 59735/63339). Our canola crop was sown well within the plantback period for Logran and Intervix and did not suffer significant damage. This result shows that plantback periods only serve as guidelines, which should be taken into consideration at all times, but may be conservative under different soil and weather conditions.

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Eyre Peninsula Soil CRC landholder survey 2020

Dr Hanabeth Luke and Dr Claire Baker
Southern Cross University

The Research

To be better able to support farmers and for farming systems to become more resilient, researchers need to understand the important challenges faced by farmers, as well as their goals and what support they need to reach those goals.

In April-May 2020, a rural landholder survey was posted to all rural landholders in the Eyre Peninsula with a landholding greater than 10 ha. This 2020 Eyre Peninsula landholder survey is part of a Soil CRC (Cooperative Research Centre) national project to understand what farm management practices are being undertaken across Australia, why farmers choose the farming methods that they do and what information and technical support farmers are seeking. Following similar surveys in other states, the Soil CRC team is gathering a national data set to gain an understanding of what is happening for Australian farmers and for soils across our farming systems, and will be repeated in five years to measure any changes. Led by Southern Cross University's Dr Hanabeth Luke, the Eyre Peninsula survey is a collaboration with local farming group AIR EP (Ag Innovation and Research Eyre Peninsula, formerly EPARF and LEADA) together with the Eyre Peninsula Landscape (formerly NRM) Board. The survey was designed with input from these local partners to guide their strategic direction (Figure 1). PIRSA and Charles Sturt University are also project partners, and the full report can be found here: https://soilcrc.com.au/wp-content/uploads/2021/01/Eyre-Peninsula-Social-Benchmarking-Report-2020.pdf

The data generated by the survey is spatially referenced, which means we can cross-reference our social data with other spatial data such as soil type or rainfall patterns. A response rate of 31% was achieved, with the analysis focussed on areas of particular importance to the Soil CRC's local research partners.

A profile of landholders on the Eyre Peninsula

From our survey responses, the most common land use is cropping (76%), followed by sheep for wool and meat (both 62%) and pasture (54%). The median land holding is 1500 ha, held over an average of two Eyre Peninsula properties. 76% of respondents live on their local property, with the median length of family ownership sitting at 50 years. The median age of respondents was 59 years, of which 90% were male.

Across all LGAs, the majority of landholders self-identified as either full-time or part-time farmers, except in the more urban LGA of Port Lincoln. Overall, the numbers were:

- Full-time (FT) farmers: 62%
- Part-time (PT) farmers: 14%
- Hobby farmers: 8%
- Non-farming land holders: 16%

The most important issues are identified by farmer type in Figure 2, with soil-related property-scale issues identified in Figure 3.

Figure 1. The survey development workshop, October 2019.

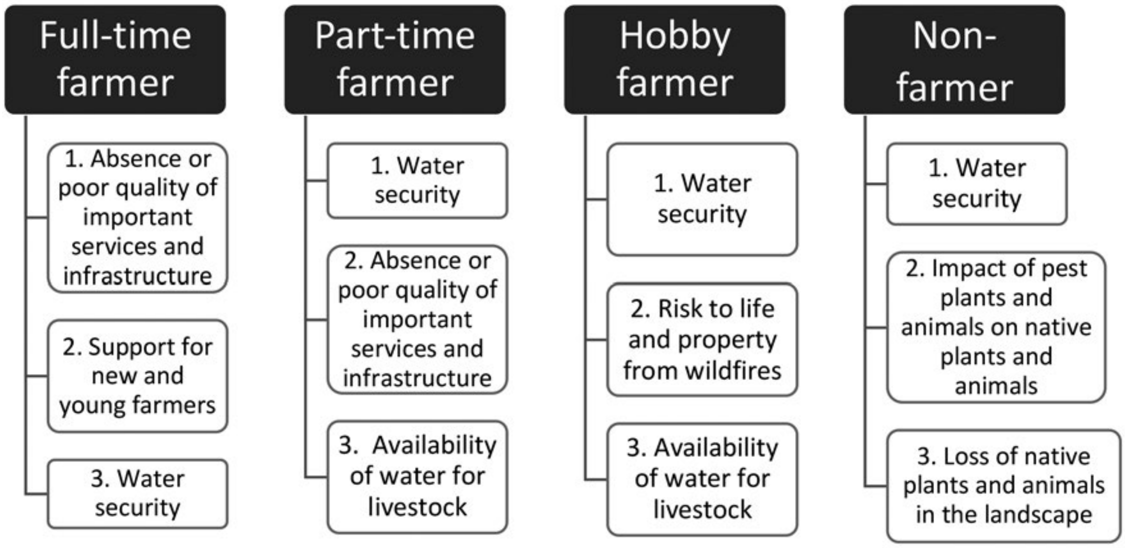

Figure 2. Most Important Regional Issues by Farmer Type.

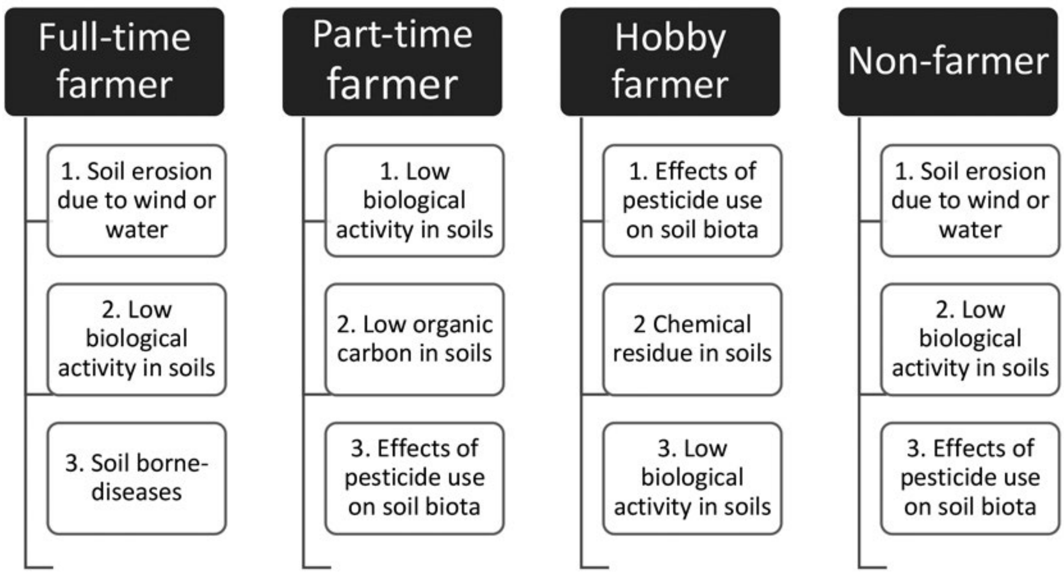

Figure 3. Top 3 Most Important Soil-related Issues on the Property by Farmer Type.

Farm Management

On-farm management appears to be largely collaborative, with 75% of all respondents and 86% of full-time farmers reporting that they usually include another person or people in their management decisions. Most commonly this was reported as being a family member (e.g. spouse, child, parent), and beyond the family, agronomists were the most common advisor. Continuity was the dominant theme of landholders' long-term plans. The majority (79%) of all respondents indicated that it was likely or highly likely that ownership of the property would stay within the family, rising to 85% of full-time farmers and 74% of part-time farmers.

Farmer values

Values guide action and the Eyre Peninsula encompasses landholders with a range of intersecting values. The '*ability to pass on a healthier and more sustainable farm for future generations*' was the most important value attached to the property for both full- and part-time farmers. This group also identified the value of their property as '*a great place to raise a family*' and having a '*sense of accomplishment from building/maintaining a viable business*' as extremely important. On the other hand, we saw a strong trend among hobby farmers and non-farmers to value the attractiveness and amenity properties of their land most highly, including a strong focus on native vegetation.

With regard to respondents' guiding life values, '*looking after my family and their needs*' was the most important value across all landholder types, followed by the environmental value of '*preventing pollution and protecting natural resources*'. The third most important value was the creation of '*wealth and striving for a financially profitable business*' for both full and part-time farmers, whereas for hobby farmers and non-farmers it was '*respecting the earth and living in harmony with nature*'.

Sourcing information

Respondents are most likely to seek information and advice on property management from other farmers (89% of full-time farmers and 85% of part-time farmers in particular). The top three sources of knowledge for full-time farmers were other farmers, friends/neighbours/relatives, and independent agricultural consultants such as agronomists. This shows a strong reliance on knowledge networks within the Eyre Peninsula and indicates the significant potential of these networks and relationships for knowledge transfer. Combined with the fact that 'Field Days' was the highest ranked mode of receiving information for full-time farmers and second for part-time farmers, the benefits of combining networking and communication/education activities may be a useful mode of knowledge transfer in the region. Other knowledge sources for the majority of respondents are the Bureau of Meteorology, independent agricultural advisors, and PIRSA/SARDI.

Farming practices, risk and resilience

As shown in Figure 2, water security ranked in the top three issues for all farmer types, and soil-related issues are detailed in Figure 3. 43% of all full-time farmers (32% of all respondents) indicate that an area of their land was lost to production due to soil problems. For issues listed in the survey, we saw strong crossover in concern between the different farmer types regardless of their level of farming, particularly that of soil erosion (68% overall) and low biological activity in soils (63% overall). Indeed, soil-related issues were one of the few survey items in which there were almost no significant differences by farmer type.

The results suggested very strong engagement with issues related to soil health. Almost all full-time and part-time farmers (both 98%) agreed that they feel a personal responsibility to maintain their soil's productive capacity. Clear links between farmer practices, the extent of their knowledge, and their confidence in benefits emerged for several topics, including sowing perennial pastures, minimum or no-tillage and soil testing. However, overall knowledge was quite low for many best-practices, with less than 50% of farmers having sufficient knowledge to act on or implement the majority of listed practices. This suggested a gap in education or knowledge translation amongst respondents.

Table 1 highlights some key practices implemented by full-time and part-time farmers on the Eyre Peninsula, some of which show a decline in intended implementation over time.

Reported farmer knowledge of related topics is shown in Table 2, with the greyed-out boxes indicating knowledge-levels of 50% or less.

All landholders engaged in agriculture indicated a very high degree of openness toward new ideas about farming (90%). That said, only half or less of the same groups self-identified as early adopters, with only moderate agreement that they could financially afford to take risks, and experiment with new ideas. The twin measures of risk avoidance/risk openness were fairly evenly split amongst full- and part-time farmers, presenting a mixed picture of actual willingness to take on new ideas. Time availability did not appear to be an important barrier to change, with only 17% of indicating they do not have sufficient time available to consider changing their practices.

Table 1. Management practices over time by full-time (FT) and part-time (PT) farmers, 2020 (n= 463 – 466).

Management Practice	Prior to 2015		Past 5 years (2015-2020)		Intend to implement in next 5 years	
	FT	PT	FT	PT	FT	PT
Testing of soils for nutrient status in paddocks where have applied fertiliser/soil conditioners in the past	54%	39%	49%	48%	32%	20%
Use of no-tillage techniques to establish crops or pastures	54%	36%	58%	44%	30%	22%
Application of soil ameliorants other than fertiliser and lime (e.g. gypsum, organic manure)	33%	20%	31%	31%	26%	15%
At least one lime application to arable land	17%	14%	19%	22%	14%	19%
Preparation of a nutrient budget for all/most of the property	20%	15%	26%	22%	25%	19%
Reduction of chemical use	11%	9%	21%	27%	28%	25%

*Table 2. Reported farmer knowledge levels on a range of soil-related topics by farmer type. ### indicates significant difference across landholder types and *** indicates significant difference across rainfall zones.*

Knowledge Topic	FT Farmer	PT Farmer	Hobby Farmer
Strategies to maintain ground cover to minimize erosion in this area ###	4.2 86%	3.9 83%	3.5 52%
Preparing a farm/property plan allocating land use according to land class ###	3.8 68%	3.7 59%	3.0 38%
How to build soil organic matter/soil carbon ###	3.6 58%	3.5 52%	3.1 28%
How to identify the main constraints to soil productivity on your property ###	3.6 56%	3.4 47%	2.9 38%
The processes leading to soil structure decline in this area ###	3.5 50%	3.4 47%	3.1 34%
How to use soil testing to prepare a nutrient budget that will increase soil productivity ### ***	3.3 46%	3.0 30%	2.5 19%
The production benefits of applying biological soil supplements (e.g. compost, manure, microbial inoculants) ###	3.3 37%	3.1 28%	3.4 47%
Time controlled, cell or rotational grazing strategies ### ***	3.1 32%	3.1 30%	2.7 31%

Although water security and changes in weather patterns were deemed to be important regional issues, this did not appear to fully translate to concern about climate change, with less than half (49%) of all respondents believing that humans were causing it, and 21% disagreeing that this could be so. Those agreeing that 'human activities are influencing changes in climate' dropped further for full-time farmers to 40%, and to 35% for the younger generation of farmers.

The future of farming

There was a strong interest from AIR EP to gain a stronger understanding of the needs and experience of younger farmers, so our data was cut to explore differences by generation. Whilst the following do not represent statistically significant differences, generations of full- and part-time farmers exhibited the following characteristics:

- Generation Y (born 1981-1996), had the highest rates of both tertiary education (24%) and other post-secondary education (24%) amongst all full and part-time farmers, and were the only group for which every respondent had Year 10 education and above. Generation X (born 1965-1980) had 12% tertiary qualification and the Baby Boomer and over generation, 8% (born prior to 1965).
- Generation Y were the most likely to include another person in their decision-making, with 97% agreeing that they 'usually include another person or people in my on-farm management decisions'. Common advisors were listed as consultants such as agronomists, family and friends.
- Generation Y felt the least supported to conduct farming and land management activities on their property, with only 56% agreeing that they felt adequately supported and 34% indicating they were unsure. When asked what sort of support would enhance their agricultural and land management activities, this group indicated they would like more engagement with grower groups and knowledgeable organisations, including through field trials and extension officers; and financial support, including subsidising the cost of fixing soil challenges.
- In terms of succession planning, 85% of full-time farmers thought it likely that a family member would take over the farm, however only 56% had a family member interested in stepping into this role.

In addition to gaining insight into what farmers value and do, the end goal of the project is to ascertain how to best engage and support farmers so that there is a better integration of farm management and soil health outcomes into the future. Achieving this this well means scientists continually working with farmers to gain a strong understanding of their needs, the challenges they face, and their ideas for a more resilient farming system, now and into the future. We thank every landholder who took the time to complete the survey - we cannot do this work without their significant contribution.

SOIL CRC Performance through collaboration
Southern Cross University
LANDSCAPE SOUTH AUSTRALIA
Charles Sturt University
AIR EP Ag Innovation & Research Eyre Peninsula

Section 4

Break Crops

Section Editor:
Amy Gutsche and Kaye Fersuson
SARDI Port Lincoln

Eyre Peninsula 2020 NVT canola trial yields in t/ha and expressed as percentage of site mean.

Nearest town	Lock		
Variety	**t/ha**	**%**	**Oil (6% moisture)**
Pioneer 44Y90 (CL)	1.44	105	44.2
Pioneer 43Y92 (CL)	1.29	94	43.4
Site mean (t/ha)	**1.37**		
CV (%)	6.56		
Probability	0.14		
LSD (t/ha)	*0.13*		
Sowing Date	30/04/2020		
Trial comments	Trial has a high P value (0.14) indicating low significance of variety effect. Results in quarantine report published later. Interpret results with caution.		
Variety			
ATR Bonito	0.95	75	40.1
ATR Stingray	0.90	71	40.5
Hyola Blazer TT	1.38	109	41
Hyola Enforcer CT	1.14	90	40.1
HyTTec Trident	1.54	122	40.2
HyTTec Trophy	1.41	112	39.7
InVigor T 4510	1.45	115	
SF Spark TT	1.22	97	42.3
Site mean (t/ha)	**1.26**		
CV (%)	7.03		
Probability	<0.001		
LSD (t/ha)	*0.14*		
Sowing Date	30/04/2020		
Variety			
Nuseed Diamond	1.52	106	42.2
Nuseed Quartz	1.36	94	43.7
Site mean (t/ha)	**1.44**		
CV (%)	7.37		
Probability	0.00		
LSD (t/ha)	*0.10*		
Sowing Date	30/04/2020		

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

Eyre Peninsula 2020 NVT field pea trial yields in t/ha and expressed as a percentage of site mean.

Nearest town	**Minnipa**	
Variety	**t/ha**	**%**
GIA Kastar	1.04	80
GIA Ourstar	1.08	82
Kaspa	1.31	100
PBA Oura	1.40	107
PBA Pearl	1.31	100
PBA Percy	1.33	102
PBA Wharton	1.39	106
Site mean (t/ha)	**1.30**	
CV (%)	10.93	
Probability	0.02	
LSD (t/ha)	*0.24*	
Sowing Date	06/05/2020	

Nearest town	**Murdinga**	
Variety	**t/ha**	**%**
GIA Kastar	1.27	72
GIA Ourstar	1.11	63
Kaspa	**1.74**	99
PBA Oura	1.54	88
PBA Pearl	1.96	111
PBA Percy	1.72	98
PBA Wharton	1.80	102
Site mean (t/ha)	**1.76**	
CV (%)	5.48	
Probability	<0.001	
LSD (t/ha)	*0.16*	
Sowing Date	19/05/2020	

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

Eyre Peninsula 2020 NVT lentil trial yields in t/ha and expressed as percentage of site mean.

Nearest town	**Yeelanna**	
Variety	**t/ha**	**%**
Nipper	1.28	70
PBA Ace	1.40	76
PBA Blitz	1.09	60
PBA Bolt	1.19	65
PBA Hallmark XT	1.83	100
PBA Highland XT	2.10	114
PBA Hurricane XT	2.16	118
PBA Jumbo2	1.44	78
PBA Kelpie XT	1.79	98
Site mean (t/ha)	**1.83**	
CV (%)	13.50	
Probability	0.01	
LSD (t/ha)	*0.58*	
Sowing Date	19/05/2020	
Trial comments	Trial affected by preseason Group B herbicide residues. Treat results with caution.	

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

GRDC NATIONAL VARIETY TRIALS™

"Studenica" a new common vetch variety offering early grazing options

Stuart Nagel, Gregg Kirby and Angus Kennedy
National Vetch Breeding Program, SARDI Waite

Key messages

- **Studenica is a new white flowering variety of common vetch that will be available in 2021.**
- **It has the earliest flowering and maturity of the common vetches.**
- **Studenica was bred for very low rainfall areas, it can be used similarly to other common vetch varieties for grain/seed, grazing, hay/silage or green manure.**

Morphological characteristics

Studenica is a new white flowering variety of common vetch that will be commercially available for sowing for the first time in 2021. This variety has the earliest flowering and maturity of the common vetches, flowering in approx 85-90 days. It is rust resistant but susceptible to Botrytis, like other common vetch varieties. Studenica has toxin/anti-nutritional (BCN) levels similar to Morava .

Studenica has the best early vigour of all existing common vetch varieties in Australia, combined with good cold tolerance. In early growth stages it has medium to large leaves without anthocyanin, it is has medium pod size, medium seed size, greyish seed testa and greyish/brown cotyledons.

Main advantages

Studenica was bred for very low rainfall areas, it can be used similarly to other common vetch varieties for grain/seed, grazing, hay/silage or green manure. Studenica is particularly suited to shorter season areas where the growing season finishes sharply. It has superior winter growth when compared to existing common vetch varieties, which results in earlier nodule development and nitrogen fixation for crops in rotations.

The advantage Studenica has over other varieties is its superior winter growth and vigour combined with good frost tolerance, this enables it to put on more bulk through the cold parts of winter, continuing to grow through June/July and providing fodder earlier in the season. This variety is particularly well suited to low rainfall marginal cropping/mixed farming systems looking for early feed to fill the winter feed gap or late planting for spring fodder and hay, it offers a more reliable legume option in mixed enterprises in marginal cropping environments. Studenica has grain and hay yields comparable with Timok and Volga in most environments. It is its early growth and vigour which sets it apart, particularly in cold environments, this is demonstrated in Table 2. See Tables 1 and 2 for Studenica production data.

Its early maturity and vigour offer diversity in the system and enable this variety to be used in several different ways. It can be sown early, around ANZAC Day or before for early fodder in late winter/autumn. Or sown later in the program, after the major crops, for more traditional fodder production in spring.

Yield and adaptation

Studenica has high grain and herbage yields and is well adapted to all areas of Australia where vetch is currently grown. For comparative yields see 2021 South Australian Crop Sowing Guide. https://grdc.com.au/resources-and-publications/all-publications/publications/2020/2021-south-australian-crop-sowing-guide

Studenica is well suited to situations where the season finishes sharply (dry September and October, a common issue in many low to mid rainfall areas) because of its early flowering and maturing characteristics. It can be successfully grown in many Australian soil types, from non-wetting sand to heavy clay loam with pH 5.8 - 9.4, like other common vetch varieties. Studenica is resistant to vetch rust (*Uromyces viciae-fabae*). Studenica shows better growth in low temperatures than other Australian vetch varieties. Studenica is not prone to pod shattering and has shown no evidence of sensitivity to the broad leaf herbicides Diuron, Simazine, Sencor/metribuzin or Terbyne, or to mixtures of these herbicides in post-plant pre-emergence treatments. It has also shown similar reactions to existing varieties when treated with grass herbicides registered for use in common vetch (Verdict or Select/Clethodim).

Table 1. Average Vetch Hay yields, taken from four low rainfall sites in South Australia, cut mid-September

Line	2014	2015	2016	3yr Ave.
Studenica	2.24	3.09	2.19	2.51
Rasina		2.86	2.21	2.54
Timok	2.13	3.15	2.08	2.45
Volga	2.26	3.06	2.45	2.59

Table 2. 2018 Dry Matter yields, t/ha, at low rainfall Mallee sites in SA and Vic, cut mid-August

Line	Waikerie	Walpeup
Studenica	4.81	3.22
Morava	3.69	1.71
Rasina	3.96	
Timok	3.75	2.11
Volga	4.21	2.19

 # Data taken from National Vetch breeding MET trials, LSD not calculated

Table 3. Average dry matter (DM) quality of Studenica, taken from 4 sites

Product	Dry Matter (%)	Moisture (%)	Crude Protein (% DM)	ADF (% DM)	NDF (% DM)	Digestibility (% DM)	Estimated Metabolisable Energy (MJ/kg DM)	Water Soluble Carbohydrates (% DM)
Hay	90.4	9.6	23.7	26.2	38.4	67.2	10.6	6.4

**Samples tested by Feedtest*

Studenica was bred, developed and trialled by the SARDI National Vetch Breeding Program in conjunction with GRDC and SAGIT and it will be available from S&W Seeds.

What does this mean?

Vetches have the ability and potential to fit into modern farming rotation, particularly in mixed farming systems where farmers are looking for a versatile break option that still allows for strategic action against specific cropping problems. Unlike pulses and other break crops, the focus is not solely on grain production. Vetch can be used as a tool against herbicide resistant grass weeds and still produce a return with hay, grazing or grain and have an impact on subsequent cereals with increased levels of soil nitrogen.

Studenica can fit into this role well as it offers the option of early feed to fill the late winter feed gap, or to be used to tidy up paddocks late in the cropping program.

The key to a successful vetch crop and achieving the maximum benefits from vetch is to treat it as a crop, not as a set and forget break option. Inoculate with appropriate rhizobia, control weeds where possible and monitor for insects and disease.

When successfully grown vetch can be an effective risk management tool on farm. Allowing for a reduction in fertilizer and chemical use in following crops, reducing costs and the risks involved with in crop nitrogen applications. This can have a significant impact on profitability and the stress levels associated with these decisions.

Acknowledgments

The research undertaken as part of this project (DAS1711-015RTX, National Vetch Breeding Program) is made possible by the significant contributions of Australian growers through both trial cooperation and investment via GRDC levies; the author would like to thank them for their continued support. As well as SARDI and SAGIT investment.

Exploiting the indeterminate nature of pulses

Amy Gutsche[1], Penny Roberts[2,3], Dylan Bruce[2]

[1]SARDI Port Lincoln, [2]SARDI Clare, [3]Affiliate of The University of Adelaide

Location
Wudinna
Ashley Barnes
Rainfall
Av. Annual: 268 mm
Av. GSR (Apr-Oct): 187 mm
2020 Total: 231 mm
2020 GSR: 178 mm
Paddock history
2019: Wheat
2018: Wheat
2017: Field pea
Soil type
Sandy loam
Soil test
0-10 cm pH = 8.52 (water), PBI + Col P 141, Organic Carbon 1.35%
Plot size
2 m x 10 m x 3 replicates
Trial design
Experimental: Split plot randomised design

Location
Tooligie
Bill Long
Rainfall
Av. Annual: 331 mm
Av. GSR (Apr-Oct): 249 mm
2020 Total: 287 mm
2020 GSR: 252 mm
Paddock history
2019: Barley
2018: Wheat
2017: Field pea
Soil type
Sandy loam
Soil test
0-10 cm pH = 8.33 (water), PBI + Col P 39, Organic Carbon 0.85%
Plot size
2 m x 10 m x 3 replicates
Trial design
Experimental: Split plot randomised design
Yield limiting factors
Frost, weed competition, residual herbicide damage

Key messages

- **Preliminary data shows faba bean are consistently a better option for early sowing opportunities in seasons where an early break occurs compared to wheat and lentil.**
- **PBA Marne was consistently the highest yielding bean variety when sown early.**
- **Lentil has a more variable response to time of sowing.**

Why do the trial?

In Eyre Peninsula cropping systems, pulses are commonly sown throughout May. Generally, growers plan pulse sowing times around their cereal systems, as cereals have a higher sensitivity to sowing date. Past research in South Australia has explored time of sowing (TOS) in faba bean and lentil across the high rainfall zone (HRZ) and medium rainfall zone (MRZ) (Roberts *et al*. 2021). In that study, faba beans were sown at three timings - an early (mid-April) sowing and two subsequent delayed sowing times, 3-4 weeks apart. Lentils were sown at two timings, early May and late May-early June. Earlier sown faba bean generally displayed a positive grain yield response across the MRZ. However, lentil recorded a complex response to early sowing in these trials and environmental factors including frost and weed and disease pressure had a detrimental effect on production potential.

To look at exploiting the indeterminate nature of pulses, trials were established at Wudinna and Tooligie on the Eyre Peninsula in 2020. The aim of the trials was to identify opportunities to sow a pulse crop prior to optimum cereal sowing windows in seasons where an early break occurs. This would provide growers with the chance to have each crop species in the ground at a time that would achieve an optimum flowering window, working to close the yield gap.

How was it done?

To look at the response of pulses to early sowing, four replicated trials were conducted across different environments throughout South Australia in 2020. Trials were not localised and covered different rainfall zones and soil types at Wudinna, Tooligie, Warnertown and Farrell Flat. Wudinna and Tooligie are the focal sites for this article. The Wudinna trial examined early sowing in three varieties of lentil and faba bean. This was replicated at Tooligie with three varieties of wheat included to look at comparisons between pulse and cereal responses to early sowing. The selected varieties represented varying phenological characteristics (Table 1). Both trial sites were situated on an alkaline soil with pH of 8.52 (H_2O) at Wudinna and 8.33 (H_2O) at Tooligie.

All sites were sown with an experimental plot seeder, with Tooligie sown at 25 cm spacing and Wudinna sown at 27 cm spacing. The first time of sowing for Wudinna was 31 March and Tooligie 2 April (Table 2).

Table 1. Phenological characteristics of each crop variety compared with the phenology observed at Tooligie and Wudinna, 2020.

Crop Type and Variety		Phenology Characteristics		Observed Phenology Dates			
				Tooligie		Wudinna	
		Flowering	Maturity	TOS1 50% Flowering	TOS2 50% Flowering	TOS1 50% Flowering	TOS2 50% Flowering
Faba Bean	PBA Marne	Early	Early-Mid	18-Jun	27-Jul	25-Jun	4-Aug
	PBA Bendoc	Mid	Early-Mid	25-Jun	30-Jul	17-Jul	4-Aug
	PBA Samira	Mid	Early-Mid	2-Jul	3-Aug	17-Jul	4-Aug
Lentil	PBA Jumbo2	Mid	Mid	22-Jun	5-Aug	17-Jun	11-Aug
	PBA Bolt	Early-Mid	Early-Mid	22-Jun	5-Aug	17-Jun	11-Aug
	PBA Highland XT	Early	Early-Mid	22-Jun	5-Aug	17-Jun	11-Aug
Wheat (Tooligie only)	Longreach Trojan		Mid-Slow	5-Aug	14-Sep		
	Scepter		Mid	15-Jul	14-Sep		
	Illabo		Mid quick + winter	14-Sep	30-Sep		

To simulate an early break, Wudinna was irrigated with the equivalent of 14 mm rainfall on all plots and received 7 mm of natural rainfall three days post-sowing. Tooligie received 10 mm of irrigation on all plots and 8 mm of natural rainfall was recorded two days post-sowing. The second time of sowing at Tooligie and Wudinna was 6 and 7 May, respectively. The Tooligie site received 8 mm rainfall within the following two days and the Wudinna site received 2 mm.

Plot arrangement was in a split plot randomised design with 3 replicates. Crop species were randomly assigned to the whole plot and variety was randomly assigned to the subplot. The use of this design ensures each crop species receives appropriate management. Measurements taken throughout the trial included key phenological stages, biomass yield, grain yield, harvest index and grain quality. Key phenology dates were recorded at emergence, canopy closure, flowering, pod development and maturity to identify the phenological progression and timing of each individual variety. Biomass yields were recorded at 50% flowering to distinguish any benefits from early sowing for early plant growth. These trials were analysed with Genstat 20th Edition using a mixed model (REML) analysis.

What happened?

The first three months of 2020 experienced drier than average conditions at both Tooligie and Wudinna. Good early rains occurred in April at both sites and then below average rainfall was recorded throughout the winter months leading up to a wet spring. September recorded an average rainfall and October recorded more than double the average rainfall at both Wudinna and Tooligie. The growing season rainfall (April - October) totalled 195 mm at Wudinna and 255 mm at Tooligie. A below zero frost event occurred on 23 July at Tooligie, coinciding with the flowering windows of the early sown pulses and wheat (cv. Scepter) (Table 1).

The earlier sown plots at Tooligie experienced weed control issues due to simulated rainfall and tillage. In lentil and wheat, early sowing showed a significant decrease in biomass yield which may have been a response to increased weed density (Figures 1 & 2). In an ideal year, with average rainfall during May and winter, larger biomass would be expected. The large biomass associated with these crop types is known to cause increased incidence of disease, pest problems, lodging and necking. It is expected that earlier sown spring wheat will experience accelerated phenology and will not tiller as much as wheat sown in optimal May timing, resulting in reduced biomass and grain yield. Early sown faba bean recorded increased biomass yield at both sites (Figure 2).

Table 2. Trial details for early sown pulses at Wudinna and Tooligie, Eyre Peninsula, 2020.

Site		TOS 1	TOS 2
Wudinna	Sowing Date	31 March 2020	7 May 2020
	Harvest Date	6 November 2020	6 November 2020
Tooligie	Sowing Date	2 April 2020	6 May 2020
	Harvest Date	28 October 2020	24 November 2020

Break Crops

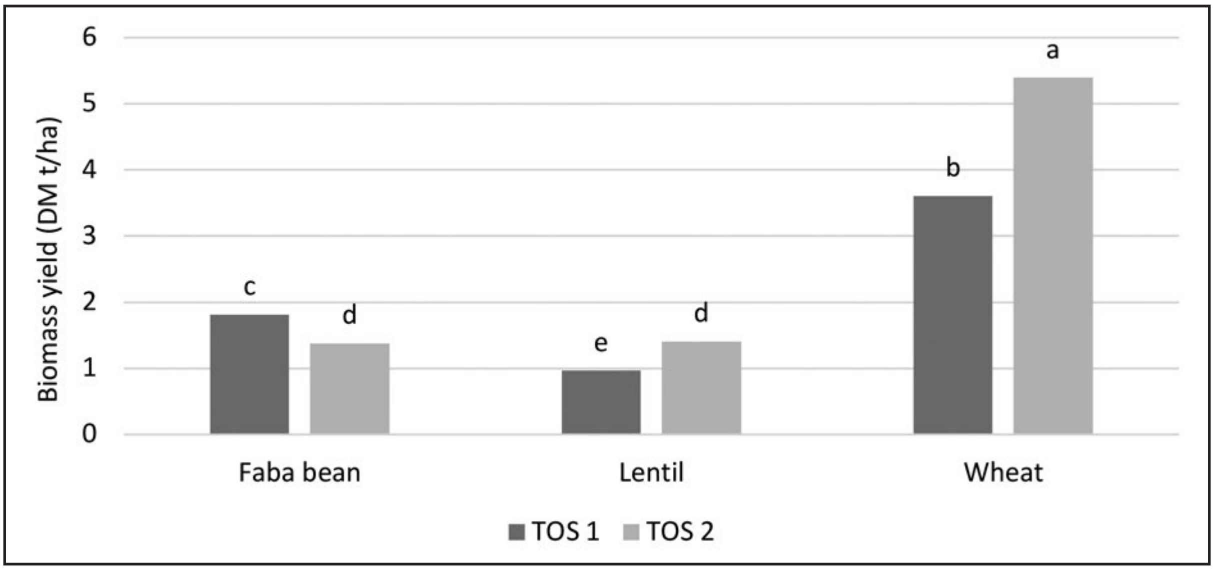

Figure 1. Biomass yield (t/ha) response to TOS in faba bean, lentil and wheat at Tooligie, Eyre Peninsula, 2020. Bars labelled with the same letters are not significantly different.

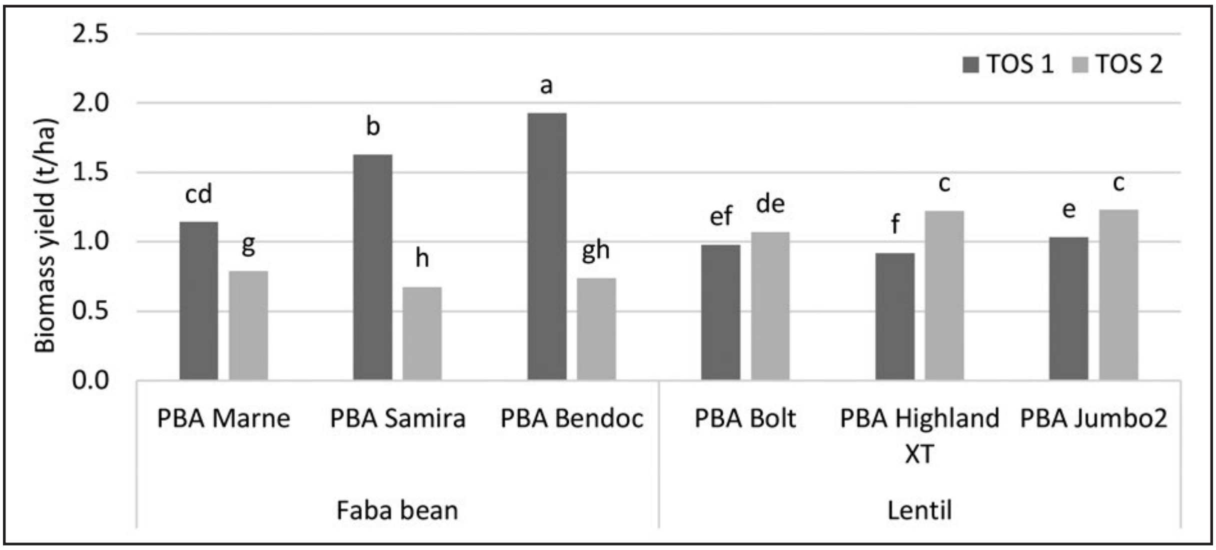

Figure 2. Biomass yield (t/ha) response to TOS in faba bean and lentil at Wudinna, Eyre Peninsula, 2020. Bars labelled with the same letters are not significantly different.

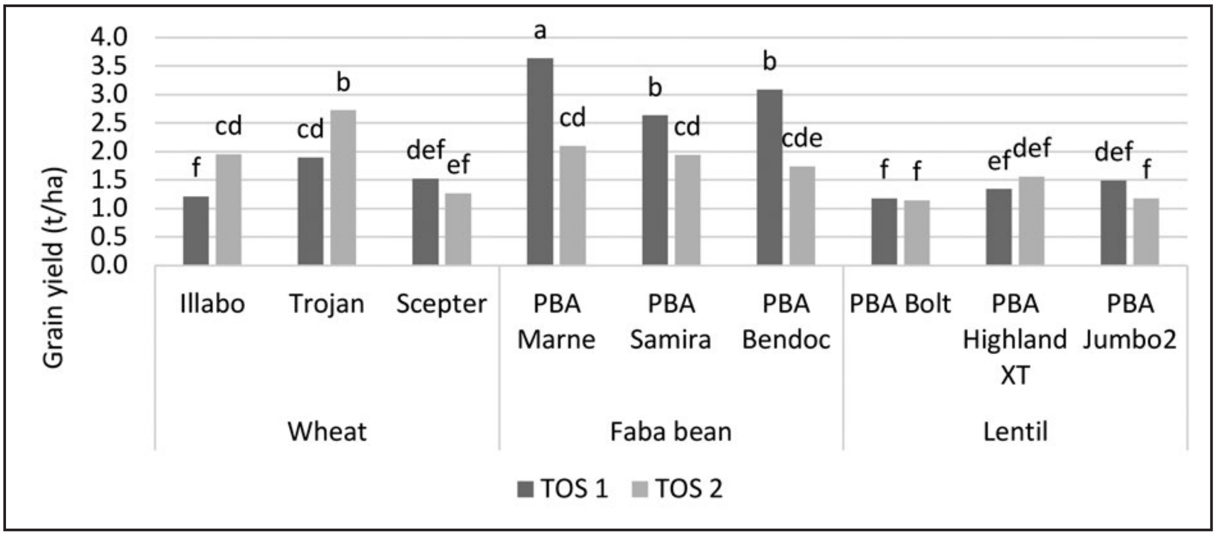

Figure 3. Grain yield (t/ha) response to TOS in faba bean, lentil and wheat at Tooligie, Eyre Peninsula, 2020. Bars labelled with the same letters are not significantly different.

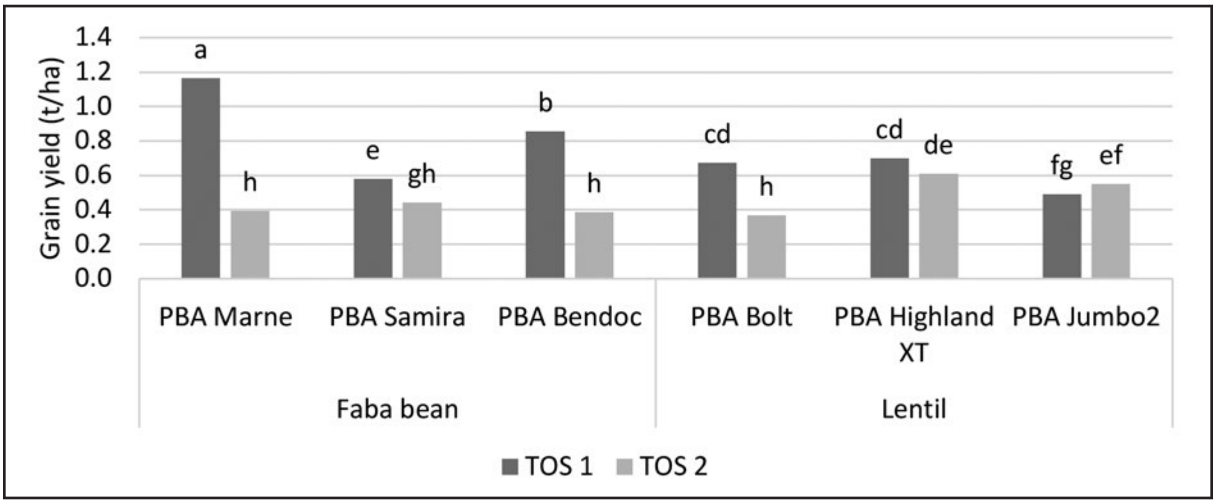

Figure 4. Grain yield (t/ha) response to TOS in faba bean and lentil at Wudinna, Eyre Peninsula, 2020. Bars labelled with the same letters are not significantly different.

Faba bean displayed positive results as an early sowing option at both Tooligie and Wudinna in 2020 (Figure 3 & 4). PBA Bendoc and PBA Marne showed a significant increase in grain yield when sown in early April, compared to May sowing time. To a lesser extent, PBA Samira also showed a significant increase in grain yield compared to PBA Bendoc and PBA Marne when sown early. PBA Marne recorded the highest grain yield in faba bean, particularly when sown early.

No consistent trend in grain yield was recorded in early sown lentils at Wudinna or Tooligie (Figures 3 & 4). At the Warnertown site in the Mid-North, there was a positive response recorded in early sown lentil (data not shown). This preliminary data suggests that further research is required for early April sowing in lentil.

What does this mean?

Under the conditions of this trial, faba bean recorded the greatest positive response to early sowing, with significant increases in biomass and grain yield in all varieties trialled. This suggests an opportunity to sow faba bean early in seasons where an early break occurs. Preliminary data suggests PBA Marne is best suited to early sowing in low to medium rainfall environments.

Although time of sowing in pulses has been researched by Roberts *et al*. (2019) previously, further seasons of data are required to draw accurate conclusions on the responses of pulse crops to early April sowing. A broader phenology range in lentil also needs to be investigated to explain the variable response to time of sowing observed in these trials.

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Penny Roberts, Christine Walela, Larn McMurray and Helena Oakey (2021), (Paper in preparation).

Acknowledgements

The research undertaken as part of this project was made possible by the significant contributions of growers, through both trial co-operation and the support of the GRDC (DAV00150), and the authors would like to thank them for their continued support. The continued assistance in trial management from SARDI Agronomy groups at Port Lincoln, Minnipa and Clare is gratefully acknowledged and appreciated.

Lentil and vetch management and alternative end use in the low rainfall zone

Sarah Day[1,3], Penny Roberts[1,3], Amy Gutsche[2]
[1]SARDI Clare, [2]SARDI Port Lincoln, [3]Affiliate of The University of Adelaide

Location
Kimba
Trevor Cliff
Rainfall
Av. Annual: 345 mm
Av. GSR (Apr-Oct): 247 mm
2020 Total: 369 mm
2020 GSR: 289 mm
Paddock history
2019: Oats
Soil type
Red sandy loam
Plot size
2 m x 10 m x 3 replicates
Trial design
Dry winter conditions

Key messages

- **Gibberellic acid can be utilised to aid plant growth in vetch, however, the effects on biomass production, grain production and phenology need to be investigated further.**
- **Lentil is extremely sensitive to Group C herbicide use in dry conditions. Herbicide choice, rate and application timing is critical in reducing risk of crop injury.**
- **Seeding rate of lentil and vetch can be reduced to three quarters of the recommended seeding rate in some environments without compromising biomass and grain production.**
- **Lentil provides a favourable alternative to vetch in many low to medium rainfall regions.**

Why do the trial?

Lentil and vetch production area has increased over the last decade in the Western and Eastern Eyre Peninsula regions (Figure 1). This increase in production area has coincided with a reduction in area sown to field pea, as well as recent high grain prices for lentil and developments in breeding. In particular, the release of varieties with improved herbicide tolerance characteristics and varieties better adapted to low rainfall environments. The majority of pulse management research is conducted in medium and high rainfall zones and strategies developed in these environments are often not viable or economical for growers in low rainfall regions. To improve grower confidence in pulse production there is a need for the development of pulse management strategies specifically for low rainfall environments. This article highlights and discusses agronomic management trials in vetch and lentil with a focus on novel management approaches, diversifying risk and reducing input costs. The aim of the pulse end use trial was to identify optimum seeding rate and variety selection for vetch and lentil depending on target end use. Where gibberellic acid (GA) was applied to vetch the aim was to quantify the effects of GA applied at different growth stages on dry matter production. The lentil herbicide management trial aimed to assess lentil herbicide management strategies for pre- and post-emergent herbicides in low rainfall environments on different soil types.

How was it done?

All trials were sown using an experimental plot seeder and harvested with an experimental plot harvester. Analysis of variance (ANOVA) was conducted for all trial data using Genstat 20th Edition.

Pulse end use trials

Growing lentil for grazing or hay is rising in interest among low rainfall growers, which led to the initiation of these research trials to compare biomass and grain production of vetch and lentil sown at multiple seeding rates, at four trials sites (Table 1). The seeding rates compared the recommended target plant density (120 plants/m^2 for lentil and 60 plants/m^2 for vetch), with a target density of half and three-quarters of the recommended rate to assess whether input costs could be reduced without compromising production potential. Higher than recommended rates were not included, as high plant density crops increase the risk of disease infection and lodging and reduce the resource efficiency due to larger canopies.

Three varieties each of vetch (Volga, Timok, Morava) and lentil (PBA Jumbo2, PBA Blitz, PBA Highland XT) with varying phenology characteristics were included to refine variety selection depending on target end use.

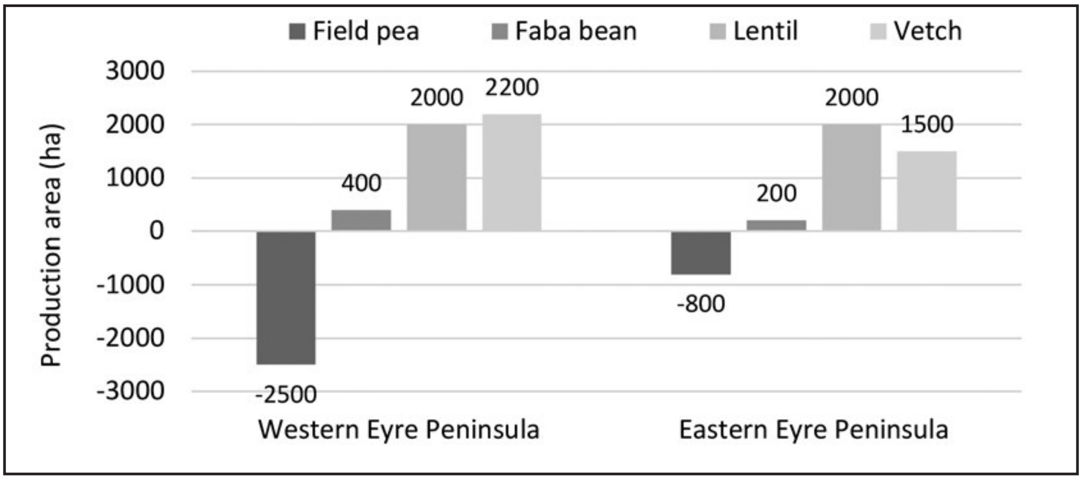

Figure 1. Change in production area (ha) of pulse crops in the Western and Eastern Eyre Peninsula regions, 2012 to 2020 [1].

Table 1. Pulse end use trial site information, including sowing date, soil type and rainfall, 2020. GSR = growing season rainfall (April-October).

Location	Kimba	Stokes	Eudunda	Booleroo
Average annual rainfall (mm)	345	522	442	391
Average GSR (mm)	247	419	325	278
2020 annual rainfall (mm)	369	406	389	467
2020 GSR (mm)	289	334	311	339
Soil type	Clay loam	Clay loam	Clay	Clay
Soil pH ($CaCl_2$)	8.1	6.5	8.7	7.6
Row spacing (cm)	25	25	23	23
Sowing date	20 May	28 May	4 May	12 May
Harvest date	3 December	26 November	24 November	25 November
Yield limiting factors	Dry winter conditions	Dry winter conditions, residual herbicide damage, weed competition	Dry winter conditions	Dry winter conditions, poor nodulation

Measurements taken included site soil characteristics, biomass yield, grain yield and crop height. Biomass measurements were taken at late vegetative and early podding growth stages to identify production potential for grazing or hay production. Plots were arranged in a split plot randomised design with three replicates, with crop species randomly assigned in blocks to the whole plot, and variety and plant density randomly assigned to the sub plot. The use of this design ensures that both crop types receive appropriate agronomic management.

Gibberellic acid use in vetch

GA was applied to Volga vetch at two growth stages (Table 2) and compared to an untreated Nil to quantify the effects of GA on vetch growth and dry matter production at Kimba and Booleroo, 2020. Measurements included plant height at regular intervals following GA application, biomass dry matter production two weeks post-application, and grain yield. Plot arrangement was in a randomised block design with four replicates.

Lentil herbicide management trials

To assess Group C herbicide risk, two trials were sown on two different soil types at Tooligie, 2020. Similar trials have been conducted at Minnipa in previous years [2] and were expanded in 2020 to include new locations and stacking of Group C and Group B herbicides for use on Group B tolerant lentil varieties. Nine herbicide treatments were applied to PBA Hallmark XT and compared to an untreated Nil (Table 6). Measurements included crop injury score and grain yield. Plot arrangement was in a randomised block design with three replicates.

What happened and what does it mean?

Pulse end use trials

At three of four sites seeding rate was reduced by a quarter without compromising biomass or grain production (Table 3). Reducing the seeding rate further to half of the target density did reduce production at some sites. A seeding rate that is too low exposes the crop to aphid infestation, weed establishment and increases harvest difficulty.

Table 2. Gibberellic acid treatments applied to Volga vetch at Kimba and Booleroo, 2020.

Treatment	Details	Product	Rate
Nil	Untreated	-	-
GA @ 6-8 weeks	Gibberellic acid applied at 6-8 weeks post sowing	GALA Growth Regulator (100 g/L gibberellic acid)	80 mL/ha
GA @ early podding	Gibberellic acid applied at early podding	GALA Growth Regulator (100 g/L gibberellic acid)	80 mL/ha

Table 2. Gibberellic acid treatments applied to Volga vetch at Kimba and Booleroo, 2020.

Treatment	Details	Product	Rate
Nil	Untreated	-	-
GA @ 6-8 weeks	Gibberellic acid applied at 6-8 weeks post sowing	GALA Growth Regulator (100 g/L gibberellic acid)	80 mL/ha
GA @ early podding	Gibberellic acid applied at early podding	GALA Growth Regulator (100 g/L gibberellic acid)	80 mL/ha

There are many unfavourable aspects of vetch production, including limited disease resistance and fungicide options, limited herbicide options, hard seededness of some varieties, poor harvestability and market access. Lentil offers some advantages over vetch and is considered a more favourable break crop option in many regions. In many low rainfall environments lentil biomass and grain production has been equal to or greater than vetch [3]. Optimal variety selection can be complex depending on target crop end use, although there have been some stand out varieties in the low rainfall zone [4]. Volga vetch produced the highest quantity of biomass at Stokes in 2020 (Table 4).

However, this early maturing variety was not the optimal selection for grain yield.

Volga and Timok vetch and PBA Blitz lentil varieties had the lowest grain yield at both Kimba and Stokes. The late maturing vetch variety Morava had the highest grain yield, followed by PBA Jumbo2 and PBA Highland XT lentil. Seasonal conditions on the Eyre Peninsula in 2020 started out dry followed by rainfall during April and May, aiding crop establishment and vigour of early maturing varieties. This was followed by a relatively dry winter and a wet spring, where mid to late maturing varieties benefitted from rainfall during flowering and pod development. Additional trials are required in future seasons to further validate this research under different seasonal conditions.

Table 3. Biomass production (t/ha) at early podding and grain production (t/ha) responses to multiple seeding rates of lentil and vetch.

Seeding rate	Eudunda		Booleroo		Kimba		Stokes	
	Biomass yield	Grain yield	Biomass yield	Grain yield	Biomass yield	Grain yield	Biomass yield	Grain yield
Recommended	5.2	3.0	5.2	2.6	1.7	0.8	2.6	1.7
Three-quarter	4.8	3.0	4.8	2.7	1.6	0.7	2.2	1.6
Half	4.4	2.8	4.5	2.6	1.5	0.7	2.0	1.5
LSD (P=0.05)	*0.5*	*ns*	*ns*	*ns*	*ns*	*ns*	*0.36*	*ns*

Table 4. Biomass yield and grain yield (t/ha) varied between vetch and lentil varieties at Kimba and Stokes, 2020.

Crop	Variety	Maturity	Stokes Biomass yield (t/ha)	Stokes Grain yield (t/ha)	Kimba Grain yield (t/ha)
Vetch	Volga	Early	2.89	1.46	0.52
	Timok	Mid	2.02	1.31	0.56
	Morava	Late	1.89	2.03	1.10
Lentil	PBA Blitz	Early	2.38	1.48	0.51
	PBA Highland XT	Early-mid	2.23	1.58	0.89
	PBA Jumbo2	Mid	2.18	1.75	0.79
LSD (P=0.05)	*0.46*	*0.21*	*0.15*		

Table 5. Mean plant height (cm) increased in response to the application of gibberellic acid applied at late vegetative and early podding growth stages at Booleroo and at late vegetative growth stage at Kimba, 2020.

Site	Kimba	Booleroo	
Treatment	Late vegetative Plant height (cm)	Late vegetative Plant height (cm)	Early podding Plant height (cm)
Nil	8.6 b	11.3 b	82.8 a
GA @ 6-8 weeks	12.4 a	16.7 a	84.4 a
GA @ early podding	9.0 b	11.5 b	76.0 b
LSD (P=0.05)	*1.34*	*0.66*	*5.95*

Table 6. Mean crop injury score (0 = no crop damage, 9 = crop death) for damage caused by Group C and/or Group B herbicides applied to PBA Hallmark XT lentil at Tooligie, 2020. IBS = incorporated by sowing, PSPE = post-sowing pre-emergent, POST = post emergent.

Herbicide	Site 1 (Loam/clay loam)	Site 2 (Sandy loam)
	Score	Score
Nil	0.2 d	0.0 c
Diuron 830 g/ha IBS	0.6 bcd	0.1 bc
Diuron 830 g/ha IBS + Intercept® 600 mL/ha (POST)	0.8 bc	0.5 b
Terbuthylazine 860 g/ha IBS	0.4 cd	0.1 bc
Terbuthylazine 860 g/ha IBS + Intercept® 600 mL/ha (POST)	1.0 ab	0.3 bc
Metribuzin 280 g/ha IBS	0.5 bcd	0.3 bc
Metribuzin 280 g/ha IBS + Intercept® 600 mL/ha (POST)	0.8 bc	0.5 b
Metribuzin 280 g/ha PSPE	1.0 ab	2.3 a
Metribuzin 280 g/ha PSPE + Intercept® 600 mL/ha (POST)	1.4 a	2.1 a
LSD (P=0.05)	*0.58*	*0.46*

Gibberellic acid use in vetch

The application of GA at the late vegetative growth stage increased vetch plant height by 3.8 cm at Kimba and 5.4 cm at Booleroo compared to the Nil plots (Table 5). However, the early podding GA application reduced plant height by 6.8 cm compared to the Nil treatment at Booleroo. It is important that when GA is applied there is adequate soil moisture and nutrition to support and sustain the rapid growth. Following dry seasonal conditions in winter it is likely that soil moisture levels were not adequate to support the late growth of vetch when GA was applied at early podding. Although GA did increase vetch plant height, there was no biomass production response to GA. Vetch biomass production was 0.2 t/ha at late vegetative and 6.7 t/ha at early podding growth stages at Booleroo. Production potential was much lower at Kimba, with 0.18 t/ha biomass at late vegetative and 2.3 t/ha at early podding. There was no grain yield response to GA application in 2020. However, a negative grain yield response has been observed in previous research trials from the application of GA (unpublished). Further research is required to quantify the effects of GA on vetch biomass production, grain production and phenology under different environmental conditions.

Lentil herbicide management trials

Preliminary research was undertaken at Minnipa in 2018 on neutral to alkaline clay loam soil to assess the risk of commonly used Group C herbicides on lentil [2]. Terbuthylazine expressed a lower safety level and higher economic risk than Diuron and Metribuzin, with lentil generally more sensitive to Terbuthylazine than other pulse crops. In this study, on loam and sandy loam soils at Tooligie, minimal crop injury occurred from Terbuthylazine (Table 6). Crop injury did occur from Metribuzin, with minimal damage from IBS application and chlorosis from PSPE application.

Herbicide choice and application timing is important to reduce risk associated with lentil production, particularly as lentil is extremely sensitive to Group C herbicide use in dry conditions. Often a combination of herbicides with different solubility and leaching rates can be used to reduce the risk of damage while targeting a wider spectrum of weeds. Crop injury from herbicides can result in reduced grain yield and nitrogen fixation and increased weed competition and risk of soil erosion over summer. Applying herbicide prior to sowing is considered a lower risk option than a post-sowing pre-emergent (PSPE) application. Herbicide application incorporated by sowing (IBS) will disperse the herbicide between the furrows so that it does not sit close to the seed, reducing risk of crop injury. Herbicides applied PSPE are at a higher risk in low rainfall environments as the first rainfall event post application can leach herbicide into the seed bed. The solubility of each herbicide influences how much rain is required for herbicide incorporation and the likelihood of the herbicide moving down the profile [5]. Herbicides with low solubility (Diuron and Terbuthylazine) require good soil moisture and rainfall to achieve incorporation and are less available in the soil profile than herbicides with high solubility (Metribuzin). A herbicide with high solubility can move more readily within the soil and is more likely to cause off target damage, as seen on sandy loam soil at Tooligie.

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Acknowledgements

The research undertaken as part of this project is made possible by the significant contributions of growers through both trial cooperation and the support of the GRDC (DAV00150 - Southern Pulse Agronomy), and the authors would like to thank them for their continued support. The continued assistance in trial management from SARDI Agronomy groups at Clare, Pt Lincoln and Minnipa is gratefully acknowledged and appreciated.

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Mixed species cropping and intercropping: where, how and why?

Penny Roberts[1,3] and Amy Gutsche[2]

[1]SARDI Clare, [2]SARDI Port Lincoln, [3]Affiliate of The University of Adelaide

Location
Tooligie Hill
Bill Long
Rainfall
Av. Annual: 331 mm
Av. GSR: 249 mm
2020 Total: 287 mm
2020 GSR: 252 mm
Paddock history
2019: Barley
2018: Wheat
2017: Field Pea
Soil type
Sandy loam
Soil test
0-10 cm pH = 8.33 (water), Nitrate N 5 mg/kg, Ammonium N 2.2 mg/kg, PBI + Col P 39, Organic Carbon 0.85%
Plot size
2 m x 10 m x 3 reps
Trial design
Experimental: Split plot, whole plot = row arrangement, sub plot = companion variety
Yield limiting factors
Frost, residual herbicide damage

Key messages

- **In 2020, intercropping was more productive than monoculture cropping at the medium rainfall site of Tooligie Hill. The results from this one-year trial are consistent with the outcomes of previous intercropping work in South Australia.**
- **Adoption of an intercropping system needs careful planning including the species mix, variety choice, and the logistics of seeding, weed control and harvest. This planning can lead to productivity gains and ancillary benefits including soil health.**

Why do the trial?

The aim of this work is to increase combined pulse-oilseed productivity and profitability in the medium rainfall zone. Additionally, to increase the knowledge of mixed cropping systems and begin dialog around adapting from a monoculture system to mixed species systems.

There is a need for more robust break crop systems in the low and medium rainfall zones where traditional break crop systems are not yield stable, and risk leaving paddocks susceptible to erosion. Intercropping is a system that has been shown to provide production and sustainability benefits in low rainfall cropping systems. Nine field trials conducted across South Australia from 2016 to 2020 achieved productivity gains of 30 to 80% compared to monoculture, with combinations of canola and either lentil or vetch. Early season ground cover was improved in some intercrop combinations over traditional monoculture systems (Roberts *et al*. 2019 and Roberts, unpublished). This work demonstrated that intercropping has the potential to increase productivity and could lead to ancillary benefits such as increasing groundcover on erosion prone soils.

What happened?

To determine the relative productivity benefit of intercropping, compared to growing crops as monocultures, land equivalent ratio (LER) values were calculated. The LER is expressed as:

$$LER = LA + LB = YA/SA + YB/SB$$

Where LA and LB are the LER for the individual crop yield components, YA and YB are the individual crop yields in the intercrop combinations, and SA and SB are the yields of the monocultures (adapted from Mead and Willey, 1980). An LER value of 1.0 means the productivity of the intercrop components was equivalent to the monocultures. An LER value of <1.0 means the productivity of the intercrop components are less than the monocultures, while an LER value >1.0 means the intercrop components are more productive than the monocultures, which is referred to as 'over-yielding'.

Consistent with the results from previous work the intercropping treatments at Tooligie Hill (Table 1) over-yielded, meaning it was more productive to grow the two crops as a mix compared to growing them as separate monoculture crops (Figure 1). The largest productivity benefit was achieved when growing the pulse crop with a short stature and low yielding canola variety for this environment. Canola-pulse combinations generally performed better than pulse-pulse combinations, however, lentil-faba bean appeared promising from this first year trial. With the exception of the chickpea-faba bean combination, all other intercrop combinations could be harvested, and the two grain types separated with ease.

Table 1. Trial management details at Tooligie, 2020.

Trial design	**Split plot; whole plot = row arrangement, sub plot = companion variety x 3 replications.**
Treatments	Whole plot 1. Sole faba bean 2. Sole canola 3. Sole lentil 4. Sole chickpea 5. Lentil + faba bean mixed row 6. Lentil + canola mixed row 7. Lentil + faba bean skip row 8. Lentil + canola skip row 9. Chickpea + faba bean mixed row 10. Chickpea + canola mixed row 11. Chickpea + canola skip row 12. Chickpea + faba bean skip row Sub plot 1. Short variety (ATR Bonito/PBA Marne) 2. Tall variety (Nuseed Diamond/PBA Samira) 3. Imi tolerant variety (Pioneer43Y92/PBA Bendoc)
Varieties (sole plots)	Chickpea: CBA Captain Lentil: PBA Hallmark XT Canola and faba bean: as per sub plot treatments
Management	Sowing date: 13 May 2020 Fertiliser applied at sowing: 100 kg/ha MAP Fertiliser applied to monoculture canola: 100 kg/ha MAP In crop fungicides and herbicides: Clethodim @ 800 mL/ha (2 applications), Mancozeb @ 2.2 kg/ha, Carbendazim @ 500 mL/ha, Aviator Xpro @ 600 mL/ha (2 applications), Veritas @ 1 L/ha, Weedmaster DST @ 2 L/ha Harvest date: 20 December 2020
Measurements	Soil nitrogen, Plant numbers, NDVI, Plant height, Biomass at late flowering early podding (hay cut simulation), Lowest pod height, Harvest index, Grain yield, Grain quality
Analysis	A spatial analysis was undertaken on the data using Genstat version 20.1.

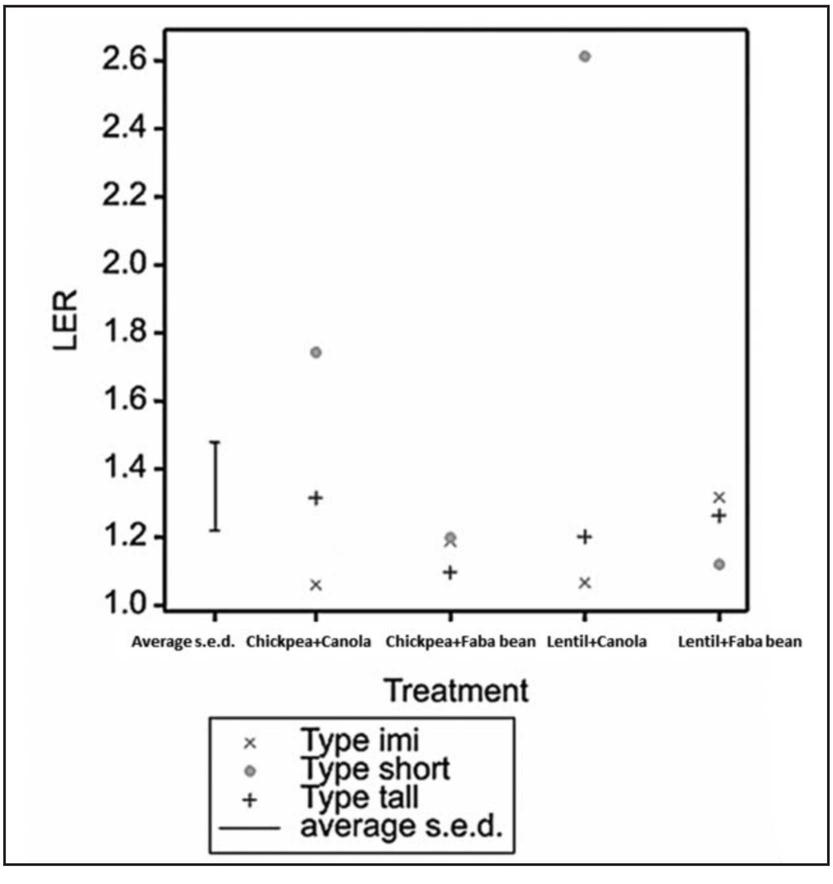

Figure 1. Intercropping demonstrates grain yield benefits for the intercrop combinations with land equivalent ratio (LER) values of greater than one at Tooligie Hill, 2020.

Whilst, productivity gains from intercropping can be measured using LER, it assumes equal value of the two crops and doesn't account for the relative proportion that each crop contributes to the overall plot yield. The aim of the work at Tooligie Hill was to achieve most of the intercropping yield and economic return from the pulse crop, as such the canola is considered the secondary crop in this system and sown at a reduced seeding rate in intercropping treatments. The lower canola plant numbers in the intercrop, compared to the monoculture canola that was sown at the full seeding rate, is reflected in the grain yields. The canola grain yields were lower in intercrop compared to monoculture canola, ranging between 54% and 90% of the monoculture canola yields (Figure 2a).

The impact of intercropping on the pulse crop varied between the pulse species and was influenced by variety (Figure 2b, 2c, 2d). Intercropping chickpea with canola was largely more successful than intercropping chickpea with faba bean, with the chickpea grain yield when intercropped with faba bean 37% to 40% of that of monoculture chickpea (Figure 2b and 2c). The canola variety was an important factor in the relative yield of the intercropped chickpea and lentil compared to the monoculture crop of each. When intercropped with a low yielding canola there was no yield reduction of the pulse in the intercrop, conversely when intercropped with the higher yielding canola varieties yield was reduced by 36% to 61% for chickpea intercrops, and 36% to 61% for lentil intercrops. Intercropping lentil and faba bean showed relative yield reductions of 28-47% and 41-53% in each crop, respectively (Figure 2c and 2d).

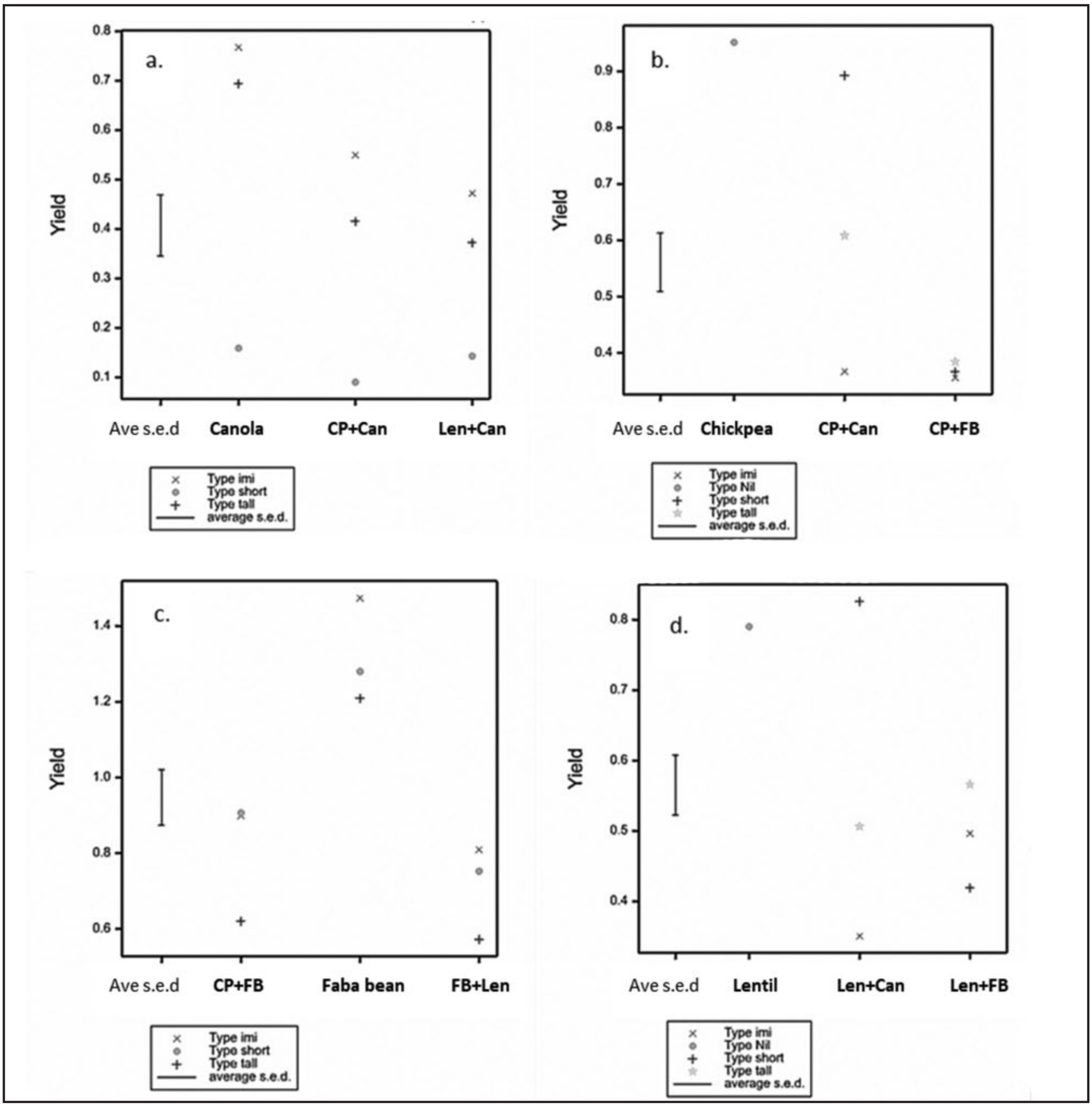

***Figure 2.** Grain yield (t/ha) was generally reduced in intercrop compared to the sole crop treatments a) canola, b) chickpea, c) faba bean, and d) lentil. Key: CP = chickpea; Can = canola; FB = faba bean; Len = lentil.*

What does this mean?

This work demonstrated the suitability of intercropping in the medium rainfall zone of the Eyre Peninsula for some combinations. Whilst the data represents only one season, results are consistent with previous intercropping work undertaken in the low to medium rainfall zones of South Australia and it is reasonable to conclude that some intercropping combinations can be more productive than monoculture cropping in this environment. All intercrop combinations in these trials over-yielded, meaning they were more productive than growing the components as monoculture crops. The best intercropping combinations measured by productivity gain (LER) in this trial were canola-pulse and lentil-faba bean. This supports previous work demonstrating vetch-canola and vetch-lentil as the most promising combinations for the lower rainfall environments.

The additional complexity of intercropping systems includes logistical challenges during sowing, harvest, handling and grain storage. Some types of intercropping lend themselves to a more seamless integration into current farming practices than others. However, with careful planning including the species mix, variety choice, and the logistics of seeding, weed control and harvest, these systems can be successfully adopted at a broadacre scale as demonstrated by grower adoption of intercropping in Australia. To support an increase in adoption of intercropping systems there is a need to support growers through a combination of peer-to-peer learning and further focused research and validation trials.

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Management of Group A, J and K resistant annual ryegrass in pulses

Navneet Aggarwal[1,2] and Penny Roberts[1,2]
[1]SARDI Clare, [2]Affiliate of The University of Adelaide

Location
Mid North
Hart Field Site Group
Rainfall
Av. Annual: 406 mm
Av. GSR: 253 mm
2019 Total: 189 mm
2019 GSR: 132 mm
2020 Total: 546 mm
2020 GSR lentil: 273 mm
2020 GSR chickpea: 327 mm
Soil type
Silty clay loam
Soil test
See Tables below
Plot size
10 m x 1.35 m x 3 reps
Trial design
Randomised complete block design
Yield limiting factors
Early finish and below average rainfall in 2019

Key messages

- **Ultro® (a new Group E herbicide with active carbetamide) and Group D propyzamide proved equally effective for annual ryegrass control in lentil and chickpea.**
- **Boxer Gold® and Sakura® herbicides need to be rotated with other mode of action herbicides, especially with Group D propyzamide and Group E Ultro, in the pulse crop phase.**
- **Integrated weed management tactics of wick wiping and clipping + wick wiping reduced annual ryegrass seed set.**

Why do the trial?

The increased adoption of herbicide tolerant break crops, such as triazine tolerant (TT) canola, Group B imidazolinone (IMI) tolerant Clearfield® canola and XT lentil, has produced an increased reliance on Group A chemistry (fops and dims) to control annual ryegrass, leading to rapid development of resistance to these herbicides. Currently there is an increase in the uptake of alternative pre-emergent chemistry like Group D, J and K herbicides for managing dim-resistant annual ryegrass in break crops. However, annual ryegrass populations are starting to evolve resistance to these Group J and K herbicides in South Australia (Aggarwal *et al*. 2019), which could severely reduce herbicide options available for the control of annual ryegrass in pulse crops. Therefore, research trials were conducted to identify effective management options for annual ryegrass resistant to Group A, J and K herbicides in lentil and chickpea. The preliminary work was presented in EPFS 2019 Summary, p 146.

Soil test - Hart 2019

Depth	Ammonium nitrogen (mg/kg)	Nitrate nitrogen (mg/kg)	Phosphorus Colwell (mg/kg)	Potassium Colwell (mg/kg)	Sulphur (mg/kg)	Organic Carbon (%)	pH level ($CaCl_2$)	pH level (H_2O)
0-10 cm	1	9	27	564	5.6	1.51	7.8	8.5
10-20 cm	<1	10	12	322	3.5	1.04	7.8	8.6

Soil test - Hart 2020

Depth	Ammonium nitrogen (mg/kg)	Nitrate nitrogen (mg/kg)	Phosphorus Colwell (mg/kg)	Potassium Colwell (mg/kg)	Sulphur (mg/kg)	Organic Carbon (%)	pH level ($CaCl_2$)	pH level (H_2O)
0-10 cm	5	10	35	374	8.6	1.37	7.7	8.5
10-30 cm	4	4	7	217	5.5	0.96	8.1	9.2

How it was done?

Plot size: 1.35 m × 10 m
Fertilizer: 80 kg/ha MAP
Seeding dates:
Lentil - 16 May 2019 and 25 May 2020
Chickpeas - 29 May 2019

Research trials were sown at Hart Field Site (Mid-North) with SARDI Group C tolerant lentil germplasm line (M043) in 2019, PBA Hurricane XT and Group C lentil germplasm line GIA 2004L in 2020, and *kabuli* chickpea Genesis 090 in 2020. The new pre-emergent herbicide Ultro® (active carbetamide, Group E) was included for controlling annual ryegrass applied incorporated by sowing (IBS) in all three trials. Ultro (IBS) + clethodim post-emergence (POST) at 5-node growth stage was compared to growers' practices of propyzamide (IBS) + clethodim (POST), Boxer Gold® (IBS) + clethodim (POST) and Sakura® (IBS) + clethodim (POST) in lentil 2019 and chickpea 2020 trials (Table 1). The potential of integrated weed management tactics such as clipping, and clipping + wick wiping annual ryegrass at embryo development stage was studied, in addition to pre-emergent herbicides in 2020 lentil (Figures 1 and 2) and chickpea trials (Table 2). A gravity-based wick wiper was used for wick wiping with Glyphosate + LVE MCPA + water mixed 1:1:1, and clipping of annual ryegrass growing above the crop canopy was done manually. All herbicide doses are mentioned in terms of the commercial product (Tables 1, 2 and 3; Figures 1, 2 and 3).

Seeds of annual ryegrass resistant to Group A clethodim, Group J and Group K herbicides were broadcast at 250 and 500 seeds/m^2 in 2019 and 2020, respectively. This was completed ahead of seeding and weed seeds were incorporated prior to IBS herbicide application with a shallow pass of the seeder with a roller attached. Ryegrass spike density and seed set was assessed near crop harvest from three randomly selected spots using a quadrant of 50 cm × 50 cm. The dead spikes resulting from wick wiping treatments were not included in the final spike count in 2020 trials. Harvesting of lentil was completed on 29 October 2019 and 17 November 2020, and chickpea on 9 December 2020. The statistical analysis was done with ANOVA through Genstat version 20.

What happened?

Effect on annual ryegrass in lentil

In 2019, T_4: propyzamide (IBS) + clethodim (POST) and T_6: Ultro (IBS) + clethodim (POST) proved equally effective for Group A, J and K resistant annual ryegrass control (Table 1). Both of these Group D and Group E herbicide treatments proved more effective than growers' practices of T_1: Sakura (IBS) + clethodim (POST) and T_2: Boxer Gold (IBS) + clethodim (POST) for reducing annual ryegrass spike density and seed set. Furthermore, herbicide treatment T_4: propyzamide (IBS) + clethodim (POST) and T6: Ultro (IBS) + clethodim (POST) reduced annual ryegrass seed set up to 99% and 97%, respectively over T_7: unsprayed control.

In 2020, propyzamide (IBS) and Ultro (IBS) proved equally effective for controlling Group A, J and K resistant annual ryegrass (Figures 1 and 2). Both herbicides resulted in a 74-78% reduction in annual ryegrass spike density and a 74-76% reduction of seed set, compared to the unsprayed control in Group C lentil. Furthermore, the integrated weed management tactic of wick wiping annual ryegrass at embryo development stage resulted in 54% and 69% reduction in spike density and seed set respectively, as compared to no clipping/wick wiping. The treatment of clipping alone did not prove effective in reducing annual ryegrass spike density and seed set, as the clipped annual ryegrass plants could regrow, producing a similar seed set to no clipping/wick wiping. Combining clipping and wick wiping reduced annual ryegrass spike density and seed set compared to clipping alone and no clipping/wick wiping, but was not significantly different to wick wiping alone.

Table 1. Annual ryegrass management in Group C lentil at Hart in 2019.

Herbicide treatment (dose/ha)		Ryegrass spikes/m^2	Ryegrass seed set/m^2
T_1	Sakura 118 g (IBS) + clethodim 500 mL (POST)	19.6 c	650 c
T_2	Boxer Gold 2500 mL (IBS) + clethodim 500 mL (POST)	57.3 b	2228 b
T_3	Propyzamide 1000 g (IBS)	6.2 cd	246 cd
T_4	Propyzamide 1000 g (IBS) + clethodim 500 mL (POST)	0.6 def	23 de
T_5	Ultro 1700 g (IBS)	4.7 de	156 de
T_6	Ultro 1700 g (IBS) + clethodim 500 mL (POST)	3.1 def	108 de
T_7	Unweeded control	136.7 a	5506 a

Figures labelled with the same letter are not significantly different (P=0.05).

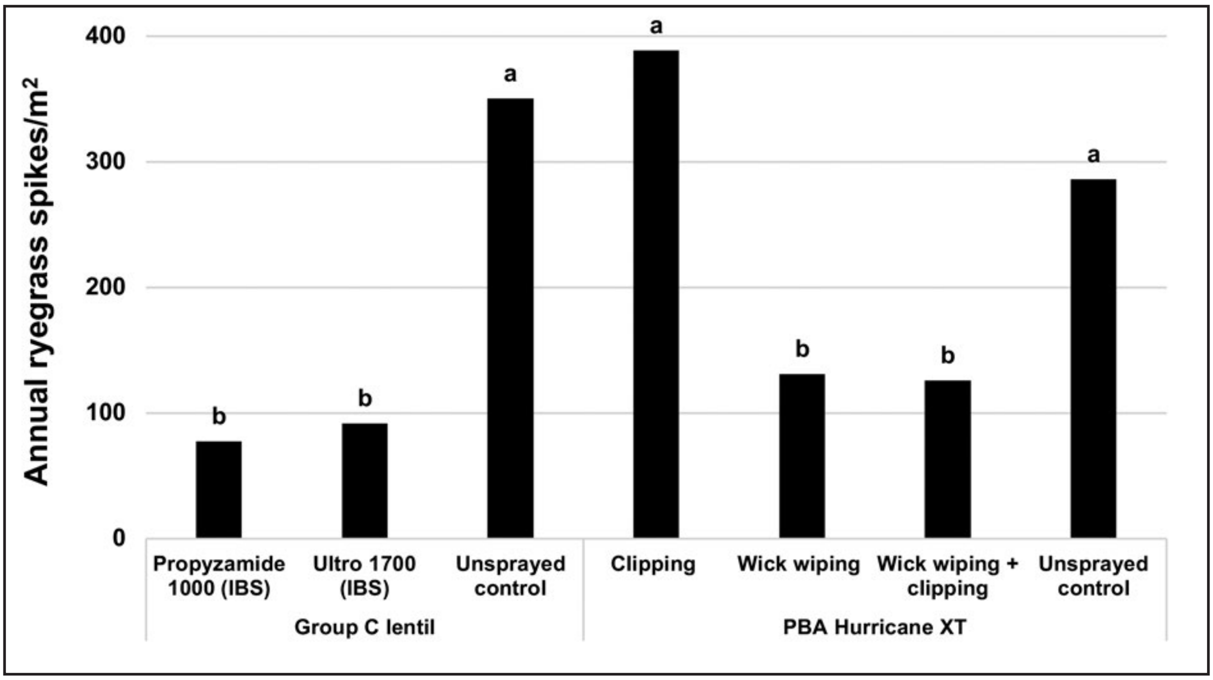

Figure 1. Annual ryegrass spike density response to weed control treatments in lentil at Hart 2020. Bars labelled with the same letters are not significantly different (P=0.05).

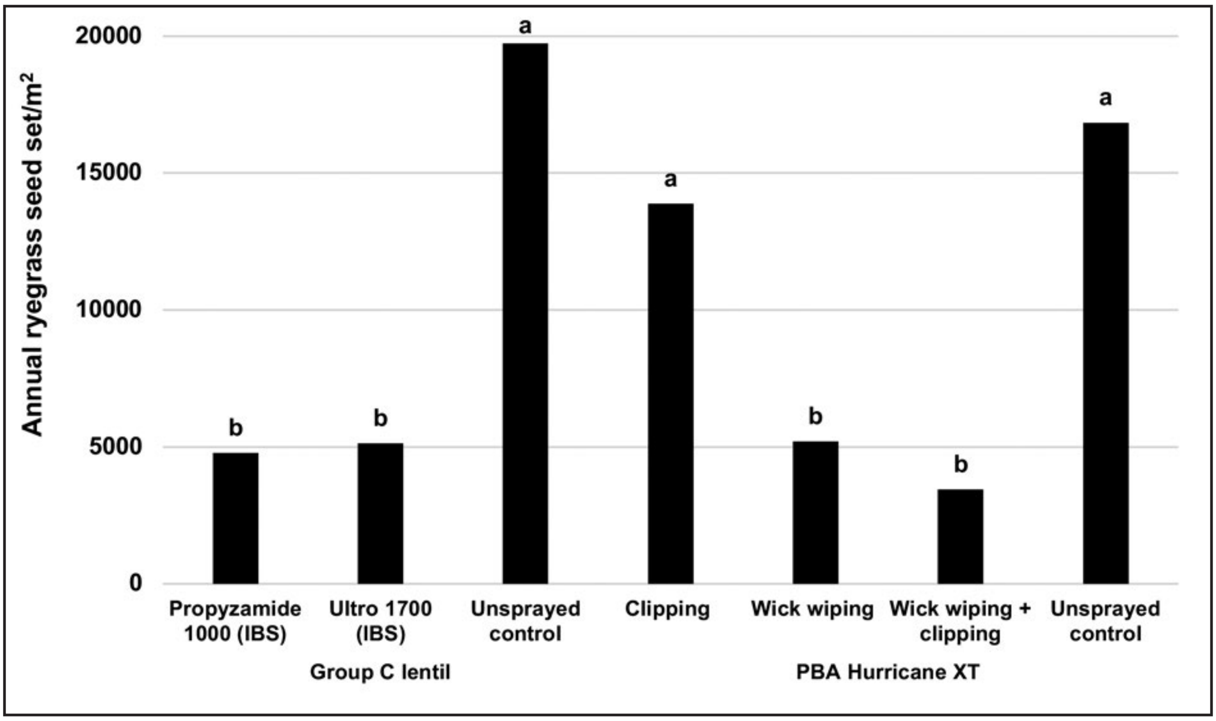

Figure 1. Annual ryegrass seed set response to weed control treatments in lentil at Hart 2020. Bars labelled with the same letters are not significantly different (P=0.05).

Effect on annual ryegrass in chickpea

Application of T_3: propyzamide (IBS) + clethodim (POST) and T_4: Ultro (IBS) + clethodim (POST) proved equally effective for Group A, J and K resistant annual ryegrass control in chickpeas (Table 2). Annual ryegrass produced 62 spikes in T_3: propyzamide (IBS) + clethodim (POST), 83% and 70% less than T_1: Boxer Gold (IBS) + clethodim (POST) and T2: Sakura 118 (IBS) + clethodim (POST) respectively. Similarly, T_4: Ultro (IBS) + clethodim (POST) reduced annual ryegrass spike density by 71% and 51% relative to T_1: Boxer Gold (IBS) + clethodim (POST) and T_2: Sakura 118 (IBS) + clethodim (POST) respectively. Ryegrass seed production reflected the similar trends observed in spike density data. Application of T_3: propyzamide (IBS) + clethodim (POST) and T_4: and Ultro (IBS) + clethodim (POST) resulted in significant reduction in annual ryegrass seed set as compared to both T_1: Boxer Gold (IBS) + clethodim (POST) and T_2: Sakura 118 (IBS) + clethodim (POST).

Furthermore, a protective inter-row spray of Spray.Seed before chickpea canopy closure proved equally effective to pre-emergent herbicides propyzamide and Ultro for annual ryegrass control. As in the lentil crop, integrated weed management tactics of wick wiping and clipping + wick wiping proved more effective in reducing annual ryegrass spike density and seed set, compared to clipping alone.

Effect on grain yield of lentil

In 2019, all the herbicide treatments resulted in a significantly higher lentil grain yield over the unsprayed control (Figure 3). Application of Ultro (IBS) + clethodim (POST) produced similar grain yield as achieved with propyzamide (IBS) + clethodim (POST) and Sakura (IBS) + clethodim (POST). Poor annual ryegrass control with Boxer Gold (IBS) + clethodim (POST) resulted in the lowest lentil yield as compared to other pre-emergent herbicides. In 2020, propyzamide (IBS) application produced similar lentil grain yield (0.73 t/ha) as achieved with Ultro (IBS) (0.82 t/ha).

Table 2. Ryegrass management in chickpeas at Hart in 2020.

Herbicide treatment (dose/ha)		Ryegrass spikes/m²	Ryegrass seed set/m²
T_1	Boxer Gold 2500 mL (IBS) + clethodim 500 mL (POST)	357 ab	23256 a
T_2	Sakura 118 g (IBS) + clethodim 500 mL (POST)	210 c	12679 b
T_3	Propyzamide 1000 g (IBS) + clethodim 500 ml (POST)	62 d	3819 c
T_4	Ultro 1100 g (IBS) + clethodim 500 mL (POST)	104 d	6610 c
T_5	Protective inter-row spray of Spray.Seed before canopy closure	104 d	6384 c
T_6	Clipping at reproductive stage	380 a	11946 b
T_7	Clipping + wick wiping	221 c	4264 c
T_8	Wick wiping at reproductive stage	266 bc	4343 c
T_9	Unsprayed control	426 a	26896 a

Figures labelled with the same letter are not significantly different (P=0.05).

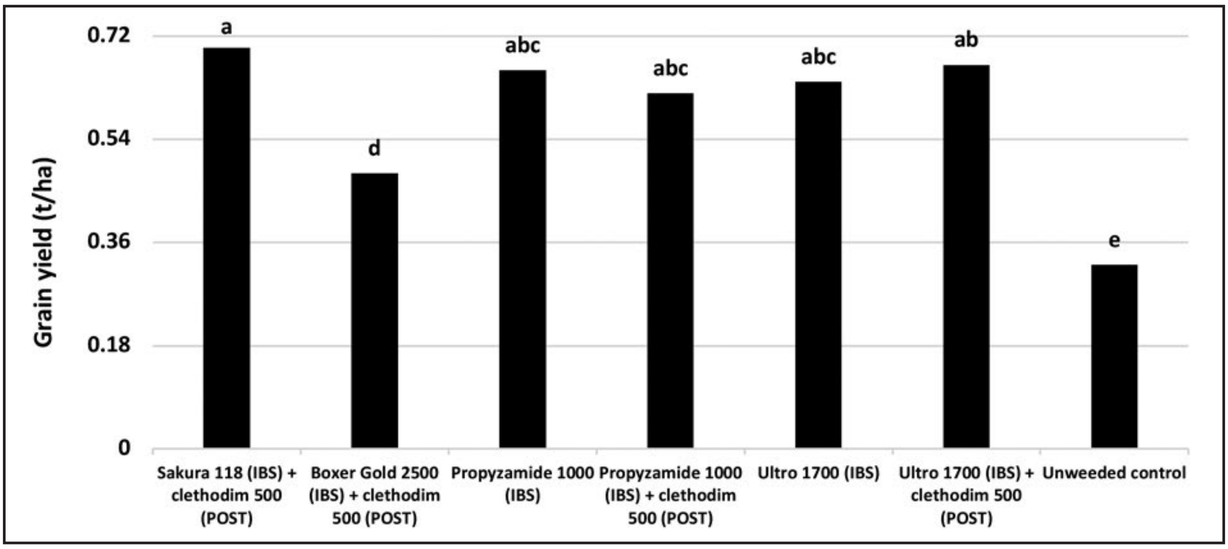

Figure 3. Lentil grain yield at Hart 2019. Bars labelled with the same letters are not significantly different (P=0.05).

Table 3. Chickpea grain yield response to ryegrass management at Hart in 2020.

Herbicide treatment (dose/ha)		Grain yield (t/ha)
T_1	Boxer Gold 2500 mL (IBS) + Clethodim 500 mL (POST)	0.98 c
T_2	Sakura 118 g (IBS) + clethodim 500 mL (POST)	1.27 b
T_3	Propyzamide 1000 g (IBS) + clethodim 500 mL (POST)	1.64 a
T_4	Ultro 1100 g (IBS) + clethodim 500 mL (POST)	1.39 ab
T_5	Protective inter-row spray of Spray.Seed before canopy closure	1.29 b
T_6	Clipping at reproductive stage	0.51 d
T_7	Clipping + wick wiping	0.54 d
T_8	Wick wiping at reproductive stage	0.44 d
T_9	Unsprayed control	0.52 d

Figures labelled with the same letter are not significantly different (P=0.05).

Effect on grain yield of chickpeas

Application of T_3: propyzamide (IBS) + clethodim (POST) produced higher grain yield compared to growers' practice of T_1: Boxer Gold (IBS) + clethodim (POST) and T_2: Sakura (IBS) + clethodim (POST) (Table 3). Application of T_4: Ultro (IBS) + clethodim (POST) produced similar yields as with T_3: propyzamide (IBS) + clethodim (POST) and T_2: Sakura (IBS) + clethodim (POST). Integrated weed management tactics of wick wiping and clipping + wick wiping, though resulting in similar annual ryegrass seed set as in T_3: propyzamide (IBS) + clethodim (POST) and T_4: Ultro (IBS) + clethodim (POST), produced chickpea yields no different to the unsprayed control. This was due to the competition from annual ryegrass before applying wick wiping and clipping + wick wiping tactics. Therefore, early season annual ryegrass control with pre-emergent herbicides is crucial for achieving good chickpea yields, and late season weed seed set control tactics such as wick wiping and clipping + wick wiping reduce the weed seed burden for the following seasons' crops.

What does this mean?

The new mode of action herbicide Ultro (active carbetamide, Group E) is an important tool, along with Group D propyzamide, in reducing selection pressure for existing Group J and K pre-emergent, and Group A dim chemistry post emergent herbicides for annual ryegrass control in pulse crops. In addition, adopting proven strategies for stopping annual ryegrass setting seed such as crop topping and wick wiping, and collecting remaining seed through harvest weed seed collection measures across different phases of the crop rotation, are important to reduce soil weed-seed bank and delay resistance build-up to herbicides.

Acknowledgements

The research undertaken as part of this project is made possible by the significant support of GRDC and SARDI (DAS00168BA), Southern Pulse Agronomy (DAV00150) and Hart Field site group for trial cooperation and the authors would like to thank them for their continued support. The help received from SARDI Clare team in the field work is greatly appreciated. Authors also thank Ashley Pilkington, ADAMA for making available the herbicide Ultro® for the current research studies.

Reference

Aggarwal N, Roberts P, Gontar B, Pearce A, Dzoma B, Arsego F, Oakey H, Boutsalis P and McMurray L. 2019. Sustaining Group J and K herbicides in high break crop intensity rotations. In *Eyre Peninsula Farming Systems 2019 Summary*. pp 146-48.

Section 5

Cereals

Section Editor:
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Table 1. Upper Eyre Peninsula wheat yield performance. NVT data 2015 - 19. Long-term yield expressed as a percentage of mean yield.

		Year	2015	2016	2017	2018	2019
		Mean yield (t/ha)	1.84	2.44	1.22	1.53	1.3
Variety	**Classification**	**No. trials**	**7**	**6**	**5**	**5**	**7**
MILLING WHEATS							
Ballista[A]	AH	7	–	–	–	–	119
Beckom[A]	AH	30	104	107	105	104	107
Catapult[A]	AH	12	–	–	–	107	108
Corack[A]	APW	30	111	97	102	106	97
Cutlass[A]	APW	30	98	100	102	103	92
Emu Rock[A]	AH	30	100	103	98	96	113
LG Cobalt[A]	APW	30	104	102	107	106	100
LongReach Arrow[A]	AH	30	106	102	103	104	101
LongReach Cobra[A]	AH	23	100	99	95	99	–
LongReach Havoc[A]	AH	23	–	96	99	104	97
LongReach Scout[A]	AH	30	96	106	99	95	112
LongReach Trojan[A]	APW	30	103	103	103	105	96
Mace[A]	AH	30	108	101	104	105	102
RockStar[A]	AH	12	–	–	–	107	115
Scepter[A]	AH	30	113	108	110	110	109
Vixen[A]	AH	17	–	–	109	106	125
Wyalkatchem[A]	APW	30	103	99	101	102	98
Yitpi[A]	AH	30	92	96	98	97	92
CLEARFIELD PLUS®							
Chief CL Plus[A]	APW	23	–	94	102	106	88
Grenade CL Plus[A]	AH	30	95	97	96	94	102
Hammer CL Plus[A]	AH	7	–	–	–	–	104
Kord CL Plus[A]	AH	30	95	94	97	96	96
Razor CL Plus[A]	ASW	23	–	106	103	102	112
Sheriff CL Plus[A]	APW	23	–	104	105	105	103

Data sourced from 2021 South Australia Crop Sowing Guide (https://grdc.com.au/2021-south-australian-crop-sowing-guide)

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Table 2. Upper Eyre Peninsula barley yield performance. NVT data 2015–19. Long-term yield expressed as a percentage of mean yield.

Variety	Year	2015	2016	2017	2018	2019
	Mean yield (t/ha)	2.49	3.99	2.13	2.18	2.55
	No. trials	4	4	2	4	4
MALTING						
Commander[A]	18	97	100	105	108	102
Compass[A]	18	114	100	119	118	119
La Trobe[A]	18	115	100	114	115	112
RGT Planet[A]	14	–	110	97	96	101
Scope CL[A]	18	96	95	103	99	97
Spartacus CL[A]	18	117	100	113	115	115
FEED						
Beast[A]	4	–	–	–	–	125
Fathom[A]	18	113	110	110	116	117
Fleet Australia[A]	18	103	105	109	117	107
Keel	18	111	102	107	113	111
Rosalind[A]	18	123	106	111	113	117
PENDING MALT ACCREDITATION						
LG Alestar[A]	18	94	96	93	90	90
Buff[A]	8	–	–	–	114	107
Laperouse[A]	8	–	–	–	117	115
Leabrook[A]	18	115	106	114	117	120
Maximus CL[A]	8	–	–	–	114	115

Data sourced from 2021 South Australia Crop Sowing Guide (https://grdc.com.au/2021-south-australian-crop-sowing-guide)

Cereals

New wheat and barley varieties in 2020

Amanda Cook
SARDI Minnipa Agricultural Centre

Wheat NVT

The 2021 South Australia Crop Sowing Guide (https://grdc.com.au/2021-south-australian-crop-sowing-guide) has the current information on all varieties including the 2020 recent releases Ballista^A, Denison^A , and BASF Ascot^A. Only the recently released variety descriptions are compiled in this article.

New Release Wheat Variety Notes (Compiled from 2021 South Australia Crop Sowing Guide).

Ballista^A is an AH quality, quick to mid-maturing variety, slightly quicker than Mace^A. Ballista^A has high and stable yield across a range of environmental conditions and has CCN resistance similar to Scepter^A and Mace^A. Released in 2020 (tested as RAC2598), bred and marketed by AGT, Ballista^A is eligible for AGT Seed Sharing™. (EPR $3.50 ex-GST).

Denison^A is an APW quality, slow-maturing variety suited to mid to late-April sowing. It has short stature with good lodging resistance. Released in 2020 (tested as WAGT734). It was bred and marketed by AGT and is eligible for AGT Seed Sharing™. (EPR $3.40 ex-GST).

BASF Ascot^A is an APW quality, mid-maturing variety suited to medium to high-rainfall zones. BASF Ascot^A is the first wheat variety to be launched by BASF. Released in 2020 (tested as BSWDH10-215) and bred by BASF, seed is available and marketed by Seednet. (EPR $3.85 ex-GST).

2019 Release Wheat Variety Notes (Compiled from 2021 South Australia Crop Sowing Guide).

Catapult^A was released in 2019 by AGT as a variety for late April/early May sowing. Catapult^A offers wide adaptation and has a mid to slow maturity suited for earlier planting opportunities in late April to early May. Yield evaluation of Catapult^A from earlier sowing is limited in SA and more evaluation is required. Initial data suggests Catapult^A produces grain with high test weights and low screenings and is suitable for wheat-on-wheat situations, with suitable Yellow leaf spot resistance. Seed is available from AGT affiliates, retailers, or through Seed Sharing™. (EPR $3.25/t GST ex).

Razor CL Plus^A is a quick to mid-maturity, imidazolinone herbicide-tolerant (Clearfield®) ASW wheat released by AGT. The long-term performance of Razor CL Plus^A suggests it is the highest yielding Clearfield® variety and on average is three per cent higher than Mace^A. Razor CL Plus^A 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 ex-GST.

RockStar^A has been released in 2019 by InterGrain. RockStar^A offers wide adaptation but has a slightly slower development pattern suited for earlier planting opportunities in late April to early May. Yield performance similar to or slightly higher than Scepter^A using May to June sowing dates in the long term NVT data. Yield evaluation of RockStar^A from earlier sowing is limited in SA and more evaluation is required. RockStar^A is rated MRMS to Stripe rust and Yellow leaf spot, SVS to Powdery mildew, S to Leaf rust, and MSS to Septoria. RockStar^A 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^A is an early flowering variety that develops slightly quicker than Mace. Vixen^A 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^A 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^A 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).

New Release Barley Variety Notes (Compiled from 2021 South Australia Crop Sowing Guide).

Beast[A] is a very quick-maturing variety suited to medium to low-rainfall environments and performs well in stressed growing conditions. Similar plant type to Compass[A] offering useful levels of early vigour and weed competitiveness, but care should be taken in lodging-susceptible conditions. Released 2020 (tested as AGTB0113) and marketed by Australian Grain Technologies. Seed available through AGT affiliates and is eligible for AGT Seed Sharing™. (EPR $4.00 ex-GST).

Laperouse[A] is a quick-maturing variety with a medium plant height. Accepted into Barley Australia malt accreditation in 2019, with an earliest possible decision expected in 2022. Laperouse[A] is susceptible to CCN, MR-MRMS to Net form net blotch, and MS-SVS to Leaf rust. Released 2020 (tested as WI4952). Bred by University of Adelaide and SECOBRA Recherches, marketed by Seednet. (EPR $3.80 ex-GST).

Maximus CL[A] is a very quick-maturing imidazolinone (IMI)-tolerant barley. Maximus CL[A] is resistant to CCN, MR-MRMS to Net form net blotch and has improved grain size compared to Spartacus CL[A]. It has a short coleoptile length and it is recommended that sowing depth be considered carefully. Maximus CL[A] is currently undergoing Barley Australia malt accreditation with a decision expected in 2021. Released 2020 (tested as IGB1705T). Bred and marketed by InterGrain. (EPR $4.25 ex-GST).

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SARDI research staff erecting a rain out shelter at EP Soil Moisture Probe sites, 2020.

Novel agronomy strategies for reducing the yield decline from delayed emergence

Kenton Porker[1,3], Brendan Kupke[1], Melissa McCallum[1], Courtney Peirce[1,3], Paul Swain[1], Wayne Reid[1], Peter Hayman[1,3], Dane Thomas[1,3], Bronya Alexander[1], Brenton Spriggs[2], Andrew Ware[4] and James Hunt[5]

[1]SARDI Waite, [2]SARDI Minnipa, [3]The University of Adelaide, [4]EPAG Research, [5]LaTrobe University

Location
Minnipa Agricultural Centre
Rainfall
Av. Annual: 346 mm
Av. GSR: 256 mm
2019 Total: 235 mm
2019 GSR: 216 mm
Paddock history
2018: Pasture
2017: Barley
2016: Barley
Soil type
Calcarosol
Plot size
10 m x 1.4 m x 3 reps
Trial design
Experimental: Split plot design
Yield limiting factors
Moderate early finish, moderate sand drift in trial.

Location
Cummins
Rainfall
Av. Annual: 422 mm
Av. GSR: 340 mm
2019 Total: 325 mm
2019 GSR: 307 mm
Plot size
10 m x 1.4 m x 3 reps
Trial design
Experimental: Split plot design
Yield limiting factors
Moderate early finish.

Location
Loxton
Rainfall
Av. Annual: 283 mm
Av. GSR: 170 mm
2019 Total: 128 mm
2019 GSR: 93 mm

Key messages

- **Matching crop variety development to environment should remain a key focus of crop management, such as early sowing of a slower developing winter cultivar (prior to 1 May). There are some downsides to winter wheat adoption, as there is risk of later emergence (after 1 May), hence flowering later than optimal, and reduced yields.**
- **It is very important to make the most of early establishment opportunities because, other than genetic improvement, there were a lack of solutions for negating yield decline from later emergence or for speeding up crop development.**
- **Strategies to improve earlier establishment under low soil water potentials would be transformative for lower rainfall districts.**
- **Applications of hormones showed little ability to speed up development or increase yield of late emerged crops.**
- **Barley was better suited to later emergence than wheat. There are possibilities to quantify the regional differences in the role of barley and other crops compared to wheat in the rotation, and sowing time schedules need to be revaluated accordingly.**

Why do the trial?

The aim of the trial was to investigate new management strategies to increase potential grain yield from later sowing times in wheat and barley. To maximise yield potential, growers need to be sowing early with farm sowing programs needing to be finished and germination occurred by 15 May in many districts of South Australia (SA). However, early breaking rains that allow for crop establishment are limited and inconsistent with significant seasonal breaks occurring before 1 May occurring in less than 50% of years. This means later germination and sowing dates resulting in lower potential yields from reduced biomass production, tiller number and increased risk of heat and drought stress.

How was it done?

Experiments were conducted at four locations in SA, which vary in rainfall and temperature and thus seasonal yield potential (Table 1). Three germination dates were targeted, defined here as time of sowing TOS1, TOS2 and TOS3. TOS1 was in mid-April which is optimal for winter cultivars in all environments and too early for quick developing spring cultivars. TOS2 was in early to mid-May (depending on site), which is optimal for quick developing spring cultivars. TOS3 was in early June, which is considered too late for all cultivars and the focus of this experiment. Sowing dates and site locations are outlined in Table 1.

Plot size
5 m x 1.4 m x 3 reps
Trial design
Experimental: Split plot design
Yield limiting factors
Moderate frost, moderate drought, moderate heat stress, moderate early finish

Location
Giles Corner
Rainfall
Av. Annual: 526 mm
Av. GSR: 398 mm
2019 Total: 320 mm
2019 GSR: 267 mm
Plot size
5 m x 1.4 m x 3 reps
Trial design
Experimental: Split plot design
Yield limiting factors
Low frost

How was it done cont...

Wheat and barley genotypes were selected based on developmental patterns. A winter cultivar suited to earlier sowing was selected with local adaptation to each site. For wheat this was either DS Bennett[A], Longsword[A] or Illabo[A], for barley this was Urambie[A] and Cassiopee. The quick developing spring wheat, Scepter[A] and the barley variety, Compass[A] were the controls across all sowing times.

Additional agronomic treatments applied at the latest sowing date (TOS3) aimed to maximise biomass and reduce the yield decline from later planting or missed opportunities in wheat and barley (Table 2). Agronomic interventions such as doubling plant density, doubling nitrogen (N) supply, plant hormones (auxins, gibberellic acid and cytokinins), and quicker developing cultivars were tested. Harvest index samples were collected for a measure of biomass production and grain yield harvested from plots which were both analysed using Genstat for Windows (2018) 19th ed.

What happened?

Cultivar and species responses to sowing date

The trends for wheat and barley were similar for TOS1 and TOS2. Highest yields were achieved by early sown (TOS1) winter cultivars, yielding similar to their respective quick spring cultivars sown at their optimal time (TOS2). Winter barley was approximately 0.45 t/ha higher yielding than winter wheat at both sowing times TOS1 and TOS2, suggesting winter barley might be better adapted than current winter wheat cultivars. Winter cultivar yields were optimised at the April germination date and both wheat and barley suffered a 12% yield penalty when emergence was delayed until mid-May (TOS2).

Spring barley yielded similarly to spring wheat at TOS1 and TOS2 (Figure 1 and Figure 2), however barley yielded 0.4 t/ha higher at the later planting, suggesting barley is more suited to later emergence than wheat. Both quick spring wheat and barley suffered a yield penalty from early planting, and there is evidence of less yield decline in barley relative to wheat at later planting. In the quick spring wheat, there was a 13% yield penalty from early sowing compared to May sowing and 11% from delayed planting. In the quick spring barley there was a 12% yield penalty from early sowing compared to May sowing and there was no yield penalty from delayed planting unlike wheat. This is an important consideration for growers where breaks are likely to occur past 15 May.

Management to limit the yield decline of late emerged crops

At later emergence, other agronomic interventions such as doubling plant density, doubling N supply, applying growth promoting root auxins and hormones did not reliably increase yield relative to control (Table 2, Figure 1 and Figure 2). There was also evidence of yield penalty from applied plant hormones; gibberellic acid and cytokinin. It was possible to increase biomass in wheat relative to the control, however this did not translate into increase in grain yield. In general, barley was effective at producing more biomass than wheat at later planting dates consistent with the yield responses. Currently adapted cultivars performed the best under the same management regime from early planting.

Cereals

Table 1. Site locations and corresponding sowing dates.

Site location	Sowing date		
	TOS1	TOS2	TOS3
Minnipa	17 April 2019	7 May 2019	4 June 2019
Loxton	15 April 2019	10 May 2019	4 June 2019
Giles Corner	18 April 2019	16 May 2019	6 June 2019
Cummins	15 April 2019	14 May 2019	14 June 2019

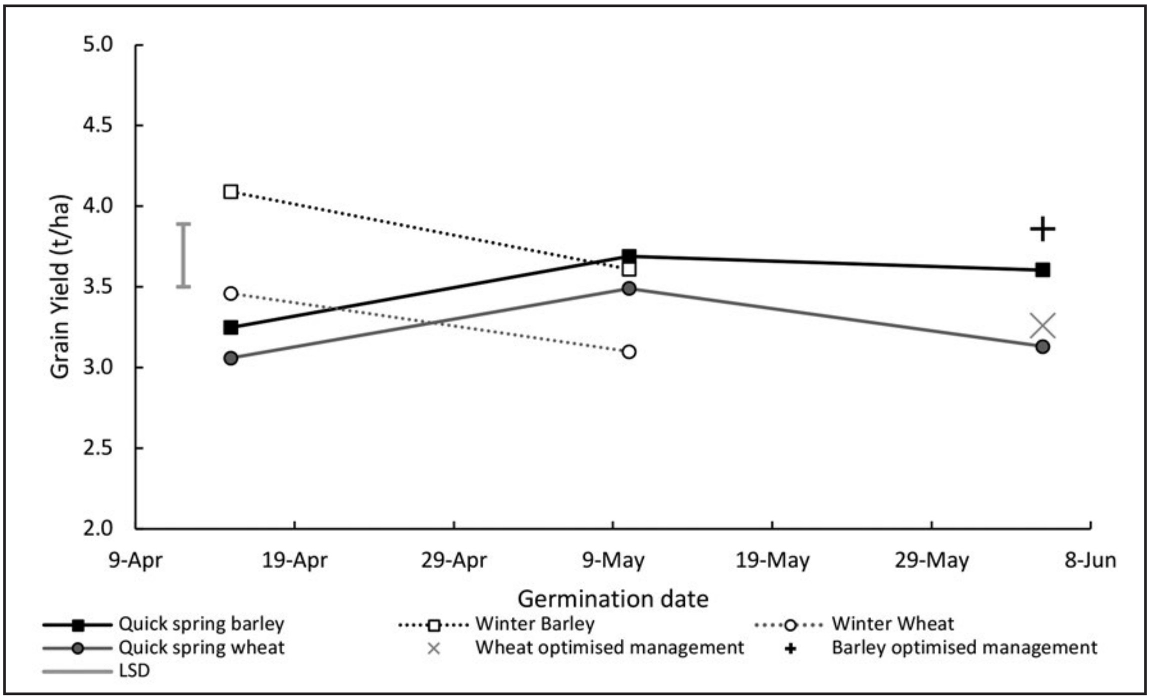

Figure 1. Grain yield responses to germination date of quick barley, quick wheat, winter wheat and barley averaged across four locations in South Australia 2019. The optimised management data points are for the late sown quick spring wheat (X) and barley (+) and represent the highest yielding treatment with different management tailored for later planting.

Table 2. Grain yield, biomass, and harvest index responses to management at later emergence (TOS3) average across all sites with standard quick - mid wheat Scepter and quick barley cultivar Compass.

Cultivar/ phenology	Management	Grain Yield (t/ha)	Biomass (t/ha)	HI
Wheat				
Scepter[A]	Control (180 seeds/m^2)	3.1	7.3	0.46
Scepter[A]	Double Seeding Density	3.1	7.4	0.42
Scepter[A]	Double Seeding Density + 50 Seedbed N	3.1	7.9	0.39
Scepter[A]	Double Seeding Density + AUXINS	3.3	7.8	0.42
Scepter[A]	Double Seeding Density + Gibberellic acid & Cytokinin	2.9	7.3	0.38
Corack[A] (Quicker)	Double Seeding Density	3.2	7.8	0.40
Barley				
Compass[A]	Control (150 seeds/m^2)	3.6	8.8	0.44
Compass[A]	Double Seeding Density	3.5	8.6	0.43
Compass[A]	Double Seeding Density + Gibberellic acid & Cytokinin	2.8	7.6	0.34
Spartacus[A] (Quicker)	Double Seeding Density	3.8	8.3	0.46
Spartacus[A] (Quicker)	Double Seeding Density + Gibberellic acid & Cytokinin	3.2	8.1	0.38
CSIROB3 (Very Quick)	Double Seeding Density	3.1	7.0	0.39
	P value Treatment	<0.001	<0.001	<0.01
	LSD	*0.35*	*0.51*	*0.02*

What does this mean?

This data highlights that there may be limited scope to reduce yield penalties from later planting with the crop management techniques evaluated here. However, species choice is critical and barley was better suited to later planting than wheat. The mechanisms for this require further investigation and may be due to faster growth or maturity rates under suboptimal temperatures associated with delayed planting. The suitability of other species such as oats would also warrant investigation.

Matching crop variety development to environment remains the best focus of management. Our other experiments suggest there are a number of solutions to slow development and negate the yield penalties associated with sowing a quick spring variety prior to its optimal time (such as winter cultivars and resetting crops). However, the lack of solutions for negating the yield decline from later emergence means making the most of early establishment opportunities, and these techniques are even more important. These solutions require validation for adoption along with further research to improve establishment of crops prior to the 15 May.

Another interesting finding is that it has previously been assumed the yield penalty from winter cultivars emerging after 1 May is significantly greater than any spring cultivars emerging after that time. However, this research suggests that the new generation of winter cultivars may not suffer the same degree of yield decline as previously thought. This means growers may actually have more opportunities in many parts of SA to establish winter wheats than currently predicted in the next module of research. This research needs to be validated.

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 (project code: DAS1910 - 003BLX), the author would like to thank them for their continued support.

Improving the productivity of oats for grain and hay

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Location
Lameroo, Southern Mallee, SA
Robert Pocock
Mallee Sustainable Farming Systems

Rainfall
Av. Annual: 379 mm
Av. GSR: 240 mm
2019 Total: 223 mm
2019 GSR (May-Oct): 197 mm
2020 Total: 387 mm
2020 GSR (May-Oct): 237 mm

Yield
Actual: Highest yielding treatments 2020
Barley: 10.1 t/ha hay; 4.8 t/ha grain
Wheat: 8.0 t/ha hay; 4.9 /ha grain
Oat: 9.6 t/ha hay; 4.6 t/ha grain

Paddock history
2019: Vetch / Canola hay
2018: Barley
2017: Wheat

Soil test
Key soil data for 2020 season presented in the table below.

Plot size
Plots 5 m x 6 rows at 0.23 m spacings using a plot seeder. Plots sown on 1.75 m centre to centre spacings.
Hay yield cut: (4 internal rows at 0.23 m spacings x 0.5 m = 0.46 m^2). Grain yields: 5 m x 1.75 m minus the hay cut area. 4 replicates per treatment.

Key messages

- **Growers have access to oat cultivars with similar development speeds to Compass barley and Scepter wheat making them suitable for both hay and grain.**
- **Oat varieties, particularly the hay varieties, sown earlier than current practice can produce biomass (hay yields) similar to Compass and Scepter.**
- **Increasing plant density and shifting N timing did not improve biomass but further analysis is required to assess whether it impacts the stem thickness and grain quality attributes.**
- **Sowing date and cultivar choice are likely to be the most important management levers to optimise hay yields.**
- **For dual-purpose oat varieties to be competitive for both hay and grain, they need to be sown early.**
- **Oats were more tolerant to flowering frost than wheat and barley, yielding higher when flowering at a similar time under extreme reproductive frost conditions at Lameroo.**
- **These findings confirm oats as an excellent risk management tool in frost prone landscapes for both hay and grain with further project work requiring economic analysis of the treatments.**

Why do the trial?

Oats are well placed as an excellent risk management tool to mitigate crop yield losses in frost prone districts and provide additional rotational benefits for improved ryegrass control if cut for hay. However, there is currently limited information on the early sowing of oats in South Australia. Sowing earlier increases potential yield and biomass but can also increase frost risk. Management strategies that can ensure good quality grain oats as well as hay are required.

The aim of this work is to help growers make better decisions as to whether to cut for hay or leave for grain in frost prone environments. This is a difficult decision for growers and sometimes a crop cannot be exclusively managed for one or the other. Despite this, current advice suggests different management of oats for hay vs grain relating to plant density and timing of nitrogen (N) application.

This research is two-fold providing guidelines to growers on crop management for maximising oat grain yield from milling or feed and the trade-off if the decision to cut for hay is made mid-season due to frost.

Table 1. Lameroo, initial pre-sowing soil test data, 2020

Depth	pH ($CaCl_2$)	Organic C (%)	Conductivity (dS/m)	P mg/kg (Colwell P)	Ammonium N (mg/kg)	Nitrate N (mg/kg)
0-10 cm	6.6	1.43	0.168	33	2	29
10-30 cm	7.5	1.28	0.320	24	1	23
30-60 cm	8.3	0.71	0.672	12	1	17
60-90 cm	8.5	0.58	1.010	9	1	7

Trial design
Split-split-plot design with 4 replicates
Block = Replicate, Whole plot = TOS, Sub-plot = Variety, Sub-sub-plot = Management.
Trial design
2019 yield limiting factors: dry summer; frost for early sown treatments, sharp spring finish – moderate impact but showed potential of early sown treatments and provided information on comparative frost tolerance of oats to wheat and barley.
2020 yield limiting factors: dry winter – low impact since spring rainfall made up the dry winter.

This project, now in its second year, is the first-time oats have been extensively evaluated in lower rainfall districts under different management regimes. This project is also being evaluated at a high-rainfall site in the Mid-North (Tarlee), but this article will focus on the Lameroo field trials only.

How was it done?

Field trials were conducted at a low rainfall site (Lameroo) and a high rainfall site (halfway between Tarlee and Riverton) in 2019 and 2020. Rainfall in 2019 was below average (annual rainfall 223 mm, decile 1 and growing season rainfall (GSR) 197 mm, decile 3) and rainfall in 2020 was average (annual rainfall 387 mm, decile 5 and growing season rainfall (GSR) 237 mm, decile 5) for the area based on long term average rainfall derived from BOM data 1900-2020.

In both seasons, 13 oat varieties as well as Scepter (wheat) and Compass (barley) were sown either late April/early May or in late May (Table 2). The variety list is included in Table 3.

The management strategy was to either set up the crop for hay or grain with different seeding densities and nitrogen management strategies.

- Grain management strategy: Seeding density of 160 plants/m² with ⅓ N applied at sowing and in 2019 ⅔ at 6 weeks after sowing (WAS) and in 2020 ⅔ delayed until Z30.
- Hay management strategy: Seeding density of 240 plants/m² with ⅔ N applied at sowing and ⅓ applied 6 WAS.

Seeding rate was adjusted expected germination and establishment rate but ranged from 53-85 kg/ha for the ‘grain strategy’ and 80-128 kg/ha for the ‘hay strategy’ depending on the seed size.

The N rate was determined by rainfall and calculated based on starting soil N and expected hay yields in 2019 which equated to 45 kg N/ha at Lameroo. Different parts of the same paddock were used for both 2019 and 2020 trials. The paddock history was 2018: barley, 2019: vetch canola hay, 2020: barley. As a result of the 2019 paddock history, starting N in 2020 was high at 210 kg/N to 90cm depth compared to 100 kg/N in the 2019 season but with better forecast rainfall, in 2020, the applied N rate was kept the same for both years. Seeding fertiliser for all plots was applied as 80 kg MAP/ha with additional N treatments top-dressed as urea to bring the total N applied up to the 45 kg N/ha level.

Growth stage of varieties were monitored from heading and hay cuts were taken for each plot (4 rows x 0.5 metres) at 15cm height above the ground when the top florets of each variety reached watery ripe (Zadoks 71) before being dried for two days at 60°C and hay yield determined. Grain was harvested using a Wintersteiger Delta small plot harvester when all varieties within a time of sowing were deemed to be harvest ripe. Grain yields have been adjusted for moisture as measured by NIR within two days of harvest.

At Lameroo in 2019, due to the dry summer, there was no germination of weeds or volunteer barley prior to sowing the early May plots. As a result, supplementary irrigation equivalent to 10 mm was applied after sowing which also germinated barley grass and barley in the plots. Hay yield for TOS1 is therefore biomass of both oats and weeds. In 2020, good summer rainfall ensured there was moisture at depth during sowing TOS1. To ensure establishment, supplementary irrigation equivalent to 10 mm was applied after sowing for the early sowing date. A good knockdown was achieved on weeds prior to sowing TOS2 in late May in both years.

Data was analysed using Genstat v20.1 by ANOVA using a split-split-plot design.

Cereals

Table 2.. Sowing and harvest dates for Lameroo trials.

		First season	Second season
Sown	TOS 1	6 May 2019	22 April 2020
	TOS 2	28 May 2019	18 May 2020
Harvested	TOS 1	17 November 2019	9 November 2020
	TOS 2	17 November 2019	16 November 2020

Table 3: Date of mid-flowering (Zadoks 65) and in brackets days from sowing to flowering for Lameroo comparing 2019 and 2020 for both sowing dates (SD).

Variety	Type	2019 Season		2020 Season	
		SD 6 May	SD 28 May	SD 22 April	SD 18 May
Compass	Barley	28-Aug (114)	20-Sep (112)	23-Aug (123)	15-Sep (120)
Scepter	Wheat	14-Sep (131)	28-Sep (123)	8-Sep (139)	23-Sep (128)
Durack	Dual-purpose	1-Sep (118)	15-Sep (110)	23-Aug (123)	12-Sep (117)
Williams	Dual-purpose	8-Sep (125)	27-Sep (122)	8-Sep (139)	19-Sep (124)
Mitika	Milling	9-Sep (126)	22-Sep (117)	29-Aug (129)	17-Sep (122)
Mulgara	Hay	10-Sep (127)	25-Sep (120)	7-Sep (138)	19-Sep (124)
Kowari	Milling	11-Sep (128)	21-Sep (110)	29-Aug (129)	13-Sep (118)
Bannister	Milling	11-Sep (128)	26-Sep (121)	12-Sep (143)	19-Sep (124)
Brusher	Hay	11-Sep (128)	25-Sep (120)	7-Sep (138)	19-Sep (124)
Yallara	Dual-purpose	12-Sep (129)	23-Sep (118)	12-Sep (143)	17-Sep (122)
Wintaroo	Hay	12-Sep (129)	30-Sep (125)	12-Sep (143)	22-Sep (127)
Wombat	Milling	12-Sep (129)	25-Sep (120)	N/A ^	N/A ^
Kingbale	Hay (Imi-tolerant)	18-Sep (135)	30-Sep (125)	14-Sep (145)	22-Sep (127)
Koorabup	Hay	19-Sep (136)	29-Sep (124)	13-Sep (144)	20-Sep (125)
Forester	Hay	22-Oct (169)	N/A*	N/A ^	N/A ^
Bilby	Milling	N/A~	N/A~	29-Aug (129)	19-Sep (124)
Vasse	Hay	N/A~	N/A~	22-Sep (153)	28-Sep (133)

**In 2019 Forester flowered inconsistently in some parts of the plot so we cut both SD on the 22/10 as the later sown had stopped growing.*
~Varieties only in 2019
^Varieties only in 2020

What happened?

2019 and 2020 were very different seasons. In 2019, the sharp dry spring finish helped produce good hay quality whilst the late winter/early spring rainfall in 2020 resulted in a season more favourable for grain than hay. Although hay yields were good in 2020, the consistent rainfall through September when crops were already cut and lying on the ground would have resulted in weather damage and a reduction in physical quality and appearance for growers that is not accounted for in our trials that are dried in an oven on the day of cutting. However, at Lameroo in 2020, some of the faster developing varieties sown on the 22 April may have been cut early enough to escape the weather damage.

Oat developmental differences

In 2020, the spread in flowering date between oat varieties excluding Vasse was just over 3 weeks when sown late April, only a slightly wider period than when sown in early May in 2019 (Table 3). Vasse was a good replacement variety for Forester in 2020, extending the development spread of varieties and providing a fit in environments when rain eventuates in late winter-early spring. However, if grown in 2019, it may have yielded poorly and struggled to progress through its growth stages like Forester did.

A decision in 2020 was made to push the first sowing date into April to see if the development speed and rankings were maintained from earlier sowing. Some varieties were able to maintain their stability in duration from sowing to mid flowering than others. Even at the earlier sowing date in 2020, there are still oat varieties with similar flowering dates to Compass and Scepter.

Hay yield responses

Hay biomass in both seasons were maximised from earlier sowing averaging 6.4 t/ha at Lameroo in 2019 and 8.2 t/ha in 2020 from the first sowing date (2019: 6 May and 2020: 22 April) and 5.2 and 6.9 t/ha respectively from the second sowing date in late May. In the 2019 season, fastest developing varieties (Bannister, Brusher, Durack and Mulgara) were the best performing varieties for hay at Lameroo, on par with Compass and there was no sowing date x variety interaction (Peirce and Porker, 2020). In 2020 however there was a sowing date x variety interaction and the top performing varieties included Vasse, the slowest developing cultivar, which was able to capitalise on the later season rain (Figure 1a). Compass was the only treatment that was able to maintain its biomass across both sowing dates whilst three of the hay only varieties (Mulgara, Vasse and Wintaroo) were able to produce the same amount of biomass when sown early. The effect of crop density and N management was negligible in both seasons for hay yield.

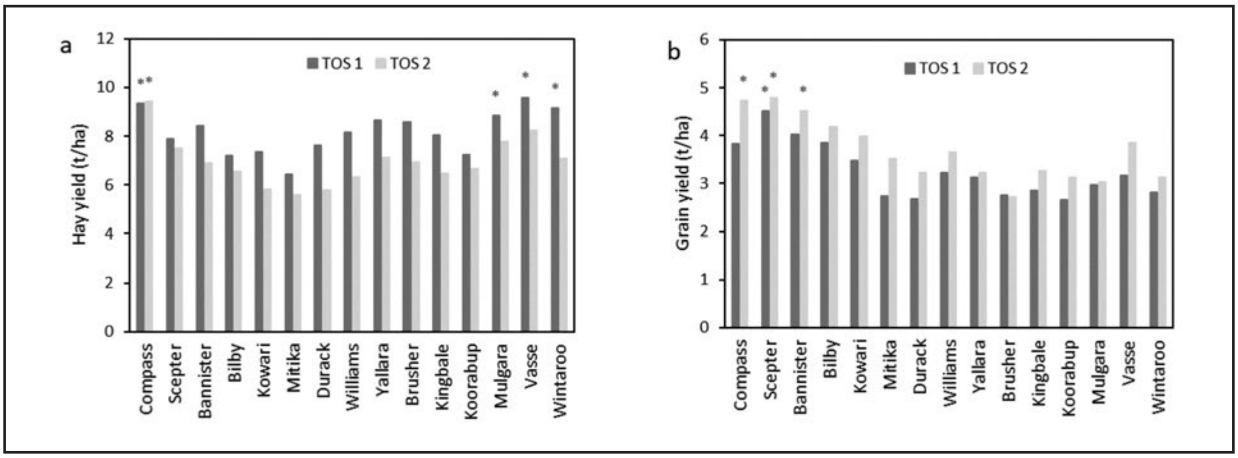

Figure 1: Interaction between Variety and TOS on (a) hay yield (p≤0.05, LSD 0.89) and, (b) grain yield (P =0.05) LSD 0.33, at Lameroo. Asterisk indicate the top performing treatments within each graph.

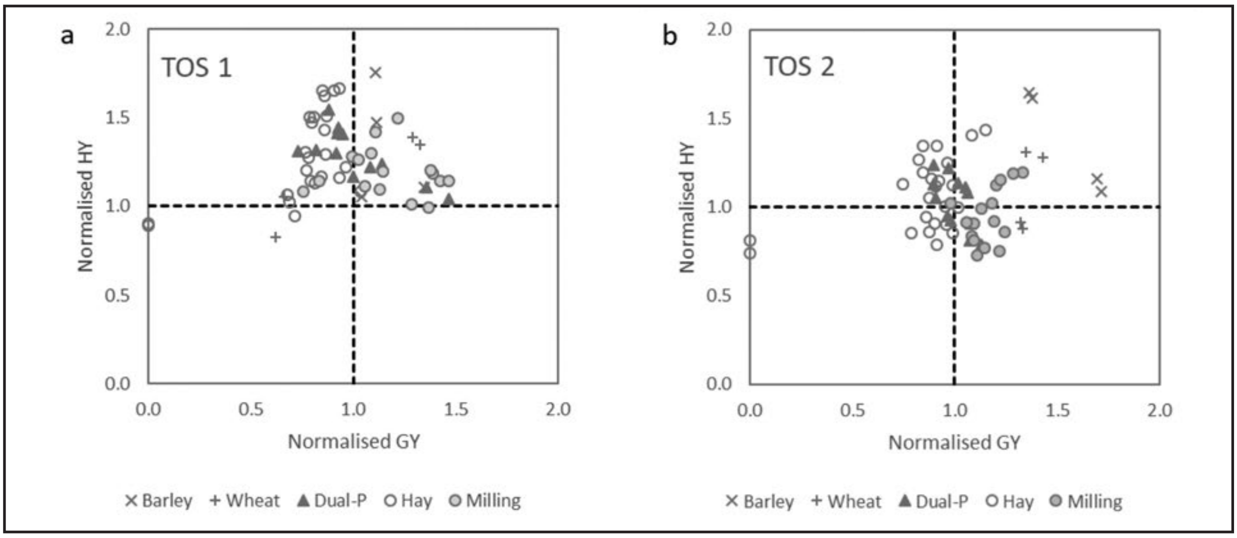

Figure 2: Comparison of the hay and grain yields of barley, wheat and oats from 2019 and 2020. Yields are normalised (by dividing by the site mean for each season). (a) Lameroo TOS 1, (b) Lameroo TOS 2. The data can then be categorised into 4 quadrats, upper left = optimised for hay, upper right = true dual-purpose outcome, lower left = underperforming treatment and lower right = optimised for grain.

Grain yield responses

Due to the late rain in 2020, later sown crops at Lameroo had higher grain yields than early sown crops (3.7 vs 3.2 t/ha respectively, LSD 0.2). Unlike hay yields, there was a small but significant increase in grain yields when crops were managed for grain rather than managed for hay. Scepter from both sowing dates had the highest grain yields (Figure 1b) showing the upside of growing a wheat which was able to capitalise on the spring rain to increase grain size. Likewise, when Compass was sown later (in May, its optimal sowing window), it also was one of the highest yielding varieties. Bannister maintained its reputation as the highest potential milling oat but performed better from late sowing at Lameroo. The grain yields in 2019 were lower (2.2 t/ha site average) than 2020 due to a combination of several severe frosts that affected the yields of some of the early developing varieties sown at the start of May and the sharp finish during grain filling. As a result, in 2019 oat yields were maximised from sowing in early May with Bannister, Kowari and Williams having the highest grain yields (Peirce and Porker, 2020).

To investigate the potential of each category of oats vs barley and wheat to achieve both high grain and hay yields, we plotted the relative grain and hay yields for Lameroo for both 2019 and 2020 (Figure 2). At both sites there is a clear genetic influence with the varieties bred for hay mainly sitting on the left side of the graphs (high hay yields) whilst the milling bred varieties sit mainly on the right side (high grain yields). Dual-purpose varieties sit somewhere in between although generally have higher relative hay yields rather than grain yields. To maximise hay and grain yields (upper left quadrat), particularly in the dual-purpose varieties, they need to be sown early. Hay varieties will rarely achieve high grain yields. In comparison, Compass and Scepter sown early were consistently in the upper right quadrat except for Scepter in 2019 which was severely impacted by frost. Compass showed its versatility in this environment by maintaining high grain and hay yield across every treatment in the two years, even when sown in late May.

What does this mean?

The results from the last two seasons have given us some good baseline data on the performance of oats for both grain and hay in the Mallee of South Australia. There are several oat varieties that will flower in a similar window to both Compass and Scepter suggesting that both hay and grain end-uses are possible in this region. Under extreme reproductive frost conditions at Lameroo in 2019, oats had higher grain yields (up to 1.5 t/ha) than Scepter (wheat) when flowering at a similar time. This suggests oats are likely to be a lower risk option in landscapes prone to reproductive (flowering) frosts for both hay and grain. In order to maximise the dual-purpose varieties, for both hay and grain end-use, they need to be sown early in this environment, although there are genetic differences and in drier seasons, the faster developing varieties will generally perform better.

This project will have one more season of field trials in 2021 and will be conducted in a paddock with lower starting fertility to compare the management role under different starting N conditions than the past two seasons. Further economic analysis will be conducted on the treatments with consideration of both hay and grain quality being factored into the best potential options for growing oats for milling, dual-purpose or hay in the region.

Acknowledgements

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Oaten hay agronomy - results from the Victorian Wimmera and Mid North of SA

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Location
Hart, SA
Rainfall
2020 crop year (Nov - Oct): 450 mm
2020 GSR (Apr - Oct): 335 mm
Av. GSR (Apr - Oct): 300 mm
Soil type
Clay loam
Paddock history
2019: Oaten hay

Location
Rupanyup, VIC
Rainfall
2020 Crop year (Nov - Oct): 467 mm
2020 GSR (Apr - Oct): 309 mm
Av. GSR (Apr - Oct): 292 mm
Soil type
Clay
Paddock history
2019: Barley

Key messages

- **In Victoria, longer season varieties and later sowing were able to take advantage of the higher than average spring rainfall but at Hart in SA, the spring rainfall fell too late to benefit the slower developing varieties or later sowing.**
- **Delaying sowing from 6 May to 29 May increased hay yield by 0.6 t/ha at Rupanyup but decreased yields by 0.9 t/ha at Hart.**
- **In Victoria, varieties responded to increased applied nitrogen up to 90 kg N/ha, except for Carrolup and Koorabup, varieties bred for WA, whilst there was no interaction between variety and N at Hart.**
- **The contrasting results from 2020 between the two sites highlight the importance of rainfall timing not just total GSR to maximise oaten hay yields.**

Why do the trial?

Oaten hay accounts for almost 75 per cent of fodder exported from Australia, to key export markets such as Japan, Korea, China and Taiwan. Hay exporters take a subjective and objective approach to determining hay quality. In the paddock they will generally look for visual indicators such as colour, stem thickness, texture and smell. Objective feed testing measures levels of metabolisable energy, sugars (water soluble carbohydrates, WSC), protein, fibre (NDF and ADF) and digestibility. These combine to determine palatability, animal intake and performance. Ideally, exporters are seeking thin stemmed, soft textured hay, with high WSC and low fibre (NDF≤50-55% and ADF≤30-35%) (Peace 2016) that is more palatable and sought after by the international markets.

The National Hay Agronomy (NHA) project is a four-year investment by the AgriFutures Export Fodder Program led by DPIRD with BCG, Agriculture Victoria, NSW DPI and SARDI. The project, now in its second year, aims to improve understanding of how agronomic practices affect export oaten hay yield 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 yield and quality of oat varieties at different times of sowing and under different nitrogen (N) nutrition strategies.

How was it done?

Trial details

Crop type/s: Oats (see Table 1)
Target plant density: 320 plants/m^2
Seeding equipment: Knife points, press wheels, 30 cm (Vic) or 22.9 cm (SA) row spacing
Sowing dates: TOS1 - 6 May (SA and Vic), TOS2 - 25 May (SA), 29 May (Vic)
Replicates: Three
Trial average yield: 6.3 t/ha (Vic), 3.1 t/ha (SA).

Trial Inputs

Fertiliser: Granulock Supreme Z + Flutriafol (200 ml/100kg) @ 60 kg/ha (Vic), DAP + Impact @ 80 kg/ha (SA)
Seed treatment: EverGol® @ 260 mL/100 kg and Gaucho® @ 240 mL/100 kg
Trial managed as per best practice for herbicides, insecticides and fungicides.

Method

A replicated field trial was sown using a split plot trial design. Treatments from the 2019 Oaten Hay Agronomy trial were repeated, except for the variety Forester (very slow maturity) which was swapped for Vasse; a mid-slow variety. Results from 2019 across all four NHA sites suggested Forester was too slow for the main hay growing districts.

Assessments included NDVI, hay biomass at GS71, plant height, lodging, leaf greenness (SPAD chlorophyll measure) and stem diameter. NIR (including DairyOne calibration) was still being analysed for the Rupanyup site at the time of writing.

What Happened?

In Victoria, 2020 time of sowing (TOS) effects contrasted with the 2019 trial at Kalkee which experienced a dry spring finish and the SA trials in both 2019 and 2020. In 2019 yields at Kalkee were favoured by earlier sowing, with early May sown treatments averaging 1.5 t/ha higher than early June sown treatments. The late maturing Forester failed to reach GS71 for hay cut at either sowing date. Yield in 2019 was generally optimised with the application of 60 kg N/ha split 2:1 between sowing and top dressing six weeks post sowing.

The 2020 season at Rupanyup experienced a very good start with 189 mm rainfall falling between January and April, providing soil moisture to support below average rainfall months between May to July (77 mm). In August and September, 66 mm and 41 mm fell respectively resulting in mild conditions as the trial moved through stem elongation until it was ready to cut (Figure 1a).

The 2020 season at Hart experienced a wet season but the rainfall was not evenly distributed throughout the year and was well below average through May, June and July (Figure 1b). The trial presented symptoms of water and nitrogen (N) stress such as red leaf tipping, dull colouring and an overall lack of vigour and biomass during this dry winter period. Concurrently, warm conditions caused rapid progression through plant growth stages, resulting in varieties which normally have a spread in cutting date all reaching watery ripe on the same date. The August to October rainfall made up for the dry winter period but occurred too late to be of benefit to hay yields in 2020.

Across the Rupanyup trial, hay yields averaged 6.3 t/ha whereas at Hart, hay yields only averaged 3.1 t/ha.

Hay yield was influenced by variety selection, sowing date and rate of applied N at both sites. There was no three-way interaction between the factors, but there were two-way interactions between each at Rupanyup.

Time of sowing

An interaction between sowing date and variety reflected the different maturity types and the nature of the season at Rupanyup. On average, varieties sown at the end of May benefited from the good spring and produced 0.6 t/ha more hay than varieties sown 3 weeks earlier at the start of May.

It is likely that the TOS1 plants became stressed during stem elongation or booting during July. Water stress during the critical growth extension phase can result in varieties rushing through and not accumulating as much biomass. TOS2 plants sown three weeks later were at an early growth stage during this period of moisture stress, so were better able to capitalise on the extra water availability in spring once they began to elongate.

The slowest varieties had the greatest time of sowing differences; mid-slow Vasse capitalised most producing 1.6 t/ha more to achieve the highest yield of 8.1 t/ha when sown later, followed by mid maturing Wintaroo producing 1.3 t/ha more to yield 7.0 t/ha.

Table 1. Treatments: Oat varieties, time of sowing and nitrogen (N) rate, at Rupanyup and Hart in 2020.

Variety Characteristics				Time of Sowing	N rate* (kg N/ha)
Variety	**End Use**	**Height**	**Maturity**		
Brusher	Hay/grazing/feed grain	Tall	Quick	6 May (SA and Vic) 25 May (SA) 29 May (Vic)	10** 30 60 90 120** 150**
Carrolup	Milling	Mod tall	Quick		
Durack	Milling/hay	Mod tall	Very quick		
Koorabup	Hay	Mod tall	Mid-quick		
Mulgara	Hay/feed	Tall	Quick		
Vasse	Hay	Mod tall	Mid-slow		
Williams	Milling/hay	Short-tall	Quick		
Wintaroo	Hay/grazing	Tall	Mid		
Yallara	Milling/hay	Mod tall	Quick		

**Nitrogen applied as two thirds at sowing and one third 6 weeks post sowing*

*** Mulgara, Wintaroo and Yallara only*

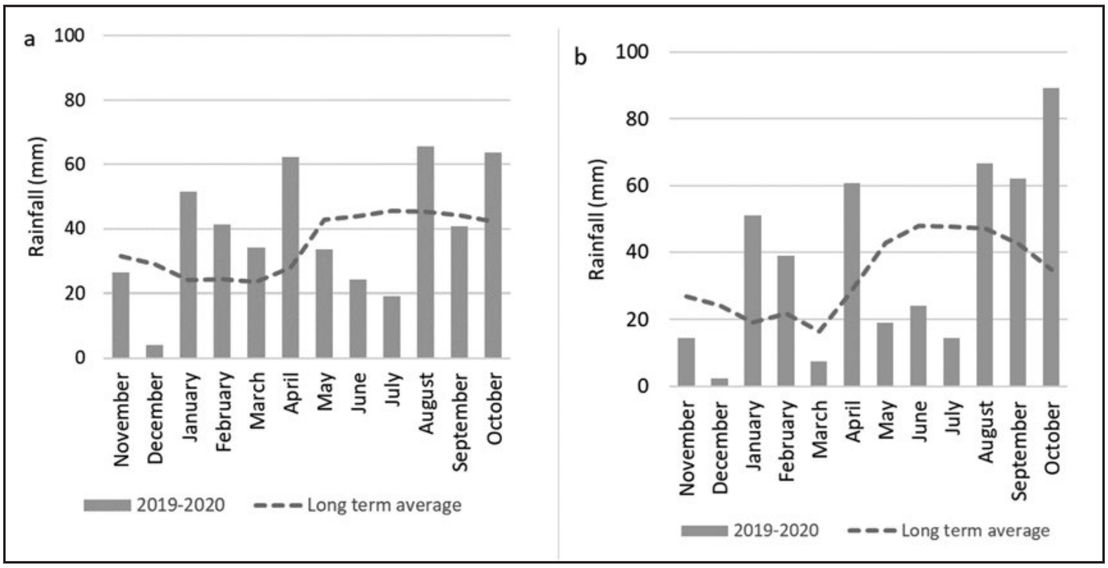

Figure 1. Average rainfall and growing season rainfall received at (a) Rupanyup, Vic and (b) Hart, SA.

Other varieties that had faster maturities were comparable between sowing times with the good growing conditions. Fast maturing varieties Carrolup and Durack had the lowest yields in the trial when sown in early May (Figure 2).

At Hart, there was no interaction between variety and sowing date but each main factor did affect hay yields (Table 2). Unlike at Rupanyup, the slowest developing variety Vasse, was unable to capitalise on the spring rainfall and all varieties had lower yields from sowing in late May. The best performing varieties ranged from very quick to mid varieties. This highlights the importance of rainfall coinciding with critical growth stages of the varieties. TOS 1 plots were advantaged by having greater access to the early season rainfall which fell prior to seeding. Whereas, the Spring rain was still too late at Hart to favour TOS 2 likely because they failed to accumulate enough biomass prior to stem elongation and were too stressed in the drier period of June and July to recover significant biomass.

Nitrogen response

At Hart, hay yield response to N fertiliser rate was significant but of little consequence in practical terms this season. Across both TOS treatments, rates up to 30 kg N/ha resulted in yield response, increasing the average hay yield from 2.7 to 3.3 t/ha. At all rates above 30 kg N/ha, there was no response to increased N applications (data not shown). The low response to N fertiliser rates can be explained by the lack of in-season winter rainfall limiting crop N uptake.

In contrast, an interaction between variety and nitrogen rate at Rupanyup indicated that varieties had different sensitivities to applied N (Figure 3). Across the nine varieties, hay yield increased as N rate increased. All varieties responded when N rate increased from 30 to 60 kg N/ha. Hay yield was optimised for Carrolup and Koorabup at 60 kg N/ha, while other varieties responded to an N rate increasing from 60 to 90 kg N/ha. Largest responses to increasing N from 30 to 60 kg N/ha were by Vasse, Yallara and Koorabup, and to increasing N from 60 to 90 kg N/ha were Vasse, Brusher and Wintaroo.

The better season finish in 2020 (compared with a drier finish at Kalkee in 2019) enabled larger responses to nitrogen. For Mulgara, Wintaroo and Yallara that received six rates of N up to 150 kg N/ha, hay yield increased with N rate up to 90 kg N/ha, where yield was optimised for Yallara. Mulgara and Wintaroo responded to a further 30 kg N/ha to optimise hay yields at 120 kg N/ha (data not shown).

Hay quality

Thinner stems (<6 mm) with lower fibre and higher water-soluble carbohydrates make better quality hay. Stem diameter for all treatments met this quality target, at both sites ranging from 3.8 to 5.2 mm at Rupanyup (Table 3) and 3.7 to 4.2 mm at Hart (Table 2), driven by the high target plant density of 320 plants/m^2 (sowing rates ranged from 138 to 177 kg/ha). There was a stem diameter response to TOS by variety (P=<0.001) at Rupanyup. Varieties Williams and Wintaroo responded strongest to later sowing with reductions in stem thickness of 1.0 and 0.8 mm respectively (Table 3). There were no differences in stem diameter between sowing times for other varieties.

At Rupanyup, varieties Koorabup, Wintaroo, Brusher, Carrolup and Yallara had the finest stems between 4.2 mm and 4.3 mm. Vasse and Mulgara were the thickest at 4.8 mm. In contrast, at Hart Vasse had the thinnest stems although this is likely due to the short height of the plants at cutting time when the panicle was not fully emerged resulting in mainly leaf matter rather than stems being cut for this variety.

Cereals

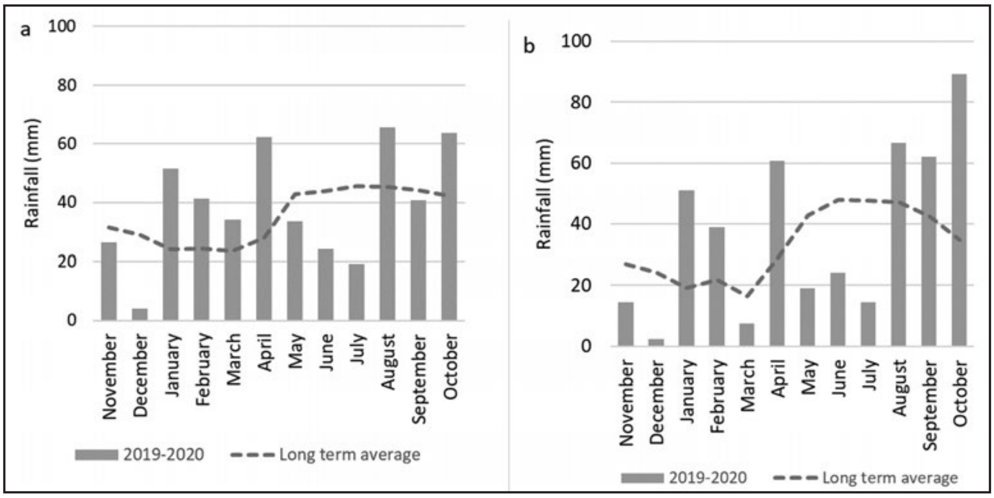

Figure 2. Oaten hay yield response to time of sowing, Rupanyup 2020. TOS x Variety: P=0.002, LSD=0.63 t/ha, CV=7.9%.

Table 2. Hay yields (t/ha), Neutral Detergent Fibre (NDF) and Water Soluble Carbohydrate (WSC) contents of hay at Hart in 2020. Values shaded in the same column are not statistically different and represent the best performing variety for that trait.

Variety	Hay yield (t/ha)	Stem thickness (mm)	NDF %	WSC %
Vasse	2.3 a	**3.7 a**	53.81 g	15.3 a
Williams	2.9 b	4.6 e	50.23 ef	21.21b
Koorabup	2.9 b	4.4 bcd	50.05 def	23.52 c
Mulgara	3.0 bc	4.4 de	49.29 cde	23.86 c
Durack	**3.1 bcd**	4.4 de	50.86 f	21.42 b
Wintaroo	**3.2 bcd**	4.3 cde	48.92 cd	24.10 c
Yallara	**3.2 bcd**	4.2 bc	**47.37 a**	**25.88 d**
Carrolup	**3.4 cd**	4.0 b	**47.58 ab**	**25.91 d**
Brusher	**3.5 d**	4.3 cd	48.73 bc	**25.89 d**
LSD (P=0.05)	*0.39*	*0.2*	*1.24*	*1.09*
Sowing date				
5 May	3.47 b	4.4	49.80	24.30 b
25 May	2.67 a	4.1	49.49	21.73 a
LSD (P=0.05)	*0.44*	*ns*	*ns*	*2.03*

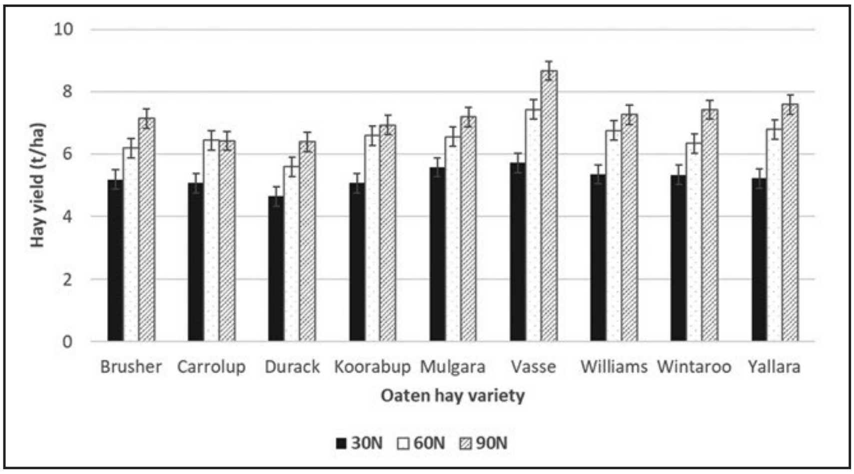

Figure 3. Oaten hay yield response to three nitrogen rates, Rupanyup 2020. Stats: P=0.045, LSD=0.62 t/ha, CV=7.9%.

Table 3. Stem diameter of oaten hay varieties at two times of sowing, Rupanyup 2020.

	Brusher	Carrolup	Durack	Koorabup	Mulgara	Vasse	Williams	Wintaroo	Yallara
TOS1	4.3 def	4.1 fg	4.5 bcdef	4.2 efg	4.9 ab	4.8 abc	5.2 a	4.6 bcde	4.4 cdef
TOS2	4.1 efg	4.4 cdef	4.5 bcdef	4.2 efg	4.8 abcd	4.8 abc	4.2 fg	3.8 g	4.2 efg
Sig. Diff.	P<0.001, *LSD 0.4 mm*								
CV%	9.8								

At the time this report was written, hay quality for the Rupanyup site has not yet been analysed. At Hart, neutral detergent fibre (NDF) was different between varieties, ranging from 47.4% in Yallara to 53.8% in Vasse (Table 3). All varieties were below the export hay threshold suggested by AEXCO.

As NDF% increases, the amount of dry matter consumed by animals generally decreases (AEXCO 2016) therefore higher values such as seen in Vasse may be less desirable than lower values such as seen in Yallara and Carrolup. Time of sowing did not affect NDF%.

Water soluble carbohydrates (WSC) content varied between varieties and ranged from 15.3 to 25.9%. Brusher, Carrolup and Yallara had the highest WSC content, and Vasse had the lowest (Table 2). Vasse did not meet the minimum of 18% WSC recommended for export quality hay (AEXCO 2016). Both sowing date treatments met export market requirements. TOS 1 had a higher WSC content than TOS 2. WSC content affects palatability and higher contents are favourable (DPIRD 2016) therefore earlier sowing and/or growing one of the listed high-performing varieties was suitable at Hart in 2020.

What does this mean?

The contrasting results from South Australia and Victorian sites in 2020 highlight the importance of timing of growing season rainfall to achieve high potential hay yields. Although the growing season rainfall was higher at Hart (335 mm vs 309 mm), Rupanyup achieved double the hay yields of Hart. The timing of the rainfall will determine whether it is more beneficial to sow early, to take advantage of opening rains as was evident at the Hart site in 2020, or delay sowing if a favourable spring is forecast as the Rupanyup results suggest.

The decision on nitrogen rate is also strongly linked to the seasonal conditions with the dry winter at Hart resulting in low mineralisation of N and therefore no yield benefit to applying more than 30 kg N/ha. The steadier rainfall at Rupanyup in comparison allowed greater mineralisation of N and more responsiveness to N as the applied rate was increased.

The challenge is to make sowing decisions that will be favoured by the season forecast, and then for that forecast to happen. On both occasions over the past two seasons in Victoria, the spring forecast has eventuated, although nerves have been tested along the way. In SA however, the spring rainfall did not arrive in 2019 and arrived too late at the Hart site in 2020.

The trial will be conducted for a third season in the Wimmera and at Hart in 2021 to evaluate the varieties, TOS and N rate effects in a further set of seasonal conditions. Results from similar trials nationally will be collated to produce guidelines for agronomy to optimise hay quality in different seasons and regions across Australia.

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Thanks to the Clare SARDI group for sowing and harvesting the Hart trial and the Hart Field Site Group for the coordination and running of the trial in SA.

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Section 6

Nutrition

Calibration of the commercial soil test for P on a red calcareous loam

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[1]SARDI Struan, Naracoorte, [2]SARDI Waite, [3]University of Adelaide Affiliate-Senior Lecturer and [4]SARDI Minnipa Agricultural Centre

Location
Pildappa, Upper EP
Gareth Scholz
Rainfall
Av. Annual: 324 mm
Av. GSR: 241 mm
2018 Total: 208 mm
2018 GSR: 155 mm
2019 Total: 235 mm
2019 GSR: 205 mm
2020 Total: 319 mm
2020 GSR: 218 mm
Yield
2018 Potential: Wheat - 2.0 t/ha
2018 Actual: 1.0 t/ha.
2019 Potential: Wheat - 2.1 t/ha
2019 Actual: 1.7 t/ha.
2019 Potential: Canola - 1.7 t/ha
2019 Actual: 0.25 t/ha.
2020 Potential: Wheat - 2.6 t/ha
2020 Actual: 2.3 t/ha.
2020 Potential: Canola - 1.7 t/ha
2020 Actual: 0.35 t/ha.
Paddock history
2017: Long term pasture
Soil type
Red calcareous sandy clay loam
Soil test
Low P reserves (6 mg/kg of Cowell P in top 10 cm)
Plot size
20 m x 6 rows x 1-3 reps
Trial design
Partially randomised complete block
Yield limiting factors
Poor years, frost

Key messages

- **Critical levels of Colwell P estimated at Pildappa on a red calcareous soil were similar to the existing industry standard of 26 mg/kg for wheat and canola. However, current critical concentrations in paddocks with intensive, no-till cropping histories may be higher than those established at the Pildappa site.**
- **Season had no consistent effect on critical Colwell P concentrations.**
- **Yield penalties in canola were more severe than in wheat when grown on soil with low Colwell P and without P fertiliser.**

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 nutrient concentration in the soil test and likely response to applied fertiliser needs to be well calibrated. Many of the current calibrations were developed from fertiliser trials conducted over 30 years ago, with this work providing robust guidelines on many soil types, but mostly for cereals. However, 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 those gaps 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 individual 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. Prior to seeding in 2018, P fertilisers were applied at 11 rates from 0-200 kg P/ha, to create a wide range of soil P concentrations in the initial and (hopefully) subsequent crop seasons.

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 additional P fertiliser.

In 2020, P was re-applied at half the rates used in 2018 to recreate a wide range of P concentrations prior to seeding. Soil tests taken prior to sowing the 2019 crop had shown that the concentration of plant available P had already fallen by 50% in the 12 months since the 2018 application, and we wanted to ensure at least some plots were able to grow without P limitations in 2020.

Scepter wheat was seeded over the canola trial from 2019 and 44T02 canola over the wheat trial from 2019. Crops were inter-row seeded on the previous crop rows with no extra P fertiliser and in such a way that the plots were in the same position as in 2018.

What happened?

Both crops established well in 2020 but suffered during dry periods in winter and early spring. The wheat recovered well once wetter conditions returned in late September/early October but the canola never fully recovered. As had occurred in the two previous seasons, both crops grew poorly when Colwell P concentrations were low (Table 1). In 2020, grain yield of wheat in plots with the background concentration of Colwell P (10 mg P/kg - Table 1) was more than 30% lower than yields with Colwell P concentrations of 30-40 mg P/kg or greater.

Despite strong P responses in both crops, yields with adequate P varied greatly (i.e. averaging 2.3 t/ha for wheat but only 0.35 t/ha) for canola. This pattern of canola yielding poorly relative to wheat (regardless of P status) and the impact of low P reserves being more damaging to canola (70% yield loss) than to wheat (30% yield loss) was consistent in all 3 seasons of the trial.

The history of P fertiliser additions prior to seeding in 2018 and in 2020 created a large range of Colwell P concentrations in each season (Table 1 has the Colwell P values for 2020). These values were used to estimate critical concentrations for Colwell P (for both crops in all 3 seasons) using curve fitting approaches developed in the MPCN2 program and adapted for this project (UQ00082). The critical concentration is defined as the Colwell P at which 90% of maximum grain yield as obtained. Critical concentrations were different between wheat and canola but not in a consistent way (Table 2) and also varied between seasons but again, not in a way which matches any clear differences between those seasons. The canola data may not be relevant to high yielding canola crops, as the consistently poor grain yields represented very limited crop P demands and so may not reflect the true sensitivity of higher yielding crops to inadequate soil P.

Nutrition

Table 1. Effect of P additions on soil reserves of P (expressed as Colwell P) and on grain yield of wheat and canola in 2020 at Pildappa on upper EP.

Applied P in 2020 (kg/ha)	Canola		Wheat	
	Colwell P in top 10 cm (mg/kg)	Grain yield t/ha)	Colwell P in top 10 cm (mg/kg)	Grain yield (t/ha)
0	8	0.10	10	1.62
3.75	9	0.25	12	1.95
7.5	15	0.29	11	1.88
10	16	0.39	13	2.05
15	18	0.34	18	2.11
20	26	0.32	25	2.27
25	34	0.33	33	2.32
37.5	55	0.34	47	2.21
50	45	0.33	46	2.42
75	65	0.29	95	2.28
100	103	0.38	123	2.38

Table 2. Critical values for Colwell P over three seasons for grain yield of wheat and canola at Pildappa on upper EP.

Year	Canola		Wheat	
	Maximum yield (t/ha)	Critical Colwell P (mg P/kg)	Maximum yield (t/ha)	Critical Colwell P (mg P/kg)
2018	- [1]	- [1]	1.0	21
2019	0.3	22	1.8	31
2020	0.35	31	2.3	22

[1]*Canola was re-sown in 2018 and did not reach maturity*

What does this mean?

The current industry standard for situations similar to this trial at Pildappa for wheat and canola is approximately 26 mg/kg of Colwell P in the top 10 cm of soil. The critical concentrations estimated from the trial reported here are not consistently and sufficiently different to that industry standard to suggest that the industry standard is no longer relevant to current farming systems. A value of approximately 26 mg/kg of Colwell P should be used by farmers and advisers on the upper EP as a level above which yield losses would be small to non-existent if little or no P fertiliser were applied to wheat or canola on a red calcareous sandy clay loam. A maintenance strategy for P fertiliser would be very appropriate in these situations. Below this level of 26 mg/kg adequate P fertiliser rates to either crop are required to avoid major yield losses due to P deficiency. Optimum rates for P fertiliser in those situations are determined by many factors such as value of the commodity and the long term goal for soil P reserves. However, attempts to build up the soil bank of available P using a few large applications should note the rapid decline in Colwell P concentrations observed in this soil type from 2018-2019. This suggests smaller annual applications are a more efficient way to ensure adequate available P.

Trends from other sites in the UQ00082 project are suggesting that critical P concentrations may now be higher than existing industry standards. This appears to be due to prolonged no-till practices which are leaving high concentrations of P reserves very close to the soil surface, rather than more evenly spread through the cultivated layer which tended to happen with conventional tillage practices of the past. The Pildappa site did not have an intensive cropping history leading up to the start of the trial, and so did not exhibit these strongly stratified P distributions. Similar situations to the Pildappa site but with more intensive cropping histories may have higher critical concentrations for Colwell P than established at this site.

In this trial, although the critical concentrations for Colwell P were similar for wheat and canola, the reductions in canola yield when grown in soils with low Colwell P were more severe than for wheat. This suggests that under-fertilising for P in canola grown on soils low in P reserves may result in more severe economic penalties than in wheat.

UQ00082 has now finished its field trial programme and the next few months will be spent interrogating the data from trials across SA, Vic, NSW and QLD for their industry messages. These trials have investigated soil test criteria for N, P, K and S across a wide range of crop types.

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THE UNIVERSITY OF QUEENSLAND AUSTRALIA

GRDC GRAINS RESEARCH & DEVELOPMENT CORPORATION

Government of South Australia Department of Primary Industries and Regions

SARDI SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE

P fertiliser banded at 20 cm did not improve wheat performance compared to shallow P at Brinkworth in 2020

Nigel Wilhelm
SARDI Waite, University of Adelaide Affiliate-Senior Lecturer

Location
Brinkworth, Mid North, SA
Leigh Fuller
Rainfall
Av. Annual: 406 mm
Av. GSR: 297 mm
2019 Total: 499 mm
2019 GSR: 324 mm
Yield
Potential: Wheat - 5.1 t/ha
Actual: 2.4 t/ha
Paddock history
2019: Wheat
Soil type
Brown loam over calcareous clay loam
Soil test
Colwell P, 36 mg/kg in top 10 cm
Colwell P, 12 mg/kg in 10-20 cm layer
PBI, 120
pH 8 near surface, over 9 at depth
Plot size
20 m x 6 row x 4 reps
Trial design
Randomised complete block
Yield limiting factors
Marginal moisture at seeding slowed emergence, dry spells in winter

Key messages

- **Wheat performance improved strongly with P fertiliser.**
- **Wheat performed better when P fertiliser was banded just below the seed row rather than when P was banded 20 cm below the soil surface in the first crop following application.**
- **Adding trace elements or doubling the number of deep bands did not improve the performance of deep P.**

Why do the trial?

The aim of the trial reported here is to determine whether the dual placement of shallow (0-10 cm) and deep (20-30 cm) banded P can improve crop yields compared with shallow P placement alone.

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

In southern Australia, although rainfall is more frequent during the growing season, periods of prolonged dry topsoils still occur and many soil profiles in southern Australia have very low P reserves below the cultivated layer. GRDC funded a new project starting in 2020 (Maximising the uptake of phosphorus by crops to optimise profit in central and southern NSW, Victoria and South Australia. DAN2001-033RTX) to investigate the merits of deeper placed P on crop performance.

How was it done?

Deep P treatments were imposed in early May 2020 (after opening rains in the last week of April) with narrow profile tines on 60 cm spacings which resulted in 3 P bands per plot (except for one treatment where deep P was applied in 30 cm bands, resulting in 6 bands per plot). P was placed 19-20 cm below the surface.

The trial was seeded with Scepter wheat, and shallow P applied during seeding, on 11 May. Eight mm of rain had fallen between implementation of deep P and seeding. Seeding was conducted in such a way that crop rows at 30 cm spacings were equally spaced between the bands of deep P. For the one treatment of deep P in 6 bands, crop rows were placed over the top of each deep P band. Seed was placed 1-2 cm below the presswheel trench and shallow P was 2-3 cm below the seed.

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

MAP was used as the source of shallow and deep P and N was adjusted with urea to ensure that all plots had received a total of 46 kg N/ha by the end of seeding. There was one mid-season application of N during the season to the whole trial.

Establishment, growth, grain yield and quality were assessed.

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

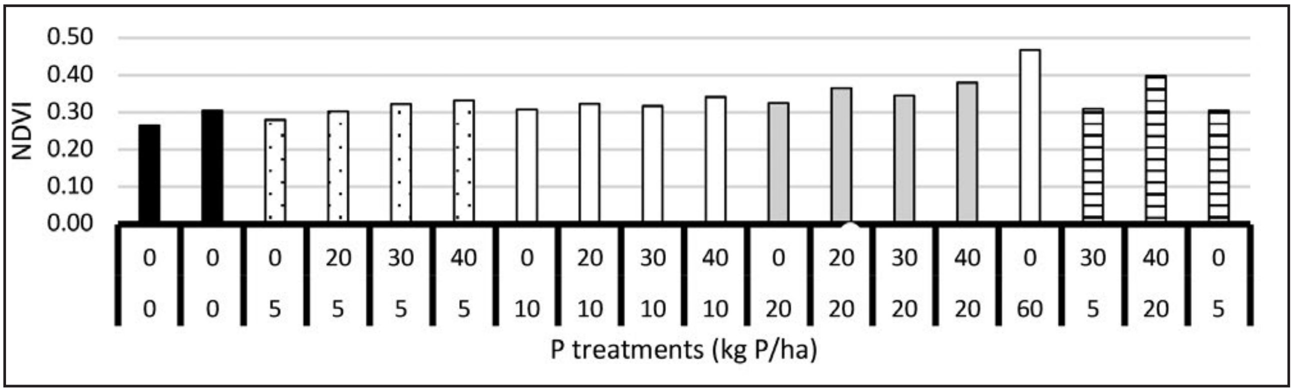

Figure 1. Effect of P rate and placement on vigour of Scepter wheat at late tillering, Brinkworth in 2020. Note: Top figures on X-axis labels are deep P, bottom figures are shallow P (LSD, P=0.05: 0.04). First treatment is nil P and ripped, second treatment is nil P without ripping. Last three treatments are deep P applied in 6 bands; with trace elements; and finally P applied as a fluid.

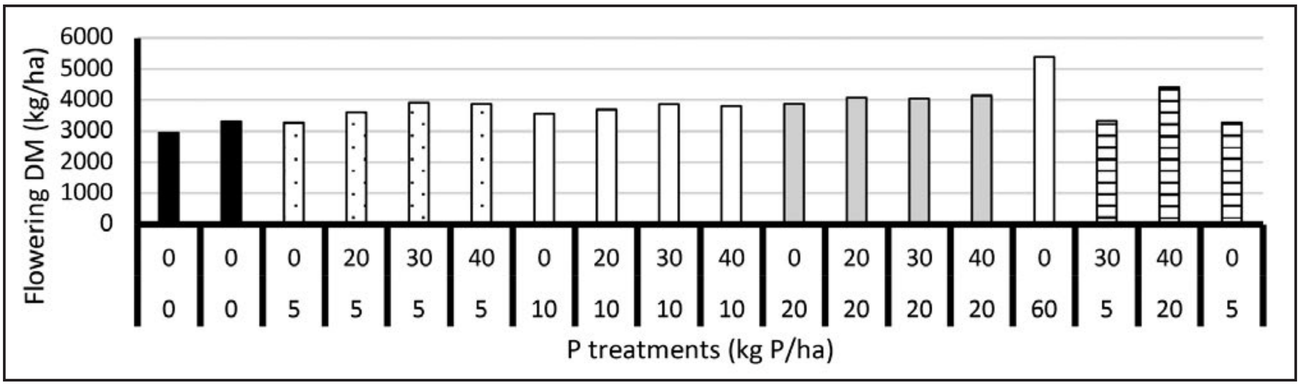

Figure 2. Effect of P rate and placement on dry wt of shoots at flowering of Scepter wheat at Brinkworth in 2020. Note: Top figures on X-axis labels are deep P, bottom figures are shallow P (LSD, P=0.05: 400). First treatment is nil P and ripped, second treatment is nil P without ripping. Last three treatments are deep P applied in 6 bands; with trace elements; and finally P applied as a fluid.

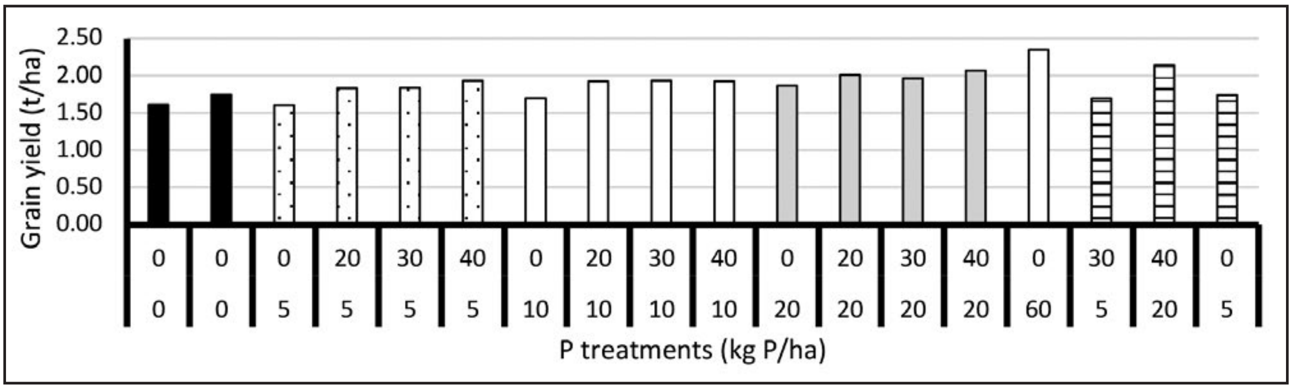

Figure 3. Effect of P rate and placement on grain yield of Scepter wheat at Brinkworth in 2020. Note: Top figures on X-axis labels are deep P, bottom figures are shallow P (LSD, P=0.05: 140). First treatment is nil P and ripped, second treatment is nil P without ripping. Last three treatments are deep P applied in 6 bands; with trace elements; and finally P applied as a fluid.

What happened?

An average of 200 plants/m^2 established across all treatments despite the rougher surface of deep P treatment plots.

There was a positive response in wheat vigour to P application, but higher rates of deep P were required to match vigour with shallow P (Figure 1). For example, 20 kg of shallow P/ha had the same NDVI as 30 kg of deep P/ha plus 5 kg of shallow P/ha.

The best treatment for early vigour was 60 kg of shallow P/ha which stood out as being more vigorous than any other treatment (Figure 1).

Shallow P at 60 kg/ha continued to produce the most vigorous and most advanced wheat at the site (Figure 2), despite some extended periods of dry conditions early in the season. Biomass with 60 kg of shallow P/ha was 63% better than in the un-ripped control (60 shallow P was not ripped either). Shallow P continued to produce similar crop vigour at lower rates than for deep placed P. For example, 20 kg of shallow P/ha had the same biomass as 30 kg of deep P/ha plus 5 kg of shallow P/ha.

The patterns in grain yields were very similar to those seen for biomass production during the season. There was a reasonable response to addition of P but generally yields were modest for the total rain received (Figure 3).

What does this mean?

- The highest rate of added P (60 kg/ha) increased grain yields by nearly 35% or 0.6 t/ha.
- Yields with deep P were similar or less than yields with shallow P at the same rate. For example, 20 kg shallow P/ha produced a 16% yield increase over no added P (or an extra 260 kg/ha). Yields with up to 40 kg deep P/ha, regardless of whether they also received 5 or 10 kg shallow P/ha, were similar to this treatment. To be a viable option for farmers, deep P needs to not only match the performance of shallow P, but also improve on it to justify the extra effort of placing P deep. Deep P will need to produce much superior residual benefits in subsequent seasons to make it a more attractive option.
- As another metric of efficiency, shallow P produced slightly greater increases in grain yield with increasing rate than did deep P. For every extra 10 kg/ha of shallow P, wheat yields increased by 128 kg/ha but by only 77 kg/ha with deep P (if you ignore the contribution of 5 kg shallow P/ha).
- Banding P at the same rate per ha under every crop row in contrast to bands in the gap between every other crop row produced slightly lower yield.
- Adding zinc and copper did not increase grain yields or change the effectiveness of P fertilisers.
- Fluid P was no more effective than granular P, although neither form increased yields above the control at the rate which was applied (5 kg P/ha).
- Rates of P typically used by farmers in the area (10-20 kg P/ha) only corrected half of the yield increase produced by the best treatment in the trial (60 kg shallow P/ha).
- This trial will be maintained for several more growing seasons to assess the residual benefits of both P placement strategies.

The trends in crop performance so far are that shallow P is more effective than deep P in the year of application for wheat, but comparisons may change as the residual benefits of both approaches are monitored and other crops are investigated for their responses to placement of P.

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Copper management for the future - three years of trials on lower EP

George Pedler[1] and Andrew Ware[2]

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2017
Location
Wanilla
Rainfall
Av. Annual: 513 mm
2017 Total: 457 mm
2017 GSR: 298 mm
Location
Cockaleechie
Rainfall
Av. Annual: 423 mm
2017 Total: 361 mm
2017 GSR: 305 mm

2018
Location
Edillilie
Rainfall (Cummins BOM site)
Av. Annual: 423 mm
2018 Total: 361 mm
2018 GSR: 305 mm
Location
Stokes
Rainfall (Yallunda Flat BOM site)
Av. Annual: 522 mm
2018 Total: 470 mm
2018 GSR: 387 mm

2018
Location
Edillilie
Rainfall (Cummins BOM site)
Av. Annual: 423 mm
2019 Total: 326 mm
2019 GSR: 307 mm
Location
Stokes
Rainfall (Yallunda Flat BOM site)
Av. Annual: 522 mm
2019 Total: 397 mm
2019 GSR: 365 mm

Key messages

- **Field trials to test management strategies to overcome copper deficiency at six Lower Eyre Peninsula sites were conducted over the three growing seasons of 2017, 2018 and 2019 (two sites per year).**
- **Yield loss caused by copper deficiency can be devastating to wheat yield, with significant losses of up to 48.5% in 2018 recorded at Edillilie.**
- **Soil and tissue testing can be useful in helping to detect low levels but are not always definitive. Copper response appears to be dependent on other complex interactions such as soil moisture, yield potential and other constraints (N fertility etc.) and thus soil/tissue tests alone are not a definitive guide to future responses.**
- **Chelate and sulphate formulations performed equally well.**
- **Foliar applications performed better than in-furrow liquids at Edillilie in 2018.**
- **Foliar application timings between mid-tiller and head emergence were not significantly different in yield response.**
- **In-furrow applications at seeding were not as effective as foliar applications.**

Why do the trial?

Copper deficiency disorders in cropping systems of South Australia have traditionally been most common on the more infertile and lighter soils of the State. It is estimated (Davenport pers comm) that there are approximately 3.2 million hectares of arable land in South Australia, including 129,000 hectares on the lower Eyre Peninsula (>400 mm rainfall), which are considered to be copper deficient. Cereal crops grown on these soils, require copper applications to produce reliable, profitable yields.

While many different management practices have been developed and adopted to address copper deficiency, these packages are outdated and were developed in different farming systems. Several new methods and formulations are now more commonly used such as fluid delivery in the furrow at seeding, foliar applications of chelates and high analysis fertilisers.

The most common and most effective way of correcting copper deficiency long-term is to apply copper to the soil. However due to its low mobility in the soil, sufficient incorporation is required to allow the crop to gain adequate access. Current no-till practice means a spading or other thorough incorporation method needs to be adopted, which can make this a high cost approach.

Although copper deficiency is best corrected with soil applications, foliar sprays may also overcome the problem within each season. Current foliar strategies include prophylactic applications of different forms of chelated products. These strategies have been recommended from the product suppliers with very little, to no, independent data supporting these recommendations.

To improve copper management decisions this project investigated these key questions:

- Can we get sufficient copper supplied only at seeding in through fluid delivery?
- What timing or combination of timings is most effective?
- What form of copper is most efficient, if any?
- How late can copper be efficiently applied and still meet the plant's needs?

Table 1. Trial site initial soil test data and sowing dates.

Year	Site	Soil Copper 0-10 cm (mg/kg)	Soil Colwell P 0-10 cm	Sowing Date	Copper Responsive
2017	Wanilla	1.21	24	18 May*	No
	Cockaleechie	0.76	46	18 May*	No
2018	Edillilie	0.55	58	10 May	Yes
	Stokes	0.93	30	15 May	No
2019	Edillilie	0.72	41	15 May	No
	Stokes	0.50	73	21 May	No

**Site sown dry prior to opening rain due to late break with emergence around 11 July*

How was it done?

Field trials (all sown to Scepter wheat) at six Lower Eyre Peninsula sites were conducted over the three growing seasons the project was conducted (two sites per year).

What happened?

Field trials 2017

In 2017 field trials were conducted at Strawberry Hill (North-east of Wanilla) and Cockaleechie (North-east of Cummins). Due to the short period between funding being awarded and the potential break in the season, sites were selected based on a history of copper deficiency-like symptoms.

Opening rains for the 2017 growing season did not occur until early July. Trials were sown dry, emerging on the opening rain.

The field trials consisted of 44 treatments in a randomized block design (replicated four times). The treatments included six application times (at seeding, GS21, GS31, GS41, GS49 and flowering; plus combinations of two applications at different timings), two different products were evaluated (copper sulphate and copper amino-acid chelate) and each product was applied at 2-3 different rates.

Soil tests taken prior to sowing showed DPTA copper levels to be 1.21 mg/kg at Strawberry Hill and 0.76 mg/kg at Cockaleechie. Literature shows soil test critical values of less than 0.2 to 0.4 mg/kg are deficient.

Tissue samples collected at GS41 (Zadok) showed copper levels were @ 3.4 mg/kg at Cockaleechie, with no significant difference between treatments. At the Strawberry Hill site the untreated treatment had copper plant tissue levels of 6.0 mg/kg, whereas the treatment that received 2 kg/ha copper sulphate at in-furrow at seeding had a significantly higher plant tissue level of 7.4 mg/kg. Literature shows that plant tissue levels need to be below 1.3 mg/kg to be deficient.

A site mean yield of 2.25 t/ha was achieved at the Strawberry Hill site. The Cockaleechie trial achieved a site mean yield of 2.70 t/ha. Through ANOVA analysis both sites did record treatments that were significantly different from each other, however there was no clear pattern in response.

Field trials 2018

In 2018 field trials were conducted at Edillilie (approximately 25 km south-west of Cummins) and Stokes (approximately 10 km west of Tumby Bay). At each site trials were broken up into three separate trials.

Trial 1: 17 treatments: four times of application (in-furrow @ seeding, GS22, GS31, G49), a sulphate and chelated product, each applied at two different rates plus a nil control.

Trial 2: 6 treatments: all different times of application of a chelated product.

Trial 3: 10 treatments: two different chelated products, each applied at three rates. Copper sulphate applied at three different rates and a nil control.

The Stokes site had pre-seeding soil copper levels of 0.93 mg/kg, 5.2 pH and 30 Colwell P, whilst the Edillilie site had pre-seeding soil copper levels of 0.55 mg/kg, 5.7 pH and 58 Colwell P.

Plant tissue tests collected at flowering found samples contained 3.81 mg/kg copper from untreated plots at the Edillilie site and ranged up to 8.7 mg/kg where copper sulphate was applied at a high rate (300 g/ha). Plant tissue tests collected at flowering found samples contained 1.55 mg/kg copper in untreated control plots and 2.59 mg/kg where copper sulphate was applied at a high rate (300 g/ha).

The Stokes site achieved a site mean grain yield of 5.16 t/ha. In trials 1 and 3 there were no significant differences between any of the treatments. In Trial 2, the application of a 2 L/ha chelated copper achieved a significantly higher yield than the nil treatment

The Edillilie site achieved a site mean grain yield of 2.82 t/ha. This trial site showed very strong visual symptoms traditionally associated with copper deficiency around flowering time. In trial 1 all treatments, with the exception, of a low rate (1 L/ha) of copper chelate applied in furrow, yielded significantly more than the untreated control. Treatments where copper was applied in furrow generally yielded lower than foliar applications.

As can be seen in the yield results, the foliar applications at times earlier than traditional copper application (prior to head emergence) yielded as well as, if not better than the traditional timing.

Trial 2 demonstrated that the time of application did not have any effect on grain yield.

In trial 3 all treatments (applied at GS49) yielded higher than the untreated control, with the exception of copper sulphate, applied at half the recommended rate. However, beyond this there was no product or rate that was able to demonstrate a yield benefit higher than any other.

Field trials 2019

In 2019 field trials were conducted at Edillilie (approximately 25 km south-west of Cummins) and Stokes (approximately 15km west-northwest of Tumby Bay). Each site trials had three separate trials.

Trial 1: 17 treatments: four times of application (in-furrow @ seeding, GS22, GS31, G49), a sulphate and chelated product, each applied at two different rates + a nil control.

Trial 2: 13 treatments: application of three chelated products and one sulphate product, each applied at three rates.

Trial 3: 10 treatments: application of a chelated product at four timings and combinations of timings.

The Stokes site had pre-seeding soil copper levels of 0.5 mg/kg and the Edillilie site was 0.72 mg/kg.

Plant tissue tests collected at flowering found samples contained 1.55 mg/kg copper in untreated control plots at the Stokes site and 2.59 mg/kg where copper sulphate was applied at GS31 timing at a high rate (300 g/ha). Plant tissue tests collected at flowering found samples contained 3.81 mg/kg copper from untreated plots at the Edillilie site and ranged up to 8.72 mg/kg where copper sulphate was applied at GS31 timing at a high rate (300 g/ha).

None of the trials at Stokes and Edillilie showed a response to copper application in 2019.

What does this mean?

The program demonstrated that:

- At some sites where copper deficiency was historically assumed, no response to any form of copper application was observed. Copper response is likely to vary by site and season.
- Yield loss caused by copper deficiency can be devastating to wheat yield.
- Soil and tissue testing can be useful in helping to detect low levels but are not always definitive. Copper response appears to be dependent on other complex interactions such as soil moisture, yield potential and other constraints (N fertility etc.) and thus soil/tissue tests alone are not a definitive guide to future responses.
- Foliar applications performed better than in-furrow liquids.
- Chelate and sulphate products performed equally well when applied as foliar applications.
- Timing did not appear to be critical, with a wide band of opportunity from mid-tiller to early head emergence providing similar results.

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Fiona Tomney
SARDI Minnipa Agricultural Centre

Weeds

Herbicide resistance in barley grass populations from the low rainfall zones in South Australia

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Key messages

- **Thirty two barley grass populations were collected from grower paddocks from Eyre Peninsula and Upper North regions in 2019 and screened for resistance to major herbicide groups in 2020. This was not a random survey because most of these populations were considered difficult to control with herbicides.**
- **All of these barley grass populations collected in 2019 from Eyre Peninsula and Upper North regions were completely killed by glyphosate and paraquat and were rated as herbicide susceptible.**
- **Resistance to the FOP herbicide quizalofop was confirmed in 50% (n=16) of these targeted populations tested in 2020. In addition to this, 19% of the populations (n=6) were classified as developing resistance.**
- **Ten barley grass populations were confirmed resistant to clethodim at 250 mL/ha. At the higher clethodim dose (500 mL/ha), only three populations were rated as resistant. This result is consistent with research results for annual ryegrass where higher rates of clethodim can improve weed control. Growers could improve barley grass control by increasing clethodim dose but this is unlikely to be a long-term solution to the problem.**
- **Out of 10 clethodim resistant populations only 3 showed resistance to butroxydim at 90 g/ha and only 1 was resistant at 180 g/ha. These results are consistent with the findings from the previous year, which showed susceptibility of many clethodim resistant populations to butroxydim.**
- **Resistance to the IMI herbicides still appears to be very low in barley grass. Only one barley grass populations from Eyre Peninsula was found to be highly resistant to Intercept® and showed no reduction in plant survival or biomass.**

Why do the trial?

Barley grass possesses several biological traits that make it difficult for growers to manage in the low rainfall zone, so it is not surprising that it is becoming more prevalent in field crops in SA. 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. In this survey, barley grass was ranked as the 7th most costly weed to control by the growers in SA and VIC Mallee and Mid-North, Lower Yorke and Eyre Peninsula. In a previous random survey in SA in 2012, Shergill *et al*. (2015) identified resistance to quizalofop in 15% of barley grass populations from Upper North and Eyre Peninsula. Additional herbicide resistant populations have been identified since the previous survey.

Growers in these regions have observed many control failures and have been collaborating with this GRDC funded project to confirm resistance status of their barley grass populations.

How was it done?

Thirty two barley grass populations were collected from Eyre Peninsula (n=22) and Mid North and Upper North regions (n=10) at maturity in 2019. Most of these populations were collected from fields where growers had observed ineffective weed control. Therefore, this was not a random survey and a higher level of herbicide resistance than in a random survey was expected. Herbicide susceptible barley grass populations collected from Yaninee in 2006 was used as the control. This population has been used in several previous studies of herbicide resistance at the University of Adelaide.

Barley grass seeds of all populations were sown into potting mix (cocoa peat) in seedling trays in April (1st run) and June (2nd run) 2020. When barley grass seedlings reached 1 leaf stage, they were transplanted into pots (10 plants/pot). Populations were grouped by herbicide treatment and randomised at the time of spraying. Seedlings were sprayed with the label rates of group A, B, L and M herbicides (Table 1). Adjuvants recommended by the manufacturers were added to the spray solution of all herbicides. A research track sprayer (De Vries Manufacturing, Hollandale, United States of America) was used to apply the herbicide treatments, which was calibrated to deliver 100 L/ha through a single TeeJet® 8002E (TeeJet Technologies, Illinois, United States of America) flat-fan nozzle at a speed of 3.6 km/h. Plants were assessed for survival 4 weeks after the herbicide treatment and individuals with new growth were counted as survivors.

Only populations classified as resistant or developing resistance were included in the 2nd run to confirm their resistance status prior to sending reports to the growers. Populations with <5% plant survival were rated as susceptible whereas those with 6-19 were rated developing resistance. Populations with >20% survival were rated to be resistant. This herbicide rating system is currently used by herbicide resistance testing labs in Australia. Populations were only screened for resistance to glyphosate and paraquat in round 1.

What happened?

Barley grass populations sprayed with glyphosate (Weedmaster® DST® 470 g/L @ 760 mL/ha) or paraquat (Para-Ken® 250 g/L @ 1200 mL/ha) were completely killed and showed no resistance to these herbicides. On a cautious note it is worth mentioning that resistance to glyphosate was recently identified by our research team in three barley grass populations from a farm on the Yorke Peninsula. Resistance to paraquat was reported previously in barley grass populations from lucerne paddocks in SA. Even though the risk of resistance to these herbicides is low, growers still need to carefully investigate any cases of unexpected survival of weeds sprayed with all herbicides.

Table 1. Details of herbicides and the timing of their application.

Active ingredient (group)	Trade name, manufacturer	Dose (round 1)	Dose (round 2)
Untreated control	N/A	-	-
Quizalofop 100 g/L (group A)	Leopard® , Adama	250 mL/ha	250 and 500 mL/ha
Clethodim 240 g/L (group A)	Grasidim® 240EC, Sipcam	250 mL/ha	250 and 500 mL/ha
Imazamox 33 g/L + imazapyr 15 g/L (group B)	Intercept®, Nufarm	600 mL/ha	375 and 750 mL/ha
Glyphosate 470 g/L (M)	Weedmaster® DST®, Nufarm	760 mL/ha	-
Paraquat 250 g/L (L)	Para-Ken 250®, Kenso Agcare	1.2 L/ha	-

Table 2. Herbicide resistance status of barley grass populations collected from Eyre Peninsula (n=22) and Mid-Upper North of SA in 2019.

Herbicide	Herbicide resistance frequency (%)[a]		
	Resistant (>20% survival)	Developing resistance (6-20% survival)	Susceptible (<5% survival)
Glyphosate (Weedmaster DST @ 760 mL/ha)	0 (0)	0 (0)	100 (32)
Paraquat (Para-Ken 250 @ 1.2 L/ha)	0 (0)	0 (0)	100 (32)
Quizalofop (Leopard @ 250 mL/ha)	50 (16)	19 (6)	31 (10)
Clethodim (Grasidim 240 EC @ 250 mL/ha)	38 (12)	6 (2)	56 (18)
Intercept @ 750 mL/ha	3 (1)	3 (1)	94 (30)

[a] *Figures in brackets are the number of populations in each class.*

Table 3. Cross-resistance pattern of a sub-set of barley grass populations screened for herbicide resistance.

Sample number	Survival (%)							
	Leopard 250 (mL/ha)	Leopard 500 (mL/ha)	Clethodim 250 (mL/ha)	Clethodim 500 (mL/ha)	Factor 90 (g/ha)	Factor 180 (g/ha)	Intercept 375 (mL/ha)	Intercept 750 (mL/ha)
2	100	100	0	0	0	0	0	0
3	100	100	10	0	0	0	0	0
4	100	100	100	0	0	0	0	0
7	100	100	33	0	0	0	0	0
17	50	0	61	0	0	0	0	0
19	0	0	0	0	0	0	**100**	**100**
23	100	100	100	33	61	67	0	0
25	100	100	100	28	0	0	0	0
26	100	100	100	22	11	0	0	0
Yaninee	0	0	0	0	0	0	0	0

There was a high level of resistance detected to the FOP herbicide quizalofop (Leopard®). Out of 32 barley grass populations investigated, 50% were classified as resistant and 19% were developing resistance (Table 2). All resistant populations were retested in the 2nd run and resistance was confirmed. It was encouraging to see the consistency in the results of quizalofop resistance between the two rounds of testing. The frequency of resistance detected to clethodim (44%) was slightly lower than to quizalofop (69%) but still a cause for concern. Resistance to the IMI herbicide Intercept was very low with only 1 population classified as resistant and 1 developing resistance. This low frequency of IMI resistance is consistent with the results from the resistance screening of barley grass undertaken on samples collected in 2018.

Generally plant survival of FOP resistant barley grass populations was 100% at both rates of Leopard (Table 3). However, there was one exception to this trend. Sample 17 showed high plant survival (50%) at the lower dose of quizalofop but was completely killed at the higher rate of this herbicide. Some barley grass populations were highly resistant to quizalofop but were completely controlled by clethodim even at the lower rate (e.g. sample 2). Sample 17 also survived (61%) the lower rate of clethodim but was killed at 500 mL/ha. There were 3 populations from the Mid-North that showed complete survival at the lower rate of clethodim and moderate survival (22-33%) even at the higher rate. Consistent with the results from last year, butroxydim provided effective control of most of the clethodim resistant barley grass populations (Table 3). However, Sample 23 from near Tarlee was even resistant to the higher rate of butroxydim. Presence of different patterns of cross-resistance to group A herbicides indicates presence of different resistance mechanisms within this weed species.

Based on resistance screening of barley grass populations in 2019, resistance to the IMI herbicide tends to be less prevalent than to group A herbicides. In the previous survey, only one population with a high level of IMI resistance was identified. That IMI resistant population was collected from a farm on Eyre Peninsula. Resistance screening in 2020 identified another IMI resistant population from a different farm on the EP (Table 3). It is worth noting that this population (Sample 19) is not resistant to the FOP or DIM herbicides, which indicates direct selection through the use of ALS inhibiting herbicides. This barley grass population is highly resistant to the IMI herbicides and showed no reduction in survival and biomass even at the higher rate of Intercept.

What does this mean?

Herbicide resistance screening of barley grass populations collected at the end of 2019 growing season provided some valuable information. The results clearly show that resistance to group A herbicides in difficult to control barley grass is quite common. Therefore, growers facing poor weed control with this herbicide group should undertake herbicide resistance testing to identify alternative herbicide options. Many of the FOP resistant populations were also resistant to clethodim at the lower rate (250 mL/ha) but complete control was achieved at the higher rate of 500 mL/ha. It would be tempting to increase clethodim rate to improve weed control but resistance to the higher rate is likely to evolve rapidly. This can be seen in three populations from the Mid North to Upper North that showed resistance even at clethodim rate of 500 mL/ha.

As seen last year, butroxydim (Factor®) was highly effective against most of FOP and clethodim resistant populations of barley grass. At the higher rate of butroxydim, only one barley grass population survived as compared to three populations that were resistant to the higher rate of clethodim. This study also showed that some barley grass populations on local farms are already resistant to butroxydim even at the higher rate.

The frequency of resistance to the IMI herbicide Intercept® was much lower than to the FOP and DIM herbicides. Only one barley grass population from Eyre Peninsula showed resistance to the IMIs. This population was highly resistant to this herbicide group and showed no mortality or suppression in growth. Even though IMIs are considered high risk from resistance viewpoint, current frequency of resistance on local farms appears to be very low. Therefore, growers planning to use Clearfield® crops should go ahead but efforts should be made to diversify crop rotations and herbicide use as well as integration of non-chemical control tactics.

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Collecting barley grass seed on upper EP for resistance screening, October 2020.

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SARDI SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE

Demonstrating integrated weed management strategies to control barley grass in low rainfall zone farming systems

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Location
Minnipa Agricultural Centre, paddock S3
Rainfall
Av. Annual: 324 mm
Av. GSR: 241 mm
2020Total: 367 mm
2020 GSR: 255 mm
Soil type
Red Sandy loam
Paddock history
2019: Compass barley
2018: Scepter wheat
2017: Volga vetch
Plot size
27 m x 620 m x 3 replicates (3 paddock seeder strips (27 m each) wide)

Key messages

- **In 2019 the IMI system had the lowest barley grass plant numbers and the lowest weed seed set.**
- **In 2019 the desiccated Compass barley hay cut at a higher seeding rate reduced the barley grass weed seed set by 75%. Using a hay cut and hay freeze may be an important management option for paddocks with high barley grass populations.**
- **Using only clethodim and a wetter at higher rates is important to maximise the efficacy and coverage and get the best conditions for killing the grass weeds. The broadleaf spray at MAC is now done separately several days after the grass weed control, not in the same tank mix.**
- **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 a higher risk rotation strategy than cereals. Therefore, wheat and barley tend to be the dominant crops in the low rainfall zone. This project is undertaking coordinated research with farming systems groups across the Southern and Western cropping regions to demonstrate tactics that can be reliably used to improve the management of barley grass.

How was it done?

At the beginning of the project a meeting was held with growers, MAC staff, consultants and Dr. Gurjeet Gill to discuss the issue of barley grass in upper EP farming systems. A three-year broad acre management plan (2019-21) was developed to be implemented with five different strategies to be tested and compared in a replicated broad acre farm trial on the MAC farm (Table 1).

The management strategies will be tested over the three year rotation with the focus on barley grass weed management and weed seed set. For the 2019 management of the trial refer to 'Demonstrating integrated weed management strategies to control barley grass in low rainfall zone farming systems', EPFS 2019 Summary, p 175.

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-SU sown medic pasture (IMI tolerant)	Razor CL wheat (IMI tolerant)
Higher cost herbicide	Compass barley (desiccated) 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).

The trial is composed of three replicated broad acre strips of three seeder widths (27 m wide) of each treatment in MAC paddock S3. In 2020 the paddock was sprayed on 25 March with 1.5 L/ha glyphosate, 0.45 L/ha 2,4-D LV Ester 680, 50 ml/ha Hammer and 100 ml/ha LI700 for early weed control.

The Two Year Break system had Trident TT canola sown on 26 April at 1.8 kg/ha, with Granulock Z fertiliser at 80kg/ha, and 1.5 L/ha glyphosate, 0.8 L/ha trifluralin, 800 gm/ha Simazine and 50 ml/ha Hammer and an insecticide on the 4 May and 4 September. On the 3 June the canola was sprayed with 330 ml/ha clethodim and 0.75 L/ha Hasten for grass weeds. On the 11 June it was sprayed with 30 ml/ha of Lontrel advance and 800 gm/ha of Atrazine.

The IMI system, following Scope barley in 2019, was sown with Sultan-SU (IMI tolerant) medic pasture at 7 kg/ha with 50 kg/ha of GranulockZ fertiliser on the 26 April, with 1.5 L/ha glyphosate and 50 ml/ha Hammer pre-sowing. On the 25 May all pasture treatments were sprayed with 25 gm/ha Broadstrike and 0.75 L/ha Hasten for broadleaf weed control, and on the 3 June 330 ml/ha clethodim and 0.75 L/ha Hasten for grass weed control. Karate Zeon insecticide was sprayed on the 4 September. Scepter wheat was sown on the 12 May at a seeding rate of 70 kg/ha, with GranulockZ fertiliser at 70kg/ha, and 1.6 L/ha glyphosate, 1.5 L/ha trifluralin and 50 ml/ha Hammer. It was sprayed with 1 L/ha Amicide 625 for broadleaf weeds on 28 August. Unfortunately, the Gp K herbicide Sakura was not applied pre-sowing.

Crop establishment, barley grass numbers, barley grass seed set, grain yield and quality were assessed during the growing season. Late barley grass samples were taken and panicles sent to Roseworthy for the assessment of barley grass seed set. The 27 m strips were harvested with the plot header (3 times) per treatment on 19 October for canola and 3 November for wheat, and the grain quality was assessed.

What happened?

In 2019 the IMI system had no barley grass weed seed set at harvest (Table 2). The Compass barley in 2019 in the District Practice and Cultural Control systems produced similar barley grass weed seed set with 377 seeds/m^2 and 360 seeds/m^2 respectively. The desiccated compass barley hay cut at a higher seeding rate of 95 kg/ha reduced the overall barley grass weed seed set to 88 seeds/m^2 (Table 2). The Two Year Break self-regenerating pasture system had the higher barley grass numbers during the 2019 season, but the late paraquat application in early September in the pasture phase lowered weed seed set to 216 seeds/m^2 (Table 2).

In 2020 the majority of the barley grass again germinated later in the season during mid July and August avoiding the early weed control with pre-sowing herbicide applications. The residual carryover in the IMI system resulted in the lowest pre-seeding germination and low barley grass numbers/m^2 (Table 2). The different crops all established well but a lower than average rainfall in May, June and July resulted in very slow crop growth until August and September.

The chemical applications applied in the break crop systems of the canola and medic crops reduced the late barley grass plant numbers (Table 2), with the TT Canola system giving the best later barley grass weed management. Despite the lower numbers of barley grass there were differences in the number of barley grass seed heads per plant (Table 2) with the Higher Cost Chemical system sown with Scepter wheat having more seed heads per plant late in the season. The 2020 late barley grass weed seed set at harvest is still being assessed at Roseworthy.

Table 1. The five different management strategies and crops for each season (2019-2021) at Minnipa Agricultural Centre, paddock S3.

2020 Barley grass weed control strategy and crop variety	2019 Pre-harvest barley grass weed seed set (seeds/m²)	Pre seeding barley grass numbers (plants/m²) 27 April	Crop establishment (plants/m²) 16 June	Early barley grass numbers (plants/m²) 16 June	Late barley grass (plants /m²) 1 Sept	Late barley grass (heads /m²) 1 Sept
District Practice Self-regenerating medic pasture	377	9.3	45.5	34.8	1.6	3.3
IMI system Sultan (SU tolerant) sown medic pasture	0	3.7	88.3	26	1.3	4.7
Cultural Control Self-regenerating medic pasture	360	42.4	46.3	39.3	2.8	5.7
Higher cost herbicide Scepter wheat	88	20	124.7	0.1	1.3	11.3
Two Year Break Trident TT canola	216	45.9	38.5	18	0.1	0.1
LSD (P=0.05)	*84.3*	*ns*	*9.2*	*22.6*	*1.2*	*4.8*

The Trident TT canola was harvested on the 19 October and yielded 0.59 t/ha with 30% oil, 26.8% protein and 6.2% moisture. The Scepter wheat was harvested on the 3 November and yielded 1.39 t/ha. The grain quality achieved the required delivery standards with 11.9% protein, 4.2% screenings, 10% moisture, test weight 82.9 gm and 38.2 gm/1000 grain weight.

What does this mean?

The 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. The germination patterns of this barley grass population was assessed at Roseworthy and showed it was a late germinating population with a requirement for cold (vernalisation), and Group A resistance to quizalofop.

In 2019 the desiccated Compass barley hay cut at a higher seeding rate of 95 kg/ha reduced the overall barley grass weed seed set to 88 seeds/m² compared to the other Compass barley systems, reducing the weed seed set by 75%. Despite the 2019 Two Year Break self-regenerating pasture system having higher barley grass numbers during the season the late hay freeze with paraquat sprayed at 1.2 L/ha, 500 mls LI700/100L at water rate 100L/ha in early September sprayed in the morning in cooler overcast conditions (approximately 19 degrees with a Delta T around 3.5) in the pasture phase prevented weed seed set. Using a hay cut and following up with a hay freeze may be an important management option to manage barley grass populations.

With confirmed Group A resistance levels at Minnipa Agricultural Centre in barley grass populations to FOPS, moving to clethodim could be effective for the short term. Generally higher rate of clethodim (500 mL/ha) appears to be effective on most populations where 250 mL/ha rate does not work effectively at present. However, resistance to the higher rate is likely to evolve over the next few years. The broadleaf spray at MAC is done separately several days after the grass weed control, not in the same tank mix. The environmental conditions can also affect the spray efficacy, especially cold weather/frost either 2-3 days before or after spraying, so avoid these events if possible. Dry conditions, plant stress and soil constraints may also affect spray efficacy, but more research is needed in this area.

While the IMI herbicide system is working well at MAC it tends to be quite prone to evolution of resistance in weeds. The strategic use of the IMI herbicide system must be used to maximise the effectiveness and long term use of this system. Growers also need to be aware of herbicide breakdown and plant back periods, especially in low rainfall seasons to avoid bare paddocks.

The chemical applications applied in the break crop systems of the canola and medic crops reduced the late barley grass plant numbers, with the TT Canola system giving the best later barley grass weed management. All systems had some level of barley grass escapes and weed seed carry over, and the number and size of barley grass seed heads will impact on the size of the seed bank in the following season.

The Group A 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 ensure that any suspected resistant plants are dealt with in pasture systems by following up with a knockdown herbicide as early as possible to prevent seed set. Always have follow up options to control any survivors and to preserve Group 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 and ensure the best use of chemicals to maximise the herbicide efficacy. This paddock scale MAC research is ongoing for the 2021 season to assess the barley grass weed management strategies.

Acknowledgements

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Harvest at Minnipa Agricultural Centre, 2020.

Demonstrating adaptive cropping systems to improve crop competition

Amanda Cook[1,2], Ian Richter[1], Jake Hull[1], Bruce Heddle[3], Andrew Polkinghorne[4], Tim Polkinghorne[4], Wade Shepperd[1] and John Kelsh[1]

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Location
Minnipa Agricultural Centre
Airport paddock
Rainfall
Av. Annual: 324 mm
Av. GSR: 241 mm
2020 Total: 367 mm
2020 GSR: 255 mm
Soil type
Red sandy loam
Paddock history
2019: Lentils
2018: Scepter wheat
2017: Lentils
Demonstration size
27 m x 1500 m x 3 locations
(3 paddock seeder strips (27 m each) wide).
Yield: 12 strips with plot harvester in each seeding system of 8.8 m x 1.7 m

Location
Lock - A&J Polkinghorne and T&E Polkinghorne
Rainfall
Av. Annual: 336 mm
Av. GSR: 250 mm
2020 Total: 287 mm
2020 GSR: 272 mm (72 mm in Oct)
Soil type
Red loam flats and sand hills
Paddock history
2020: Wheat
2019: Self-regenerating medic pasture
2018: Wheat
Demonstration size
8 rows of splitter boot x 4 measurements on each soil type.
Yield: 4 plant cuts (50 cm x 50 cm) x three strips threshed.

Key messages

- **A split row seeding system lowered initial ryegrass numbers on red loam at Lock but did not reduce final grass weed numbers and weed seed set.**
- **A small number of grass weeds escaping through the farming system will increase the weed seed bank for future seasons.**

Why do the trial?

A NLP2 Smart Farms grant (4-BA9KBX5) was received in October 2019 to demonstrate adaptive cropping systems. Two demonstration sites were established in 2020 to show the benefits of improving crop competitiveness against weeds by increasing the distribution of seed. The sites were:

- Minnipa, 30 cm row spacings or a no-row spacing seeding system.
- Lock, Stilletto® splitter boot (25 cm row spacing) or a Seedhawk® on 30 cm single row spacing on two different soil types.

How was it done?

In 2020 a demonstration was undertaken on the Minnipa Agricultural Centre (MAC) comparing 30 cm row spacing Horwood Bagshaw PSS® with a press wheel seeding system (Jake Hull, MAC farm manager) and a no-row seeding system consisting of a sweep system with a splitter boot (Bruce Heddle - Minnipa farmer). The no-row system was chosen to increase crop competition against grass weeds.

The MAC demonstration was in the Airport paddock and consisted of three strips, each of three seeder widths (27 m), for each seeding system. Scepter wheat was sown at 70 kg/ha on 12 May, with GranulockZ fertiliser at 70 kg/ha and 1000 g/ha of Rapisol ZMC. Pre-seeding herbicides were Trifluralin @ 1.5 L/ha and Paraquat @ 1 L/ha. In-crop herbicides were Tigrex @ 750 ml/ha and Lontrel Advance @ 35 ml/ha.

The second demonstration site was undertaken at Lock by Andrew and Tim Polkinghorne. The demonstration was sown using a standard Seedhawk sowing system on 30 cm row spacings with standard boots or with Stilletto splitter boots resulting in 25 cm split row spacing. This combination was evaluated on two different soil types, a red loam and a sandy rise. The paddock was sown with Trojan wheat at 70 kg/ha on 26 April with 15 L phosphoric acid/ha (85% P), 25 L/ha of UAN, 1 kg/ha of Mn-sulphate, 1 kg/ha of Zn-sulphate and 100 gm/ha Cu-sulphate. Herbicides used pre-seeding were glyphosate @ 1.2 L/ha, Ester 680 @ 300 ml/ha and Trifluralin @ 2.0 L/ha. In-crop herbicide was Amine @ 1 L/ha with an insecticide. Trace elements of 1 kg/ha of Mn-sulphate, 1 kg/ha of Zn-sulphate and 125 g/ha Cu-sulphate were also applied in a separate spray application.

Crop establishment, grass weed numbers (early and late), dry matter, grain yield and grain quality were assessed during the growing season. Soil moisture was taken for both seeding systems at harvest. The paddock demonstration at MAC was harvested with a plot header on 13 October. Hand harvest cuts were taken at Lock on 22 October.

What happened?

Good opening rains were received in late April/early May at both sites which enabled seeding within the ideal sowing window. The rest of May, June and July had below average rainfall resulting in very little crop growth until August and later in the season, with October having above average rainfall.

The grass weed counts pre-seeding at MAC Airport were low (Table 1), which supports previous research showing that the MAC barley grass genotype has delayed germination due to a vernalization requirement. Early crop establishment resulted in 143 plants/m^2 on the 30 cm row spacing system and 95 plants/m^2 in the no-row spacing system. The lower establishment in the no-row system may have been due to Trifluralin herbicide or lower seed-soil contact. Crop dry matter and yield were similar in both systems (Table 1). There were still low levels of grass weeds in both seeding systems in the later grass weed count at Minnipa.

At Lock, wheat establishment was similar in both seeding systems (Table 1). Early ryegrass numbers were lower with the splitter boot system compared to the single 30 cm row spacing on the red loam. Dry matter of wheat was similar in both seeding systems (Table 1).

There were no differences in the grain yield of wheat at Lock between different soil types but there was a difference of yield for the seeding systems with the Stilletto splitter boots yielding 1.4 t/ha compared to the single row of 1.04 t/ha (Table 2).

Grain protein at Minnipa was similar for both seeding systems (average of 9.6%) but screenings were higher in the 30 cm single row compared to the no-row system. Grain protein at Lock was lower on the sand at 12.1% compared to on the red loam at 13.8%. Screening levels were low on both soil types. There were no differences in soil moistures at harvest at either location between the seeding systems.

Table 1: Crop performance and grass weeds in two seeding systems at two EP sites. Grass weeds were barley grass at Minnipa and ryegrass at Lock.

Soil type	Seeding system	Wheat (plants/m^2)	Early grass weeds/m^2	Early wheat dry matter (t/ha)	Late grass (weeds/m^2)	Grass weed seed set (seeds/m^2)	Yield (t/ha)
Red Loam (Minnipa)	30 cm single row	143	0	0.8	0	0	2.2
	No row seeding system	95	0	0.3	4	745	2.4
LSD (F prob=0.05)		*12*	*ns*	*ns*	*ns*	*ns*	*ns*
Red Loam (Lock)	30 cm single row	113	52	0.8	10.8	1205	1.0
	Stilletto splitter boot	117	32	0.9	8.3	850	1.1
Sand (Lock)	30 cm single row	104	7	0.6	0	0	1.1
	Stilletto splitter boot	104	4	0.9	0	0	1.7
LSD (F prob=0.05)		*ns*	*11*	*ns*	*ns*	*ns*	*ns*

Table 2: Grain yield (t/ha) of two seeding systems at Lock, 2020.

Lock	30 cm single row	Stilletto splitter boot
	1.04	1.40
LSD (F prob=0.05)		*0.35*

Figure 1. Two different seeding systems at Minnipa in November 2020. LHS, 30 cm single row Horwood Bagshaw PSS with press wheel and RHS No row seeding system.

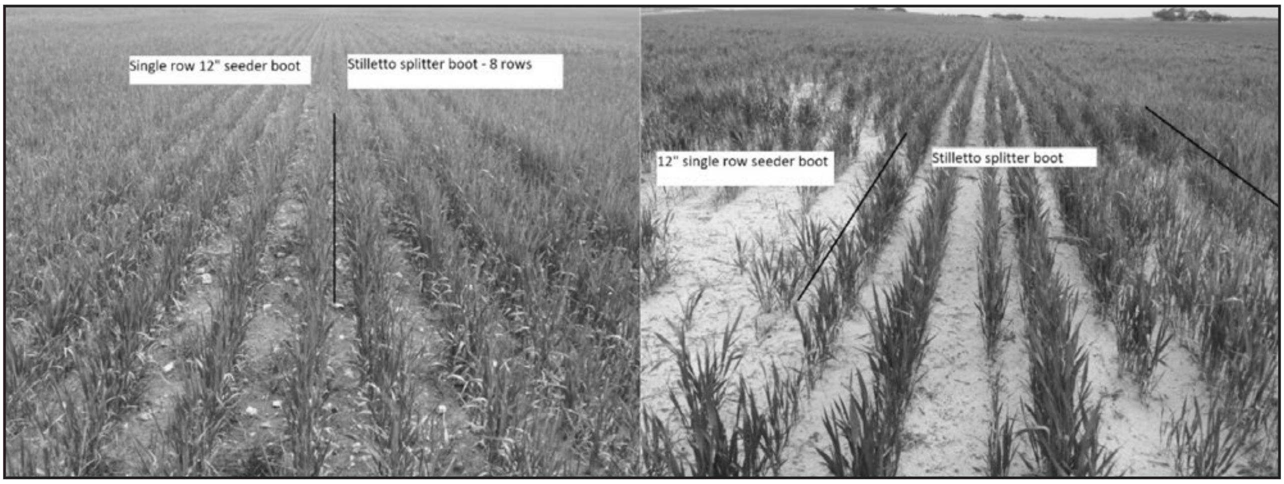

Figure 2. Two different seeding systems at Lock in 2020 on a red loam and sandy soil.

What does this mean?

The barley grass population at Minnipa was lower than expected. The no-row seeding system possibly had Trifluralin damage or lower seed soil contact at seeding which reduced initial crop numbers. Late grass seed set showed how a minimal number of plants escaping through the farming system will impact on the seed bank for future seasons.

Early ryegrass numbers were lower in the split row seeding system on the red loam at Lock supporting previous research that increasing crop competition is a management tool to lower grass weed numbers. Late grass weed numbers and seed set were similar in both seeding systems, which may have been due to high moisture stress during winter.

These demonstrations will be undertaken again in the 2021 season.

Acknowledgements

Thanks to the growers for implementing and hosting the seeding systems demonstrations. This extension demonstration was possible via NLP2 SFSG2 grants investment in project 4-BA9KBX5. Thank you to Katrina Brands and Steve Jeffs for processing samples.

Initial survey of current management practices of barley grass in upper Eyre Peninsula farming systems

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Key messages

- **The initial baseline survey received 96 responses from growers on the upper Eyre Peninsula.**
- **68% of the grower respondents identified barley grass as having a medium to high impact on their cropping systems.**
- **35% of growers used some method of harvest weed seed collection and 65% did not.**
- **Current row spacings for cropping were 3% having greater than 30 cm (12") wide rows, 35% having 30 cm (12") wide rows, 21% having 25 cm (10") and 31% having 22.5 cm (9") row spacing, 10% having 18 cm (7") row spacing, and 1% having less than 18 cm row spacing.**
- **30% of growers were using paired row or splitter systems to increase crop competition, 62% were not and 8% would like to.**

Why do the survey?

A recent NLP2 investment, Adapting cropping systems to changing climatic conditions to reduce inputs and maximise water use through improving crop competitiveness, is a demonstration and extension project which started in late 2019. An initial grower survey of current management practices and attitudes towards barley grass was undertaken in March 2020 to be used as the baseline to assess changes in grower attitudes and changes in practices at the completion of the project.

How was it done?

An electronic survey was developed undertaken in March 2020 at the farming systems group meetings on Eyre Peninsula with 96 grower responses at eight different meetings held across the region.

What happened?

The first question in the survey asked the growers about their farming systems with 75% being mixed farming with cropping and livestock, 13% being cropping only, 9% were not growers (industry or advisors), 2% had livestock over summer and 1% had livestock only.

The second survey question asked growers how big an impact barley grass had as a weed in their farming system. 38% of responses indicated barley grass had a high impact as a weed within their system, 30% indicated barley grass had a medium impact, 25% indicated barley grass had a low impact as a weed and 7% indicated it was not an issue.

The next question asked if barley grass had become more common in cropping paddocks. 57% of growers thought barley grass had become more common in their cropping paddocks, 32% said it was not more common, and 12% were unsure.

The fourth survey question asked if growers used harvest weed seed collection e.g. chaff dumps, chaff lines, windrows or harvest weed seed destructors. 35% of growers used some method of harvest weed seed collection and 65% did not.

The next survey question asked growers the current wheat and barley seeding rates used. Wheat seeding rates ranged from less than 45 kg/ha to greater the 80 kg/ha with 54% falling in the 60-70 kg/ha seeding rate range (60 kg/ha 24%, 65 kg/ha 17%, 70 kg/ha 13%). Barley seeding rates ranged from less than 45 kg/ha to greater than 80 kg/ha, with 73% falling in the 55-70 kg/ha seeding rate range (55 kg/ha 23%, 60 kg/ha 16%, 65 kg/ha 19%, 70 kg/ha 15%).

The next question asked growers about their current row spacing. Current row spacings for cropping were 3% having greater than 30 cm (12") wide rows, 35% having 30 cm (12") wide rows, 21% having 25 cm (10") and 31% having 22.5 cm (9") row spacing, 10% having 18 cm (7") row spacing, and 1% having less than 18cm row spacing.

30% of growers were using paired row or splitter systems to increase crop competition, 62% were not and 8% would like to. If there was no cost for machinery, or stubble and herbicide issues, then 56% of growers would reduce their current row spacing, 34% wouldn't reduce their current row spacing and 10% were unsure.

66% of growers have changed the cereal type on a grassy paddock eg from wheat to barley to increase crop competition, 30% haven't and 4% were unsure. 49% of growers have increased the seeding rate of a cereal on a grassy paddock as a management strategy, 43% haven't and 7% were unsure.

The last 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.

What does this mean?

This grower survey of current management practice and attitudes towards barley grass on Eyre Peninsula was undertaken as the baseline to assess changes in grower attitudes, and any change in practices after the completion of the project.

References

Llewellyn, *et al* (2016) Impact of weeds on Australian grain production.

Acknowledgements

This research was possible via NLP2 investment in project 4-BA9KBX5. Thank you to the farming systems groups for distribution of the survey and growers for their responses.

Members of the Low Rainfall RD&E committee at Minnipa, July 2020.

Weeds

Herbicide control of Lincoln weed (*Diplotaxis tenuifolia*)

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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: Pasture
Plot size
12 m x 1.76 m x 3 replicates

Location
Elliston
Rainfall
Av. Annual: 425 mm
Av. GSR: 350 mm
Soil type
Grey calcareous sandy loam
Paddock history
2019: Pasture
Plot size
12 m x 1.76 m x 4 replicates

Key messages

- **Glyphosate at the lower rate (Weedmaster DST 1.5 L/ha) with Hasten (oil + non-ionic surfactants) provided 40% control of Lincoln weed plants.**
- **The addition of other spray adjuvants such as LI700 and Liase (Ammonium sulfate) to glyphosate did not significantly change the level of weed control.**
- **When glyphosate was used alone, 5 L/ha rate of Weedmaster DST was needed to effectively control Lincoln weed.**
- **If growers intend to use the lower rates of glyphosate (Weedmaster DST 1.5 L/ha) then addition of MCPA, 2,4-D or 2,4-D + metsulfuron was found to significantly improve weed control compared to glyphosate alone.**

Why do the trial?

Lincoln weed is a perennial crucifer weed native to coastal dunes in Europe and western Asia, which was introduced to South Australia for fodder and soil stabilisation but became naturalised. It is a competitive weed in cropping and pastures. Its root system enables it to grow during summer and persist where lucerne and other pasture plants die off. Blade ploughing, or spraying with herbicides used for general broadleaf weed control can kill or dramatically reduce established Lincoln weed in arable areas. As a deep-rooted perennial, Lincoln weed will re-emerge from rhizomes after any single control treatment and also persists as seed in soil. Many farmers feel they have to use blade ploughing to control Lincoln weed even though tillage over summer-autumn months increases the risk of soil erosion. Studies on biology and ecology, along with research on different herbicide options, are needed to develop improved control tactics that do not require blade ploughing. It is ranked as the third most costly summer weed in the GRDC Mallee agro-ecological zone that includes Upper Eyre Peninsula costing $7.2M p.a. in lost crop yield and fifth most costly in the agro-ecological zone that includes Yorke Peninsula (Llewellyn *et al*., 2015).

How did we do it?

Two field trials were undertaken at Elliston and Streaky Bay on the Eyre Peninsula in 2019/20. The trials were established in a randomised complete block design with four replicates at Streaky Bay and three replicates at Elliston. The commercial names of the herbicides used and their active ingredients are described in Table 1. Plots were 12 m x 1.8 m in size. Herbicide treatments were applied on 4 December 2019 using a 2 m experimental boom sprayer with T11002 nozzles and a water rate of 100 L/ha. Herbicide efficacy was assessed using a linear rating scale (Australian Government 1979) on 18 December at 14 days after herbicide application (DAA) and again on 13 January 40 DAA. The analysis of variance was used to determine statistical significance of the differences between the herbicide treatments with Genstat 19 statistical package.

What happened and what does this mean?

Streaky Bay trial

In the trial at Streaky Bay in 2019/20, application of 1.5 L/ha with Hasten (oil + non-ionic surfactants) provided only 40% control of Lincoln weed. Furthermore, the addition of surfactants such as LI700, Liase (ammonium sulfate) to glyphosate did not significantly improve the level of weed control. Even 3 L/ha rate of glyphosate (Weedmaster DST) provided a moderate level (78%) of Lincoln weed control (Table 2), which is equivalent to the control provided by 1.5 L/ha Weedmaster DST in a similar trial during 2018/19.

Table 1. Commercial names and active ingredients used in the field trials for Lincoln weed control.

Commercial name	Active ingredient	Concentration (g/L or g/kg)
Weedmaster DST	glyphosate	470
Aspect Options	diflufenican	500
Flagship	fluroxypyr	400
Hammer	carfentrazone	400
Sharpen	Saflufenacil	700
Amicide advance	2,4-D	700
Thistle-killem	MCPA	750
Associate	metsulfuron	600

Such seasonal variation in tolerance to glyphosate is likely to be related to weeds being under water stress in 2019/20. Diflufenican (Aspect Options), which is well known for its ability to control brassica weeds, only provided 48% control of Lincoln weed. Addition of glyphosate to diflufenican did not improve weed control above the level provided by glyphosate alone. The trends observed for diflufenican are consistent with the previous trial. Similarly, addition of carfentrazone (Hammer) or saflufenacil (Sharpen) to glyphosate did not improve weed control compared to glyphosate alone. Application of glyphosate at 5 L/ha (Weedmaster DST) was the most effective herbicide treatment (97.5% control) but was statistically similar to the mixtures of Weedmaster DST at 1.5 L/ha with MCPA, 2.4-D and 2,4-D + metsulfuron.

When used alone, MCPA (Thistle-killem) showed significantly greater control of Lincoln weed than 2,4-D (Amicide Advance) even though they are both phenoxy herbicides. Addition of glyphosate to these herbicides provided 90-98% Lincoln weed control. High efficacy of these mixtures was also observed in the previous trial at this site. Therefore, growers can use the high rate of glyphosate alone (5 L/ha) or mixtures of glyphosate and MCPA or 2,4-D instead of summer cultivation for the control of this weed. Poorer efficacy of another group I herbicide fluroxypyr (Starane) than MCPA and 2,4-D when used in mixture with glyphosate was also seen in the previous trials.

Table 2. Efficacy of different herbicide treatments on Lincoln weed control at Streaky Bay at 40 days after herbicide application (DAA). Means followed by a different letter are significantly different at P=0.05.

Treatment	Weed control (%)
Untreated Control	10.0 a
Weedmaster DST @ 1.5 L/ha + Hasten @ 1% (1 L/ha)	40.0 b
Weedmaster DST @ 1.5 L/ha + LI-700 @ 0.5% + Liase @ 2 L/ha	40.0 b
Amicide Advance 700 @ 800 mL/ha + LI-700 @ 0.5%	42.5 bc
Weedmaster DST @ 1.5 L/ha + Sharpen @ 34 g/ha + Hasten @ 1%	45.0 bcd
Aspect Options @ 200 mL/ha + LI-700 @ 0.5%	47.5 bcde
Weedmaster DST @ 1.5 L/ha + LI-700 @ 0.5% (500 mL/ha)	50.0 bcde
Weedmaster DST @ 1.5 L + Aspect Options @ 200 mL/ha + LI-700 @ 0.5%	52.5 cde
Weedmaster DST @ 1.5 L + Hammer 400EC @ 45 mL/ha + LI-700 @ 0.5%	55.0 de
Weedmaster DST @ 1.5 L + Flagship @ 800 mL/ha + LI-700 @ 0.5%	57.5 e
Thistle-killem 750 @ 1 L/ha + LI-700 @ 0.5%	77.5 f
Weedmaster DST @ 1.5 L/ha + Amicide Advance 700 @ 500mL + Associate @ 3.5 g/ha + Liase @ 2 L/ha	77.5 f
Weedmaster DST @ 3 L/ha + LI-700 @ 0.5%	77.5 f
Weedmaster DST @ 1.5 L/ha + Amicide Advance 700 @ 800 mL + LI-700 @ 0.5%	90.0 g
Weedmaster DST @ 1.5 L/ha + Amicide Advance 700 @ 800 mL + Associate @ 5 g/ha + LI-700 @ 0.5%	92.5 g
Weedmaster DST @ 1.5 L/ha + Thistlekillem 750 @ 1 L/ha + LI-700 @ 0.5%	97.5g
Weedmaster DST @ 5 L/ha + LI-700 @ 0.5% (500 mL/ha)	97.5 g

Table 3. Efficacy of different herbicide treatments on Lincoln weed control at Elliston at 40 days after application (DAA). Means followed by a different letter are significantly different at P=0.05.

Treatment	Weed control (%)
Untreated Control	16.7 a
Weedmaster DST @ 1.5 L/ha + Amicide Advance 700 @ 800 mL + LI-700 @ 0.5%	30.0 ab
Weedmaster DST @ 1.5 L/ha + Sharpen @ 34 g/ha + Hasten @ 1%	31.7 ab
Aspect Options @ 200 mL/ha + LI-700 @ 0.5%	33.3 abc
Weedmaster DST @ 1.5 L + Flagship @ 800 mL/ha + LI-700 @ 0.5%	33.3 abc
Amicide Advance 700 @ 800 mL/ha + LI-700 @ 0.5%	33.3 abc
Weedmaster DST @ 1.5 L/ha + LI-700 @ 0.5% + Liase @ 2L/ha	40.0 abcd
Weedmaster DST @ 1.5 L + Hammer 400EC @ 45 mL/ha + LI-700 @ 0.5%	43.3 bcd
Weedmaster DST @ 1.5 L/ha + LI-700 @ 0.5% (500 mL/ha)	43.3 bcd
Weedmaster DST @ 3 L/ha + LI-700 @ 0.5%	43.3 bcd
Thistlekillem 750 @ 1 L/ha + LI-700 @ 0.5%	56.7 cd
Weedmaster DST @ 1.5 L/ha + Amicide Advance 700 @ 500 mL + Associate @ 3.5 g/ha + Liase @ 2 L/ha	58.3 d
Weedmaster DST @ 1.5 L/ha + Amicide Advance 700 @ 800 mL + Associate @ 5 g/ha + LI-700 @ 0.5%	86.7 e
Weedmaster DST @ 1.5 L/ha + Thistlekillem 750 @ 1 L/ha + LI-700 @ 0.5%	86.7 e
Weedmaster DST @ 5 L/ha + LI-700 @ 0.5% (500 mL/ha)	90.0 e

Elliston trial

The response of Lincoln weed to different herbicide treatments at Elliston was quite similar to that observed at Streaky Bay (Table 3). Addition of group G herbicides Sharpen or Hammer to glyphosate at 1.5 L/ha did not improve the level of weed control (30-40%) compared to glyphosate alone. In this trial, even increasing the dose of glyphosate to 3 L/ha (Weedmaster DST) did not improve weed control compared to 1.5 L/ha. Weeds at this site were slightly larger than at Streaky Bay, which may have increased their tolerance to glyphosate.

The best performing treatments were the highest rate of glyphosate (Weedmaster DST 5 L/ha) and the mixture of Weedmaster DST at 1.5 L/ha with MCPA (Thistle-killem) or 2,4-D plus metsulfuron.

Acknowledgements

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Herbicide control of Caltrop (*Tribulus terrestris*)

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Key messages

- **Field trials were undertaken at Roseworthy and Minnipa in 2018/19 to investigate caltrop control with different herbicide treatments during the summer fallow.**
- **All glyphosate treatments were highly effective and provided greater than 90% control of caltrop.**
- **Addition of the group G herbicides, Hammer - carfentrazone and Terrain - flumioxazin, to glyphosate had a significant antagonistic effect on glyphosate efficacy on caltrop. For example at Roseworthy, Weedmaster DST at 1 L/ha provided 97% caltrop control as compared to 26% when Terrain was added to Weedmaster DST.**
- **From these results, it is clear that caltrop is readily controlled with glyphosate based herbicide treatments, though care is needed when mixing it with group G herbicides.**

Why do the trial?

Managing summer weeds such as caltrop (*Tribulus terrestris*) can have a large impact on the yields of subsequent winter crops due to conservation of stored soil moisture and nitrogen, and improved crop establishment. Caltrop has been identified by the Grains Research and Development Corporations (GRDC) low rainfall zone Regional Cropping Solution Network (RCSN) as a hard to control weed. While caltrop is found in many cropping districts across southern Australia, its distribution is quite varied between districts. In a survey of summer weeds across South Australia by Fleet, Preston and Gill (GRDC - UA00149), caltrop had a higher prevalence in the Mallee (27% of paddocks), Upper South East (21% of paddocks), and Upper North (18% of paddocks). Whereas in the Lower South East and Lower Eyre Peninsula, caltrop was not detected in the survey. Growers in many areas of South Australia have reported increased prevalence and difficulty in controlling caltrop over the summer fallow period. This field study was undertaken to validate the performance of several summer fallow herbicide options on caltrop previously studied in 2018.

How did we do it?

A field population of caltrop was selected at Roseworthy Campus, to evaluate 12 summer fallow herbicide treatments. The trial was established in a randomised complete block design with twelve herbicide treatments and four replicates (Table 4.8). Plots were 20 m x 2.5 m in size. Herbicide treatments were applied on the 17 December 2018 using a 2 m experimental hand boom sprayer with 015 HARDI mini drift nozzles and a water rate of 100 L/ha. Herbicide efficacy was assessed using a linear rating scale (Australian Government 1979) on 2 January, 15 days after herbicide application (DAA) and 11 Feb (56 DAA). Data was then analysed with the analysis of variance using Genstat 15 statistical package.

An identical trial was also undertaken at Minnipa in 2018/19. In addition to the 12 herbicide treatments used at Roseworthy, Minnipa trial also included the District Practice of Weedmaster + 2,4-D (Table 4.3). Herbicide treatments were applied on 27 December and weed control efficacy was assessed at 49 days after the application of the treatments. Plots 12 m x 2 m in size at Minnipa and sprayed with a boom sprayer fitted 11002 nozzles.

What happened and what does this mean?

Roseworthy trial

Summer fallow herbicide treatments and their efficacy on caltrop are summarised in Table 1. All glyphosate (group M herbicide) treatments provided greater than 90% control when assessed at 15DAA and 56DAA. Increase in rate of glyphosate or addition of HotUp spray additive did not improve the level of caltrop control (Table 2). Addition of group I herbicides 2,4-D amine and fluroxypyr (Flagship) significantly reduced caltrop control (15 DAA) but at 56 DAA, the level of weed control was similar to glyphosate alone treatments.

Table 1. Products, active constituents and herbicide groups used in caltrop efficacy trial.

Commercial product	Active ingredients	Herbicide group
Weedmaster DST	470g/L glyphosate	Group M* (inhibitor of EPSP synthase)
Amicide Advance 700	700g/L 2,4-D amine	Group I (synthetic auxin - phenoxy)
Flagship	200g/L fluroxypyr	Group I (synthetic auxin - pyridine)
Associate	600g/kg metsulfuron	Group B (ALS inhibitor - sulfonylurea)
Hammer	400g/L carfentrazone	Group G (inhibitor of PPO – triazolinones)
Terrain	500g/kg flumioxazin	Group G (inhibitor of PPO - N-phenylphthalimides)
Biffo	200g/L glufosinate	Group N (inhibitor of glutamine synthase)
Hot-Up spray additive	340g/L non-ionic surfactant blend + 190g/L mineral oil + 140g/L ammonium sulphate	

** Information on herbicide groups from Crop Life Australia*

The strongest antagonism with glyphosate was observed with the addition of group G herbicides carfentrazone (Hammer) and flumioxazin (Terrain). Caltrop control with these mixtures did not improve over time and remained below 40%. The group G herbicides are contact herbicides that quickly cause localised damage to the plant. Whereas glyphosate is a slower working herbicide that translocates throughout the plant. If the group G herbicide causes necrosis in the leaf too quickly the plant's ability to translocate glyphosate could be reduced, which will negatively affect its efficacy. This situation is most likely to occur in summer as group G herbicide symptoms appear most quickly in bright sunny conditions at the time of application (University of California 2019).

Glufosinate (Biffo treatment 10) showed excellent brown out of caltrop 15 DAA, however by 56 DAA caltrop had partially recovered and the efficacy was significantly lower than most of the glyphosate treatments. This result is expected as glufosinate, unlike glyphosate, is a contact herbicide (BASF 2019). These results indicate that, depending on herbicide price, glufosinate could be an alternative to glyphosate for knockdown control of caltrop.

The results of this trial in 2018/19 are consistent with those reported from the previous trial in last year's annual report. Glyphosate used at 1 L/ha or greater was found to provide consistently high level of caltrop control in summer fallow. Therefore, poor weed control efficacy with glyphosate are likely to be related to spraying under unsuitable conditions (e.g. severe water or heat stress) or when using tank mixtures with group G herbicides such as Hammer or Terrain.

Table 2. The effect of summer fallow herbicide treatments on caltrop control at Roseworthy in 2018/19. Means followed by a different letter are significantly different at P=0.05.

Treatment	Caltrop control (%) 15 DAA	Caltrop control (%) 56 DAA
1. Control (untreated)	0 d	0 c
2. Weedmaster DST @ 1L + HotUp @ 1%	94.4 a	97.5 a
3. Weedmaster DST @ 2L + HotUp @ 1%	97.5 a	100 a
4. Weedmaster DST @ 1L + Amine 625 @ 900 mL + HotUp @ 1%	78.4 b	99.4 a
5. Weedmaster DST @ 1L + Flagship @ 500mL+ HotUp @ 1%	66.9 c	81.9 a
6. Weedmaster DST @ 1L + Amine 625 @ 900mL + Ally @ 5g + HotUp @ 1%	75.6 b	85 a
7. Weedmaster DST @ 1L + Hammer @ 55mL+ HotUp @ 1%	29.4 c	25.0 b
8. Weedmaster DST @ 4L + HotUp @ 1%	98.1 a	100 a
9. Weedmaster DST @ 1L + Terrain @ 30g+ HotUp @ 1%	26.2 c	40 b
10. Biffo 4L + HotUp @ 1%	94.4 a	44.4 b
11. Weedmaster DST @ 1L	97.5 a	98.8 a
12. Weedmaster DST @ 2L	98.7 a	100 a
	$P<0.001$	*$P<0.001$*

Table 3. The effect of summer fallow herbicide treatments on caltrop control at Minnipa in 2018/19. Means followed by a different letter are significantly different at P=0.05.

Treatment	Caltrop control (%) 49 DAA
1. Control (untreated)	7.5 c
2. Weedmaster DST @ 1L + HotUp @ 1%	87.5 ab
3. Weedmaster DST @ 2L + HotUp @ 1%	85.0 ab
4. Weedmaster DST @ 1L + Amine 625 @ 900 mL + HotUp @ 1%	90.0 ab
5. Weedmaster DST @ 1L + Flagship @ 500mL+ HotUp @ 1%	50.0 bc
6. Weedmaster DST @ 1L + Amine 625 @ 900mL + Ally @ 5g + HotUp @ 1%	85.0 ab
7. Weedmaster DST @ 1L + Hammer @ 55mL+ HotUp @ 1%	62.5 b
8. Weedmaster DST @ 4L + HotUp @ 1%	95.0 a
9. Weedmaster DST @ 1L + Terrain @ 30g+ HotUp @ 1%	27.5 c
10. Biffo 4L + HotUp @ 1%	70.0 ab
11. Weedmaster DST @ 1L	90.0 ab
12. Weedmaster DST @ 2L	100.0 a
13. Weed master DST @ 1.2L + Amine Advance 700 @ 600mL + LI-700 @ 0.5% (District practice)	82.5 ab
	P<0.001

Minnipa trial

The response of caltrop to the herbicide treatments at Minnipa was very similar to the trial at Roseworthy (Table 3). Weedmaster DST @ 1 L/ha provided 90% control of caltrop and the addition of surfactant HotUp did not improve weed control. Consistent with the Roseworthy trial, addition of flumioxazin (Terrain - group G) to glyphosate had a significant antagonistic effect on the level of weed control (27.5% vs 90%). As stated earlier, rapid bleaching caused by this herbicide group can antagonise glyphosate activity on weeds. There was an indication of antagonistic effect of the other group G herbicide carfentrazone (Hammer) on glyphosate but the response was statistically non-significant (62.5% vs 90%). The addition of group I herbicide fluroxypyr (Flagship) to glyphosate also caused some antagonism (50% control) as compared to 90% control with glyphosate. Patchy distribution of caltrop at the Minnipa reduced the ability of the statistical analysis to detect moderate differences in the treatment means. Glufosinate (Biffo) was investigated as an alternative to glyphosate. However, weed control provided by Biffo at 4 L/ha was significantly lower than Weedmaster DST at 2 L/ha. As a general statement, it could be argued that rather than addition of other herbicide groups to glyphosate, superior weed control can be achieved by increasing the rate of glyphosate (2 L/ha of Weedmaster DST), which provided 100% control of caltrop in this trial.

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Weeds

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Section 8

Pastures

Dryland Legume Pasture Systems (DLPS): alternative species adaptation trial

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Location
Minnipa Agricultural Centre paddock N7
Rainfall
Av. Annual: 324 mm
Av. GSR: 241 mm
2020 Total: 367 mm
2020 GSR: 255 mm
Paddock history
2019: Spartacus CL barley
2018: Scepter wheat
2017: Canola
Soil type
Red sandy loam
Plot size
5 m 1.7 m x 4 reps x 25.5 cm row spacing

Key messages

- **The largest amount of early pasture growth was produced by Sultan-SU barrel medic (1.5 t/ha dry matter (DM)) and Trigonella DL60 (1.2 t/ha DM).**
- **Margurita French serradella produced large amounts of late pasture growth with 2.4 t/ha DM, however it failed to set adequate levels of seed.**
- **In the 2020 growing season the Trigonella lines DL59, DL60 and WA1 were consistently productive pasture legume species in terms of both early and late growth, and seed production.**

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 that are available or being developed offer improved seed harvestability and are better suited to establishment when dry sown and/or provide better nutrition for livestock. Regional evaluation is being undertaken in this project 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 in Minnipa paddock N7 (loam soil) was arranged in a fully randomised block design with four replications.

Sixteen legume genotypes were sown: Casbah biserrula; five lines of trigonella; French serradella cultivars Frano (new earlier season cultivar) and Margurita; Ioman astragalus (+/- inoculation); Bartolo bladder clover and an earlier bladder clover line; SARDI rose clover; and Cefalu arrowleaf clover. The spineless burr medic cultivar Scimitar and barrel medic cultivar Sultan-SU were included as controls.

The trial was sown on 18 May 2020 into moist soil. Plant emergence counts were completed on 30 June. Green Seeker measurements were taken on 27 August, 9 September and 20 October. Plots were scored for vigour on 8 September. Plots were sprayed for Cowpea aphid on 9 September. Early dry matter (DM) cuts were completed on 14 September and late DM cuts taken on 5 November. Plots were sampled to estimate seed production on 24 November 2020.

Results were analysed using Analysis of Variance with Genstat 64, version 20.

Table1: Average dry matter production and seed yield for pasture legume species at Minnipa in 2020.

Legume Species	Early DM 14/9/20 (t/ha)	Late DM 5/11/20 (t/ha)	Seed Yield (kg/ha)
Bartolo bladder clover	0.39 de	1.81 b	726
Bladder clover WA4	0.36 de	1.33 bc	1027
SARDI rose clover	0.80 cd	1.97 ab	1158
Cefalu arrowleaf clover	0.19 e	1.92 ab	833
Ioman astragalus nil Rhizobia	0.84 cd	1.74 bc	819
Ioman astragalus inoculated	0.77 cd	1.97 ab	766
Casbah biserrula	0.25 e	2.03 ab	325
Trigonella 5045	0.58 d	1.28 c	190
Trigonella DL59	1.13 bc	1.51 bc	355
Trigonella DL60	1.19 ab	1.90 ab	476
Trigonella WA1	1.08 bc	2.14 ab	179
Trigonella WA2	0.80 cd	1.17 c	220
Margurita French serradella	0.33 de	2.37 a	28
Frano French serradella	0.25 e	1.40 bc	8
Sultan-SU barrel medic	1.47 a	1.25 c	256
Scimitar spineless burr medic	0.90 c	0.78 c	356
LSD (P=0.05)	*0.28*	*0.54*	

What happened?

The season opened in late April with 25 mm of rainfall, enabling the trial to be sown into moist soil. However, rainfall for May, June and July was more than 50% below average, resulting in slow pasture establishment and growth (Table 1). Above average spring rainfall (August to October) increased the growth of biserrula, Margurita French serradella and Cefalu arrowleaf clover, but was too late in the growing season for the medics.

The trial suffered an attack from cowpea aphids in early September. There was evidence of aphids present on all plots, but only the astragalus appeared to be badly damaged. The aphids were quickly controlled, with all lines continuing to grow, flower and set seed; however the astragalus looked less vigorous post attack.

Sultan-SU barrel medic and Trigonella DL60 had the highest DM in early spring (14 September) with 1.47 t/ha and 1.19 t/ha DM (Table 1). Other genotypes with reasonable DM (>0.8 t/ha) included Scimitar burr medic, trigonella (other than APG5045), Ioman astragalus (nil Rhizobia) and SARDI Rose clover. The other entries had low DM (<0.4 t/ha).

By late spring (5 November) Margurita French serradella, trigonella lines WA1 and DL60, biserrula, SARDI rose clover, astragalus (inoculated) and Cefalu arrowleaf clover all produced more than 1.8 t/ha. With the exception of the trigonellas and SARDI rose clover, these lines all had low DM in early spring. The annual medics did not produce any more DM than was present in early spring.

All lines flowered and set seed (Table 1). The two French serradella cultivars had very low (28 and 8 kg/ha) seed set despite producing a large amount of spring growth.

What does this mean?

Despite a challenging early growing season with below average rainfall, all pasture legume lines established, flowered and set seed, although the amount set by the serradellas is expected to be insufficient for adequate regeneration. Sultan-SU barrel medic and Trigonella DL60 produced the greatest amount of early DM. Trigonella lines DL59, DL60 and WA1 performed consistently well in terms of both early and late DM, and seed set; these recent selections appearing to perform better than 5045. SARDI rose clover also performed consistently well throughout the 2020 growing season.

The above average rainfall in spring allowed Margurita French serradella, Cefalu Arrowleaf clover and Casbah biserrula, which are later flowering than the medics included in the trial, to produce very large amounts of feed when the medics had already set seed and begun to senesce. However these later producing legumes were slow to establish and grew poorly during winter, with low biomass and ground cover. Margurita and Frano serradella also set inadequate amounts of seed. Trigonella lines DL59, DL60 and WA1 were more consistent performers in terms of both early and late biomass, and seed set.

The large differences in the seasonal production of the different legume species may be able to be exploited to provide a more consistent feed resource for livestock, where sensible combinations of the legumes are used and able to be managed for persistence and weed control.

The three growing seasons of the DLPS Project have all had above average spring rainfall, hence the performance of alternative lines has not yet been assessed in a season with average or below average spring rainfall.

In the 2018 and 2019 Dryland Legume Pasture Systems Legume Adaptation trials, astragalus was the best adapted alternative legume species. Although Astragalus did not reach its full potential in 2020 due to an aphid attack, its overall performance was still good and merits further investigation in the Minnipa environment. Seed is still not commercially available.

In 2021 species regeneration will be assessed prior to the trial being sown to wheat.

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Dryland Legume Pasture Systems: spineless burr medics - hardseed levels and boron tolerance

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Key messages

- **Improved cultivars of spineless burr medic are being developed.**
- **Many of the lines have improved levels of boron tolerance.**
- **Hardseed levels have been confirmed as suitable for ley pastures.**

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 provision of high quality feed to livestock, fixing nitrogen and reducing soil borne disease levels. Damaging levels of boron (B) in the subsoil is a widespread constraint in neutral to alkaline soils which can restrict dry matter production and seed set of annual legume pastures. All spineless burr medic (*Medicago polymorpha*) cultivars are susceptible to high boron levels. Spineless burr medics are typically used as ley pastures and hardseed levels need to be in the optimal range to allow persistence through cropping phase and early dry matter production. A cohort of boron tolerant spineless burr medics is being field evaluated at multiple sites. This article follows on from a paper on boron tolerance in annual medics in the 2019 EPFS Summary, p 219 and reports on glasshouse work to determine the boron tolerance of each line and work done to ensure they have suitable levels of hardseed. It also provides a hypothetical example to demonstrate how hardseed breakdown can affect pasture regeneration and determine the suitability of different pasture species to two-year pasture phases.

How was it done?

Boron tolerance

Marker assisted speed breeding (4 to 6 plant generations per year) techniques were used to develop a cohort of spineless burr medics with putative boron tolerance for field evaluation. The boron tolerance status of the lines has been confirmed in a greenhouse screen. Burr medic cultivars Scimitar and Cavalier, and the boron tolerant parent, were grown in potting mix amended with 0, 2.5, 5, 7.5 and 10 mg/kg boron. Boron damage symptoms were rated on the first trifoliate leaf. We then screened 16 breeders' lines at the B rate that provided clear differences in B toxicity symptoms between the cultivars and the B parent.

Hardseed levels

Ley pasture cultivars need to have suitable levels of hardseed such that they can regenerate from soil seed reserves after 2 to 3 years of crops. When developing new annual medic cultivars, we aim to have 70 to 90% hardseed at the end of the first autumn after the pasture is first introduced. If hardseed levels are below this range, long term persistence is compromised and above this range the first pasture year needs to be followed by a crop. After plants in Minnipa and Roseworthy field trials had senesced (November), pods were collected and placed inside pockets made of fly wire which were then pinned to the soil surface in Adelaide to experience the hot weather of summer and fluctuating autumn temperatures which affect hardseed breakdown. Pods were collected at the end of February and a second batch at the end of May, placed into a petri dish with moist filter paper for 14 days to allow soft seed to germinate. Hardseed remaining was expressed as percent of total seed. Plant regeneration observations were also made in the field at Minnipa and Roseworthy, soon after the opening rains.

What happened?

Field evaluation at Minnipa (see Tomney *et al*. p 192) and Roseworthy indicates several lines are performing well and it is expected that we will be able to identify a line suitable for release as a cultivar.

Confirmation of boron tolerance in the greenhouse

The boron tolerance rate trial confirmed that existing spineless burr medic cultivars Scimitar and Cavalier are susceptible to high levels of boron and confirmed the boron tolerance of the parent used to develop the boron tolerant burr medic cohort (Figure 1). At the rate of 7.5 mg boron/kg potting mix, 14 lines from the boron tolerance cohort were confirmed as being boron tolerant and two lines were found to be boron susceptible (data not shown).

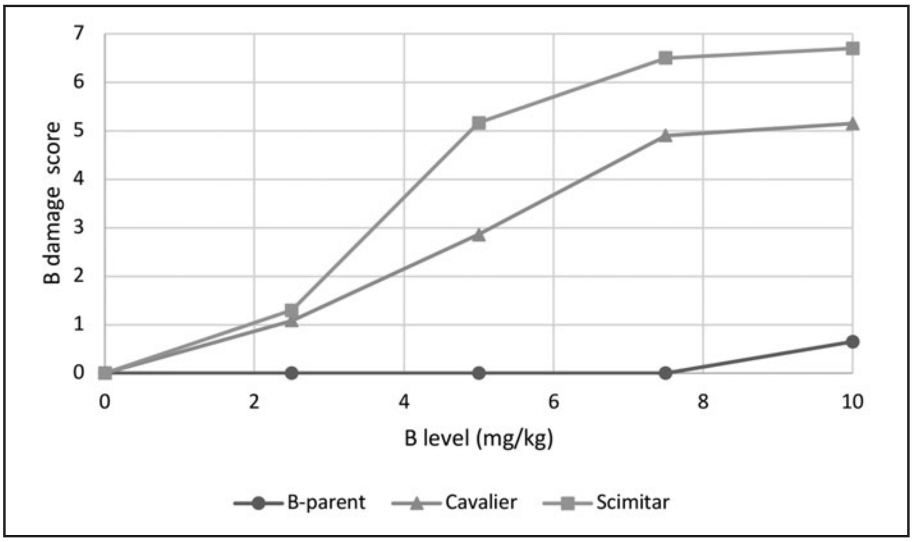

Figure 1. Boron damage score of first trifoliate leaf of B-parent, Cavalier and Scimitar grown in potting mix amended with 0, 2.5, 5, 7.5 or 10 mg/kg of B.

The boron tolerant marker used to develop the cohort has a 0.85 accuracy and finding some boron susceptible lines was expected. The potting mix method used is much simpler than hydroponic screens that we have used previously. This will allow us to screen the boron tolerance of other annual medic germplasm we are developing and will allow us to avoid releasing new medic cultivars that are very susceptible to boron.

Hardseed levels

The hardseed level of the boron tolerant parent is similar to the current cultivars Scimitar and Cavalier and fit within the target range of 70 to 90% (Table 1). This suggests that most of the bred lines will be within this range. This was confirmed with our hardseed test and germination observations. Hardseed levels were lower for pods collected from Minnipa than Roseworthy. Sixty to 90% of the soft seed softened after the end of February which protects the seeds from false breaks (i.e. early rainfall that geminates seed which then dies due to lack of follow up rainfall) while providing some seed in case the break is early.

Table 1 provides a hypothetical example of how different hard seed levels can affect germinable seed levels (expressed as equivalent sowing rate) in a regenerating pasture if seeds yields (SY) in the year of seed set were 200, 400 or 600 kg/ha. Recommended sowing rates for annual medics are 6-10 kg/ha, but sowing rates of 2-4 kg/ha are common. For Cavalier, Scimitar and the B parent, the equivalent sowing rate in the low seed yield (200 kg/ha) in a regenerating pasture is at least twice the maximum recommended sowing rate, consistent with observations that these cultivars are able to produce vigourous pastures in the year after establishment. Therefore, they are suited to the first pasture being followed by a second pasture and explaining why regenerating pastures are generally more productive than sown pastures. Genotype A is an example of a cultivar/species that has very high levels of hardseed that is not suited to consecutive pastures as indicated by low equivalent sowing rates. Examples of species with very high hardseed levels in SA trials include the species Biserrula, Yellow Serradella and Bladder clover. These species are best cropped in the year after establishment. Flohr *et al*. (p 201) report the benefits to wheat yields from two years of pasture are greater than after one year of pasture and why medic breeders aim for hardseed levels suitable for the first pasture to be followed by a second pasture as well as long term persistence.

Table 1. The hardseed levels (%) of spineless burr medic cultivars Cavalier and Scimitar and boron parent grown at Roseworthy or Minnipa. Hypothetical study of the effect of these hardseed levels on levels of germinable seed (equivalent sowing rate, kg/ha) in the regenerating pasture year for seed yields of 200, 400 or 600 kg/ha. Genotype A is theoretical and an example of a species/cultivar with very high hardseed levels.

Site	Genotype	Hardseed %	Equivalent sowing rate		
			200 kg SY	400 kg SY	600 kg SY
Roseworthy	Cavalier	90	20	40	60
	Scimitar	86	28	56	84
	B parent	88	24	48	72
Minnipa	Cavalier	89	22	44	66
	Scimitar	75	50	100	150
	B parent	72	56	112	168
	A	98	4	8	12

Pasture establishment in a regenerating year is a function of seed soil reserves (i.e. seed yields) and hardseed breakdown. Although legume genotype is a strong determinant of hardseed breakdown, it is also affected by seasonal conditions during seed fill (cooler wet spring results in less breakdown), number of hot days (increased hot weather increases subsequent breakdown) and temperature fluctuations (optimal range is species/cultivar dependant) in late summer and autumn, hence germination can vary from year to year and regional evaluation remains important to legume selection. Hardseed breakdown for some species/genotypes is inhibited by light and this is why burial at 0.5 to 1 cm is recommended for some species/cultivars (e.g. French serradella cv. Margurita, bladder clover cv. Bartolo) in February (after hot weather requirements have been met) to achieve consecutive pasture years. It is also why some cultivars are promoted as suitable for summer sowing (see Flohr *et al*. p 201).

What does this mean?

A glasshouse boron screen confirmed boron tolerance of 14 of our lines. Damaging levels of boron is a widespread constraint in neutral and alkaline soils and boron tolerance may provide increased dry matter and nitrogen fixation when grown in soils with high boron. New annual medic cultivars are being developed with hardseed levels to support persistence and regeneration after 2 to 3 years of crops and at the same time provide flexibility for consecutive pasture years. We have measured the hardseed levels of breeders' lines to ensure they are within the optimal range and that the timing of the softening is such that they are protected from false breaks. We have also provided general information about hardseed and its breakdown and how alternative species can be different to current annual medic cultivars. Spineless burr medic lines with improved levels of boron tolerance, appropriate hardseed levels and good agronomic performance will be evaluated further in the field in 2021 and line/s chosen for release as a cultivar. Pre-commercial seed build-up typically takes 2 to 3 years and if successful the new cultivar(s) will be available in limited supply in autumn 2024.

Acknowledgments

The DLPS project is supported by funding from the Australian Government Department of Agriculture and Water Resources 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.

Dryland Legume Pasture Systems: evaluation of spineless burr medics

Fiona Tomney[1], David Peck[2], Jeff Hill[2], Neil King[1], Ian Richter[1] and Ross Ballard[2]

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Location
Minnipa Agricultural Centre
paddock N7
Rainfall
Av. Annual: 324 mm
Av. GSR: 241 mm
2020 Total: 367 mm
2020 GSR: 255 mm
Paddock history
2019: Spartacus CL barley
2018: Scepter wheat
2917: Canola
Soil type
Red sandy loam
Plot size
5 m x 1.7 m x 4 reps x 25.5 cm row spacing

Key messages

- **Several boron tolerant lines showed promise as future cultivars.**
- **Some of the RLEM tolerant lines also showed promise as a future cultivar.**
- **Although included as a control, the performance of PM-250 strand medic was outstanding in 2020.**

Why do the trial?

Annual medics provide highly nutritious feed for livestock, act as a disease break for many cereal root pathogens, improve fertility through nitrogen (N) fixation, and mixed farms have reduced economic risk compared to continuous cropping or livestock farming systems. The most widely grown species of medics are barrel, strand and spineless burr medics. High levels of boron (B) in the subsoil is a constraint to plant production. Boron tolerant barrel and strand medic cultivars exist but current spineless burr medic cultivars are susceptible to high levels of B (see EPFSS 2019, p 219). A cohort of B tolerant spineless burr medics have been developed at Minnipa (Peck *et al*. p 189). Red legged earth mite (RLEM) is a common pest of germinating annual pastures and current cultivars are susceptible. This trial reports on the performance of breeders' lines of spineless burr medics relative to current cultivars; some lines of barrel, strand and disc medics were also included as controls.

How was it done?

The trial at Minnipa Agricultural Centre in paddock N7 was arranged in a fully randomised block design with four replications.

Forty medic entries were sown comprising breeding lines of spineless burr medic, the B-parent, current spineless burr medic cultivars Cavalier and Scimitar, Sultan-SU barrel medic, PM-250 strand medic and Toreador disc medic.

The trial was sown on 18 May 2020 into moist soil. Plant emergence counts were completed on 6 July. GreenSeeker measurements were taken on 26 August, 4 September and 19 October. Plots were scored for vigour on 4 September. Twenty four of the forty lines were selected for seed yield assessment. Seed was vacuum harvested from two x 0.10 m^2 quadrats per plot to measure seed yield.

What happened?

The season opened in late April with 25 mm of rainfall, enabling the trial to be sown into moist soil on 18 May 2020. Unfortunately, the rainfall for May, June and July was more than 50% below average, resulting in slow pasture establishment and growth (Table 1). August then received above average rainfall with October receiving more than double its average rainfall. This spring rainfall provided a significant boost in the growth of most of the medic species and enabled them to stay greener for longer than would be expected in a typical season, despite them already having flowered and set seed pods.

The boron tolerant parent line, and the cultivars Cavalier and Scimitar all established and grew well throughout the season, setting levels of seed that are considered adequate for regeneration. The boron tolerant parent had similar agronomic performance to the burr medic cultivars, with seed production equivalent to Scimitar. This suggests that the boron tolerant gene is not linked to negative agronomic traits that would need to be overcome with further breeding.

DL18 was the most promising of the boron tolerant lines, with growth throughout the season as good as the both the B parent and the cultivars. It also had a high pod yield (1462 kg/ha). DL17 also showed promise with good growth and a high pod yield (1234 kg/ha).

DL67 was the most promising of the RLEM lines with growth and seed set similar to the current burr cultivars.

Table 1. Plant density, green seeker scores, vigour scores and seed pod yields at Minnipa, 2020.

Pasture Legume Species		Plant density (plants/m²) 6 July	Green seeker (NDVI) 26 Aug	Green seeker (NDVI) 4 Sept	Vigour score (0-10) 4 Sept	Green seeker (NDVI) 19 Oct	Seed pod yield (kg/ha)
Boron parent burr medic	Boron tolerant line	60	0.23 c	0.29 bc	7.3	0.31 bc	1132 cd
Cavalier burr medic	Boron susceptible cultivar	69	0.26 bc	0.31 bc	7.6	0.30 bc	782 d
Scimitar burr medic	Boron susceptible cultivar	77	0.33 bc	0.40 ab	7.8	0.32 bc	1135 cd
DL03 burr medic	Boron line	86	0.23 bc	0.26 bc	7.4	0.25 c	855 cd
DL04 burr medic	Boron line	75	0.20 d	0.26 bc	6.8	0.25 c	859 cd
DL06 burr medic	Boron line	73	0.25 bc	0.29 bc	7.5	0.30 bc	882 cd
DL07 burr medic	Boron line	70	0.21 d	0.25 bc	7.3	0.33 bc	1102 cd
DL08 burr medic	Boron line	80	0.25 bc	0.30 bc	7.6	0.28 bc	922 cd
DL10 burr medic	Boron line	63	0.31 bc	0.35 b	7.5	0.32 bc	1048 cd
DL11 burr medic	Boron line	61	0.29 bc	0.34 bc	7.0	0.34 bc	1162 c
DL12 burr medic	Boron line	68	0.24 bc	0.31 bc	7.4	0.34 b	883 cd
DL14 burr medic	Boron line	65	0.28 bc	0.28 bc	7.4	0.28 bc	957 cd
DL15 burr medic	Boron line	90	0.32 bc	0.36 ab	7.9	0.30 bc	907 cd
DL17 burr medic	Boron line	57	0.24 bc	0.24 c	7.0	0.31 bc	1234 bc
DL18 burr medic	Boron line	71	0.34 b	0.37 ab	7.4	0.34 b	1462 bc
DL19 burr medic	Boron line	72	0.21 d	0.28 bc	7.3	0.28 c	862 cd
DL67 burr medic	RLEM line	74	0.27 bc	0.33 bc	7.4	0.33 bc	1038 cd
DL73 burr medic	RLEM line	69	0.30 bc	0.36 ab	7.6	0.31 bc	734 d
DL76 burr medic	RLEM line	51	0.25 bc	0.25 bc	7.4	0.27 c	573 de
DL78 burr medic	RLEM line	73	0.29 bc	0.33 bc	7.6	0.23 c	793 cd
DL79 burr medic	RLEM line	51	0.25 bc	0.27 bc	7.5	0.27 c	931 cd
Sultan-SU barrel medic	Control	67	0.29 bc	0.30 bc	7.6	0.25 c	1560 ab
PM-250 strand medic	Control	91	0.45 a	0.47 a	9.0	0.41 a	1937 a
Tornafield disc medic	Control	74	0.29 bc	0.33 bc	7.5	0.23 c	298 e
LSD (P=0.05)		-	*0.11*	*0.10*	-	*0.06*	*0.38*

Pastures

Sultan-SU barrel medic grew well and despite senescing earlier in the season than the spineless burr medics, had a high pod yield of 1560 kg/ha.

PM-250 strand medic had the highest GreenSeeker readings and vigour score and a seed pod yield of 1937 kg/ha. Although there were no quantitative measurements of biomass, the growth of PM-250 was visibly greater than that of the other medics and it could be easily recognised in each of the four replications of forty plots throughout the season, even after it had fully senesced.

Tornafield disc medic grew reasonably well throughout the season but set the lowest amount of seed with only 298 kg/ha of seed pods. Disc medics are specifically adapted to grow in sandy soils, rather than the red sandy loam in this trial, which may explain the low seed pod yield.

Table 1 reports pod yields collected through vacuum harvesting. Seed yields are yet to be measured, however typically seed yields are 50% of the pod yield for burr medics, 30% for strands, 25% for barrels and 40% for disc medics.

What does this mean?

The overall aim of this trial is to develop new spineless burr medic cultivar(s). There are promising lines in both the boron tolerant and RLEM resistant cohorts. The results of this trial will be reviewed along with the performance of the lines in trials at Roseworthy, WA and NSW. This evaluation is not complete and further trials are planned for 2021.

In 2021 the regeneration of the breeding lines will be assessed.

Acknowledgements

This project is supported by funding from the Australian Government Department of Agriculture Water and Environment 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: Minnipa grazing trial

Morgan McCallum[1], Jessica Gunn[1], Ross Ballard[2], David Peck[2]

[1]SARDI Minnipa Agricultural Centre, [2]SARDI Waite

Location
Minnipa Agricultural Centre paddock S8
Rainfall
Av. Annual: 324 mm
Av. GSR: 241 mm
2020 Total: 367 mm
2020 GSR: 255 mm
Paddock history
2019: Various legume species or Scepter wheat
2018: Various legume species or Scepter wheat
2017: Scepter wheat
2016: Medic pasture
Soil type
Red sandy loam
Soil test
$pH_{(H20)}$ (0-10 cm) 8.4
Plot size
2 ha x 3 reps

Key messages

- **Wheat grown on previous medic and alternative legume plots showed good grain protein results.**
- **Grain yield was not significantly different following various pastures but there were significant differences in grain protein.**

Why do the trial?

In southern Australian low to medium rainfall mixed farming systems there are many opportunities for pasture improvement. The Dryland Legume Pasture Systems (DLPS) project aims to boost profit and reduce risk in medium and low rainfall areas by developing pasture legumes that benefit animal and crop production systems. A component of the DLPS project aims to quantify the impacts of different pasture legume species on livestock production and crops in the rotation. Included are widely grown legumes (strand medics and vetch) and legumes with reasonable prospects of commercialisation (trigonella).

A five-year grazing and cropping system trial were established at the Minnipa Agricultural Centre (MAC) in 2018 (EPFS Summary 2019, p 222). 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, measuring pasture production, legume seed bank dynamics and animal and crop benefits from different pasture species was established in paddock South 8 at MAC in 2018. The trial consists of six treatments arranged in a randomised block design with three replications. The treatments are: Scepter wheat (Control 1); Volga vetch (Control 2), locally sourced Harbinger strand medic; PM-250 strand medic with powdery mildew resistance and tolerance to SU herbicide and intervix residues; SARDI rose clover; and Trigonella balansae, a new aerial-seeded legume closely related to medic. Each 'plot' is two hectares in size and was established to allow grazing during pasture phases and on stubbles after harvest in cropping years.

The planned rotational sequence for the five-year large-scale grazing trial aims to replicate current low to medium rainfall mixed farming practices, but also give novel pasture legumes the opportunity to successfully establish into the current system. Pastures were established in 2018 with the aim of maximising seed set, followed by pasture regeneration in 2019, a wheat crop in 2020, with a pasture regenerative phase in 2021.

In 2020 sowing occurred on the 13 May with the whole trial sown to Razor CL wheat at a sowing rate of 70 kg/ha and 50 kg/ha Granuloc Z. Soil sampling for nutrition, nitrogen and soil borne disease testing was completed on 30 March. The total rainfall for Minnipa this year was 367 mm with 255 mm falling within the growing season. The total rainfall for May was 20 mm which gave the trial a good start to the season. Plant emergence was measured on 6 June with all treatments showing good emergence. Ground cover (NDVI) was estimated using GreenSeeker commencing on 14 July (Figure 1, T1) and was repeated fortnightly until the crop started to ripen, with the last measurement on 9 September (Figure 1, T5). Grain was harvested with a small plot header on 18 November. Stubble cuts were collected after harvest and prior to grazing on 18 December and the sheep were put onto the trial to graze the wheat stubbles on 7 January 2021. Results for both of these measurements are yet to be analysed.

What happened?

Prior to sowing the wheat crop in 2020, the wheat treatment had the highest rhizoctonia level and the available soil N was at the lowest end of the treatment range (Table 1). There was no effect of treatment on wheat establishment density. Whilst there were treatment effects on wheat root health, they did not correspond to earlier differences in rhizoctonia level in the soil.

Table 1. Pre-sowing measures of soil N (0-60 cm) and Rhizoctonia AG8 levels, wheat establishment and wheat root health (0 = no damage).

2019 treatment	Available soil N (kg/ha)	AG8 Rhizoctonia (pg DNA/g)	Wheat establishment (plants/m²)	Wheat root health (0 - 5)*
Control (Scepter wheat)	124	107	78	2.2
Volga vetch	200	1	75	2.2
Harbinger strand medic	190	49	75	2.8
PM-250 strand medic	164	94	74	2.6
Trigonella balansae	210	49	72	2.8
SARDI rose clover	175	7	75	2.5
LSD (P=0.05)	*ns*	*21*	*ns*	*0.5*

** 0=healthy root, 5=severely damaged roots.*

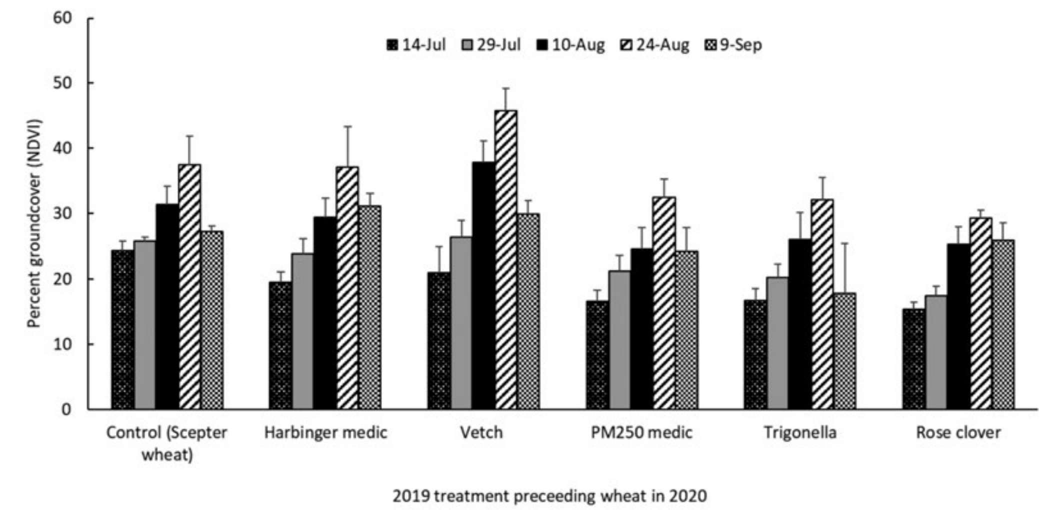

Figure 1. Percentage groundcover (NDVI Greenseeker) results for Razor CL wheat in 2020.

Ground cover (NDVI) when first measured on 14 July ranged from 24% for continuous wheat to 15% for the rose clover treatment (ns *P=0.12*). By the fourth assessment, NDVI of the pasture and continuous wheat treatments ranged from 29 to 37%, but had increased to 46% in the vetch treatment (*ns P=0.13*) (Figure 1).

There were significant differences across all six treatments for protein, test weight and screenings. The control continuous wheat showed results that were expected from a continuous cereal copping cycle (Table 2). The wheat grown following pastures generally had higher protein percentage and test weight and lower percentage screenings.

What does this mean?

In 2018, Harbinger strand medic and Volga vetch had the highest ground cover and highest early vigour (data not shown). They also had less weeds throughout the plots, which would have influenced the high yields observed this year due to less crop competition for moisture in the first year of the trial and less weeds also in 2019 and 2020. Harbinger strand medic also had a high plant density in 2019, resulting in a more productive plot for the cereal phase of the trial. In 2020 it was observed that wheat grown on the previous Volga vetch treatment emerged first, which correlates back to the ground cover and plant density results from 2018 and 2019 as this would establish good soil health for the wheat crop 2020. In 2019 trigonella, Harbinger strand medic and PM-250 fixed the highest percentage of nitrogen contributing to all three treatments producing high protein levels for wheat in 2020.

Ewes born in 2018 grazed the stubbles in early January and they grazed all treatments except the control treatment which is continuous wheat throughout the trial. The main aim of the grazing period is to record sheep weights. The results are yet to be analysed.

In 2021, the pasture treatments will be allowed to regenerate, with the continuous wheat and Volga vetch plots being re-sown. This will allow the legumes sown in 2018 a chance to show their ability to regenerate following a cereal phase. Sheep will graze the plots throughout the growing season and weights will be recorded on and off the trial. The continuous wheat plot will not be grazed.

Wheat yields are presented in Table 3, no significant differences were observed.

Table 2. Grain quality results. The treatments listed are those that were sown in 2018 and regenerated in 2019, with the grain quality results from the 2020 wheat.

Treatments	Protein (%)	Test weight (kg/HL)	Screenings (%)
Control (Scepter wheat)	10.20	77.03	4.46
Harbinger strand medic	11.95	79.71	3.08
Volga vetch	11.63	78.09	3.39
PM-250 strand medic	12.18	78.37	3.05
Trigonella balansae	12.20	79.19	3.55
SARDI rose clover	11.78	77.90	3.65
LSD (P=0.05)	*0.21*	*1.57*	*0.91*

Table 3. Grain yield for Razor CL wheat for each treatment of the Grazing trial in 2020.

2019 Treatment	Yield (t/ha)
Volga vetch	2.95
Control (Scepter wheat)	2.91
Harbinger strand medic	2.64
PM-250 strand medic	2.38
Trigonella balansae	2.18
SARDI rose clover	2.11
LSD (P=0.05)	*ns*

Acknowledgements

This project is supported by funding from the Australian Government Department of Agriculture and Water Resources 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. We gratefully acknowledge the help of Jake Hull, Wade Shepperd and John Kelsh for site set-up and management and the assistance of Steve Jeffs, Neil King and Katrina Brands for data collection, and the Waite team and Murdoch University team for data processing.

Dryland Legume Pasture Systems: pasture demonstration sites

Morgan McCallum[1], Jessica Gunn[1], David Peck[2] and Ross Ballard[2]

[1]SARDI Minnipa Agricultural Centre, [2]SARDI Waite

Location
Lock
Rainfall
Av. Annual: 340 mm
2020 Total: 322 mm
2020 GSR: 277 mm
Paddock history
2019: Medic
2018: Wheat
Soil type
Sandy loam
Plot size
2 m x 25 m x 2 reps

Location
Wirrulla
Rainfall
Av. Annual: 375 mm
2020 Total: 315 mm
2020 GSR: 293 mm
Paddock history
2019: Medic
2018: Wheat
Soil type
Calcareous grey sandy loam
Plot size
2 m x 25 m x 2 reps

Key messages

- **Grain protein, but not grain yield was significantly affected by the type of pasture legume previously grown.**
- **The findings will be used to prioritise further research and development of novel pasture species on sandy soils.**

Why do the trial?

Over the past three decades there has been a shift from integrated crop-livestock production to intensive cropping in dry areas, which has significantly reduced the resilience of farms in low to medium rainfall areas. Intensive cropping is prone to herbicide resistant weeds, large nitrogen fertiliser requirements, and major financial shocks due to frost, drought or low grain prices.

A pilot project with MLA and AWI in WA and southern NSW has demonstrated how novel pasture legumes such as serradella, biserrula and bladder clover can improve livestock production while reducing nitrogen requirements, weeds and diseases for following crops. The extent to which these new legumes establish, grow and persist on South Australia's alkaline sandy soils requires clarification.

The demonstration sites are primarily an extension tool, unlike research trials requiring detailed data collection. The purpose of these sites is to gather information on regional legume performance, including benefits to the crops that follow.

How was it done?

The demonstration trials were designed after discussions with local farmers at the Minnipa Agricultural Centre 2018/19 harvest meetings in several locations across upper Eyre Peninsula. It was decided that the two sites chosen should target challenging soil types (particularly sandy soil) for establishing and successfully growing legume pastures in the mixed farming environment. Cultivars were chosen based on recommendations from low to medium rainfall pasture experts, site locality and soil profile information, including recent soil tests undertaken.

<u>Site 1</u>

Lock, SA, (Kerran 'Gus' Glover)
Treatments established in 2019: Best bet variety demonstration - 2 reps x 10 treatments, 2 m x 25 m plots. The pastures were managed for maximum seed set, fenced off from grazing over summer and sown to Spartacus barley in 2020. Pasture treatments were:

- Casbah biserrula sown @ 5 kg/ha
- Toreador disc medic sown @ 7.5 kg/ha
- PM-250 strand medic sown @ 7.5 kg/ha
- Sultan-SU barrel medic 2.5 sown @ 2.5 kg/ha
- Sultan-SU barrel medic 10 sown @ 10 kg/ha
- Scimitar spineless burr medic sown @ 7.5 kg/ha
- Volga vetch sown @ 40 kg/ha
- SARDI rose clover & Bartolo bladder clover mix sown @ 3.75 kg/ha
- Volga (40 kg/ha) & Sultan-SU (10 kg/ha) mix
- Margurita French serradella sown @ 7.5 kg/ha

In 2020 on 8 May, the site was sown to Spartacus barley @ 60 kg/ha, with DAP @ 70 kg/ha and 1.8 L/ha glyphosate, 100 ml/ha oxyfluorfen, 2 L/ha trifluralin applied pre-sowing. Soil sampling for soil nitrogen and soil borne diseases occurred on 4 April. GreenSeeker and weed assessments were conducted on 18 August. The site was harvested on 17 November. Lock received a total of 322 mm rainfall for the year with 277 mm falling within the growing season.

Site 2

Wirrulla, SA, (Dion Trezona)

Treatments applied in 2019: Best bet variety demonstration - 2 reps x 10 treatments, 2 m x 25 m plots. The pastures were managed for maximum seed set, were fenced off from grazing over summer and sown to Scepter wheat in 2020. Pasture treatments were:

- Casbah biserrula sown @ 5 kg/ha
- Toreador disc medic sown @ 7.5 kg/ha
- Scimitar spineless burr medic sown @ 7.5 kg/ha
- SARDI rose clover & Bartolo bladder clover mix sown @ 3.75 kg/ha
- Margurita French serradella sown @ 7.5 kg/ha
- Boron tolerant DL11 sown @ 7.5 kg/ha
- PM-250 strand medic sown @ 7.5 kg/ha
- Sultan-SU barrel medic 2.5 sown @ 2.5k g/ha
- Volga (40 kg/ha) & Sultan-SU (10 kg/ha) sown @ 10 kg/ha
- Sultan-SU barrel medic 10 sown @ 10 kg/ha
- Volga vetch sown @ 40 kg/ha

On 21 May 2020, the site was sown to Scepter wheat with Granuloc Zinc DAP applied @ 60 kg/ha. Soil sampling for soil nitrogen and soil borne diseases occurred on 4 April. GreenSeeker, Canopeo (determines % area green) and weed assessments were conducted on 17 August. The site was harvested on 9 November. Wirrulla received a good amount of rainfall with an annual total of 315 mm and 293 mm of that falling within the growing season.

What happened?

In 2019, Volga vetch produced the greatest biomass on both soil types (calcareous grey sandy loam at Wirrulla and sandy loam at Lock). Pasture production at Wirrulla in general was low in 2019, with the biomass ranging from 0.80 t/ha Margurita French serradella to 3.23 t/ha Volga vetch. Seed pod set was noticeably low at the Wirrulla site due to a dry finish compared to the Lock site, where the PM-250 strand medic, Scimitar spineless burr medic and Casbah biserrula set the most pods. Overall, the majority of species at both sites produced adequate seed set for regeneration in 2021, following a cereal crop. At both sites in 2020 measurements including soil nitrogen, soil disease assessment and GreenSeeker analysis conducted throughout the growing season showed no differences between the treatments (data not shown).

The wheat and barley at Wirrulla and Lock showed consistent emergence (mean plants/m^2) across all pasture treatments, with no significant treatment differences observed. Cereal grain yields in 2020 ranged from 1.7 to 1.9 t/ha at Lock and from 1.0 to 1.2 t/ha at Wirrulla but there were no statistically significant differences between treatments.

Grain quality analysis was conducted for both sites and grain protein levels following the pasture treatments showed significant differences between treatments at both sites. At the Lock site, the average protein percentage ranged from 11.5% in the Volga vetch treatment to 10.5% for Scimitar medic (Table 2). At Wirrulla grain protein ranged from 11.6% in the PM-250 strand medic treatment to 10.8% in the Toreador disc medic.

Table 1. Grain yield of Spartacus barley (t/ha) at Lock and Scepter wheat (t/ha) at Wirrulla in 2020.

Lock		Wirrulla	
2019 Treatment	**Average yield (t/ha)**	**2019 Treatment**	**Average yield (t/ha)**
Casbah biserrula	1.88	Casbah biserrula	1.19
Toreador disc medic	1.85	Toreador disc medic	1.13
PM-250 strand medic	1.80	Scimitar spineless burr medic	1.12
Sultan-SU barrel medic 2.5	1.78	SARDI rose clover & Bartolo bladder clover mix	1.12
Scimitar spineless burr medic	1.78	Margurita French serradella	1.10
Volga vetch	1.78	Boron tolerant medic DL11	1.08
SARDI rose clover & Bartolo bladder clover mix	1.75	PM-250 strand medic	1.07
Sultan-SU barrel medic 10	1.73	Sultan-SU barrel medic 2.5	1.06
Volga & Sultan Mix	1.69	Volga & Sultan	1.06
Margurita French serradella	1.69	Sultan-SU barrel medic 10	1.06
		Volga vetch	1.04
LSD (P=0.05)	*ns*		*ns*

Table 2. Grain protein quality in 2020 from the Lock and Wirrulla sites.

Lock		Wirrulla	
2020 Treatment	**Grain protein (%)**	**2020 Treatment**	**Grain protein (%)**
Volga vetch	11.45 a	PM-250 strand medic	11.60 a
Sultan-SU barrel medic 10	11.20 ab	Volga Vetch	11.40 a
PM-250 strand medic	11.15 a	Boron tolerant medic DL11	11.35 a
Volga & Sultan Mix	11.15 a	Margurita French serradella	11.25 ab
Casbah biserrula	11.05 a	Sultan-SU barrel medic 2.5	11.20 ab
Margurita French serradella	11.0 a	Casbah biserrula	11.15 ab
SARDI rose clover & Bartolo bladder clover mix	10.95 ab	Sultan-SU barrel medic 10	11.15 ab
Toreador disc medic	10.75 ab	SARDI rose clover & Bartolo bladder clover mix	11.10 ab
Sultan-SU barrel medic 2.5	10.5 b	Scimitar spineless burr medic	11.10 ab
Scimitar spineless burr medic	10.5 b	Volga & Sultan Mix	10.95 ab
		Toreador disc medic	10.80 b
LSD (P=0.05)	*0.76*		*0.65*

What does this mean?

Grain protein content, but not grain yield was affected by the pasture treatment that proceeded the wheat crop. Wheat yield was not improved by biserrula, which produced inferior levels of dry matter production in 2019 (data not shown). Factors such as water availability, rather than pasture performance, were likely to have determined grain yield in this instance. Grain protein differences of about 1% were measured at both sites. At Lock, grain protein was highest following Volga vetch, which was the most productive species at that site, but otherwise grain protein was not obviously linked to previous legume production at either site. Whilst the trials indicate scope to improve grain protein by using pasture species aligned with the soil types, further work is needed to understand the transfer of N between the legume and crop phase.

In 2021 both sites will be left to regenerate back to their pasture species. This will provide critical information on the persistence of the sown legumes through a cereal crop and help select the best pasture prospects for future studies.

Acknowledgements

This project is supported by funding from the Australian Government Department of Agriculture and Water Resources 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 grower groups: Mingenew Irwin Group, Corrigin Farm Improvement Group, Asheep Esperance, Eyre Peninsula Agricultural Research Foundation, Upper North Farming Systems, Mallee Sustainable Farming, Lower Eyre Ag Development Association, Birchip Cropping Group, Farmlink, Central West Farming Systems. We would like to thank Kerran Glover and Dion Trezona for the use of their land for the demonstration sites and for assistance in broadacre management. We gratefully acknowledge the help of Ian Richter for site management, Neil King and Fiona Tomney for data collection, and the Waite team for data processing.

Evaluating annual pasture legume options and establishment methods for Mallee mixed farming

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Location
Waikerie
Schmidt Family
Rainfall
Av. Annual: 253 mm
Av. GSR: 164 mm
2020 Total: 323 mm
2020 GSR: 210 mm
Yield
Potential: Wheat (Yield Prophet®) 4.0 t/ha
Actual: 2.5 t/ha
Paddock history
2019: Barley
2018: Wheat
2017: Vetch/oats
Soil type
Red alkaline sand
Plot size
1.68 m x 32 m x 4 reps
Trial design
Experimental: randomised complete block with time of sowing as main plots and pasture species as sub plots
Yield limiting factors
Soil compaction at 40-60 cm

Location
Lameroo
Pocock family
Rainfall
Av. Annual: 382 mm
Av. GSR: 270 mm
2020 Total: 457 mm
2020 GSR: 343 mm
Yield
Potential: Wheat (Yield Prophet®) 6.0 t/ha
Actual: 6.0 t/ha
Paddock history
2019: Barley
2018: Wheat
2017: Wheat
Soil type
Deep sand (repellent surface)

Key messages

- **Field experiments located near Lameroo and Waikerie are evaluating establishment methods (Summer, Twin and Autumn sowing).**
- **French serradella, Rose clover and Bladder clover have demonstrated potential for summer and twin establishment methods but had low regeneration numbers following a dry establishment year at Waikerie.**
- **Further investigation is needed to define the conditions where Summer- and Twin-sowing practices are reliable, including weed management in non-grazed situations.**
- **Cereal break effects recorded at the Lameroo systems experiment were substantial in 2020 with more than 90% benefit from regenerating medic, producing an extra 2.9 t/ha of wheat yield.**

Why do the trial?

For mixed pasture-cropping farms, reliable pasture production and subsequent cereal break effects are critical to the uptake of improved pasture systems. Significant obstacles to the adoption of legume pasture species are the high cost of seed and the difficulty in successfully establishing pastures to provide early season production, 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 and 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 (with the proceeding crop) methods using unscarified 'hardseed' have shown promise (Revell *et al*., 2012), but these alternative establishment methods have had limited evaluation in south-eastern Australia. This project examines the potential of different pasture legume species to be established more efficiently, thereby providing growers with greater flexibility in moving between crop and pasture phases by avoiding clashes with peak crop sowing times, reducing establishment costs, increasing early season feed and the cropping sequence break effect. This work was introduced in an article in EPFS 2019 Summary, p 225.

How was it done?

Three establishment methods were evaluated at Lameroo in 2020 including legume pasture species/cultivars that have not been traditionally grown in the Mallee region (Table 1).

Plot size
1.68 m x 15 m x 4 reps
Trial design
Experimental: randomised complete block with time of sowing as main plots and pasture species as sub plots
Yield limiting factors
Soil compaction at 40-60 cm

The residual effects of these methods implemented in 2019 were measured at Waikerie in 2020. Growing season rainfall in 2020 was above average at both Lameroo with 343 mm (average 270 mm) and Waikerie with 210 mm (average 164 mm).

Establishment methods evaluated were: a) Twin-sowing, where 'hard' pasture seed/pod was sown with wheat seed in 2019 for 2020 pasture establishment; b) Summer-sowing, where 'hard' seed/pod was sown in February, which soften in autumn to establish on the autumn break; and c) Autumn-sowing (control treatment), where 'soft' seed was sown on the break of the season. Twin-sowing treatments were sown on 20 May 2019, Summer-sowing treatments were sown on 18 February 2020, and Autumn-sowing treatments on 28 April 2020. At each site, pasture establishment density and weed density was recorded in June, and at least two measures of biomass production were recorded. All legumes were inoculated with their specific rhizobia group using peat slurry applied at double the recommended rate. Granular inoculant (ALOSCA) was also sown with each legume at a rate of 10 kg/ha.

A pasture systems experiment was established at Lameroo in 2018 which included establishment of SARDI rose clover, Margurita French serradella, PM-250 strand medic and Trigonella 5045. In 2019 these pastures were allowed to regenerate and new treatments of rose clover, medic and serradella were sown. The residual 'break' effect of the first two years of pasture phases on subsequent wheat yield was measured in 2020. These treatments were compared against continuous cereal and 2019 grain legume (field pea and vetch) treatments. All experiments were set up in a randomised complete block design with 4 replicates (blocks) and analysed by ANOVA using Genstat version 20.

What happened?

Establishment Year 1 - Lameroo

At Lameroo the seasonal break (> 15 mm) occurred in the first week of April with 22 mm rainfall. Total rainfall prior to April was 106 mm. Sowing method had a significant effect on plant density (Table 2). Average plant establishment in Autumn sowing treatments was 72 plants/m^2, Summer sowing treatments was 29 plants/m^2 and Twin sowing treatments was 14 plants/m^2 (Table 2). The targeted population for sown pastures is typically 150-200 plants/m^2 so these numbers are well below the target. Average weed density across pasture treatments was highest in Summer sowing (13 weeds/m^2) and Twin sowing (8 weeds/m^2), compared to Autumn sowing (3 weeds/m^2). Average NDVI was highest in Summer sowing treatments, followed by Twin sowing treatments. This is due to a combination of a higher weed densities and greater pasture growth in these treatments. Though plant development was staggered with varying time of germination, plants in Twin sowing treatments of Trigonella, French serradella, medic and rose clover started to flower in mid-April.

Regeneration Year 2 - Waikerie

Prior to sowing wheat, pasture regeneration was counted as shown in Table 3. Medic plots had the highest regeneration while regeneration of other pasture species was generally very low, which may be due to low seed set in 2019 or the wrong level of hardseededness for the species x environment combination. Treatment differences in pasture dry-matter production were measured at Waikerie in 2019, despite production being limited by rainfall. Production was greatest for summer - and autumn - sown PM-250 strand medic. Although French serradella and rose clover produced more dry-matter when summer-sown, the overall production was lower, suggesting they were less well adapted. In May 2020 all plots were sown to wheat (cv. Scepter) on the 7/05/2020, with average wheat establishment of 133 plants/m^2. Pre-sowing soil mineral N (average 106 kg N/ha/m), soil moisture (average 68 mm/m) and early in-crop NDVI and wheat yield measurements were not significantly different between treatments. Pasture regeneration after 1-year of crop will be assessed in 2021.

Table 1. Sowing rates of pod or seed (kg/ha) in Twin and Summer sowing treatments and sown rate of germinable seed (kg/ha) in the autumn sown treatment.

Pasture Legume	Twin and Summer sowing (kg/ha)	Autumn sowing (kg/ha)
PM-250 strand medic	35 (pod)	8
Trigonella 5045	13 (seed)	5
Bartolo bladder clover	13 (seed)	8
SARDI rose clover	10 (seed)	8
Margurita French serradella	33 (pod)	8

Table 2. Measurements from establishment methods experiment at Lameroo, including pasture and broad leaf weed plant establishment density (03/06/2020) and NDVI (6/07/2020).

2020 Treatment	Pasture establishment (plants/m²)	Weed density (plants/m²)	NDVI
Autumn bladder	89	2	0.360
Autumn medic	51	3	0.309
Autumn rose clover	82	7	0.334
Autumn serradella	70	2	0.285
Autumn trigonella	67	3	0.314
Long fallow	0	8	0.512
Summer bladder	39	15	0.701
Summer medic	25	15	0.637
Summer rose clover	20	12	0.646
Summer serradella	22	17	0.642
Summer trigonella	32	8	0.681
Twin bladder	14	10	0.499
Twin medic	14	9	0.620
Twin rose clover	13	8	0.590
Twin serradella	21	7	0.546
Twin trigonella	6	8	0.568
Vetch	47	2	0.511
Wheat	100	1	0.366
LSD (P=0.05)	*14*	*6*	*0.073*

Table 3. 2020 season measurements from establishment methods experiment at Waikerie, including pasture regeneration (06/05/2020), wheat establishment (27/05/2020), NDVI (6/07/2020) and grain yield (t/ha).

2019 Treatment	Pasture regeneration (plants/m²)	Wheat establishment (plants/m²)	NDVI	Wheat grain yield (t/ha)
Autumn bladder	0	135	0.346	2.30
Autumn medic	189	125	0.359	2.31
Autumn rose clover	54	138	0.350	2.31
Autumn serradella	6	134	0.358	2.35
Autumn trigonella	39	128	0.375	2.50
Twin bladder	1	139	0.346	2.26
Twin medic	241	138	0.334	2.42
Twin rose clover	1	131	0.343	2.36
Twin serradella	0	134	0.335	2.49
Twin trigonella	0	138	0.324	2.38
Summer bladder	12	128	0.359	2.44
Summer medic	290	134	0.385	2.52
Summer rose clover	13	131	0.342	2.49
Summer serradella	4	132	0.378	2.53
Summer trigonella	0	129	0.354	2.34
Barley		123	0.371	2.22
Vetch		137	0.357	2.45
LSD (P=0.05)	*78*	*ns*	*ns*	*ns*

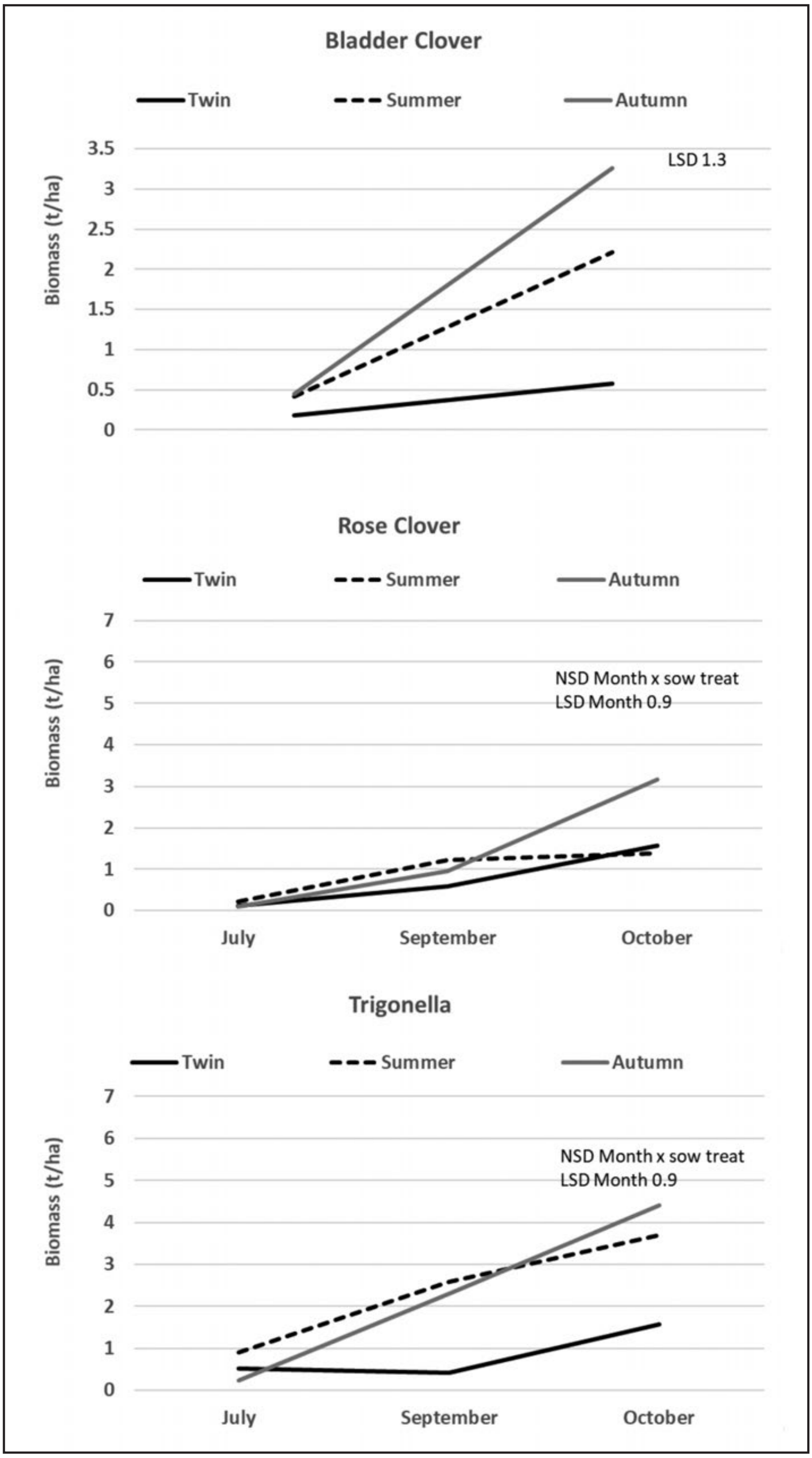

Figure 1: Biomass production of the sown pasture species (t/ha) in 2020 at Lameroo in the establishment treatments of Twin, Summer and Autumn Sowing. Within a pasture species the pasture biomass LSD for the month x sowing technique is shown on the figure (P=0.05).

Legume Biomass Production

There were considerable differences in biomass production at Lameroo for different pasture species x establishment method x time of year combinations (Figure 1). Production was greatest for summer - and autumn - sown PM-250 strand medic at all sampling times. Bladder clover produced more dry matter when twin-sown and was the second highest biomass treatment for this site x year combination. Rose clover and French serradella produced less biomass at all sampling times, suggesting they are less well adapted to Lameroo soils (Figure 1). Summer and autumn sown trigonella produced biomass that was in-between the high levels produced by medic and bladder clover and the lower levels produced by French serradella and rose clover. Weed management and competition from background medic remains a critical consideration with Twin- and Summer-sowing.

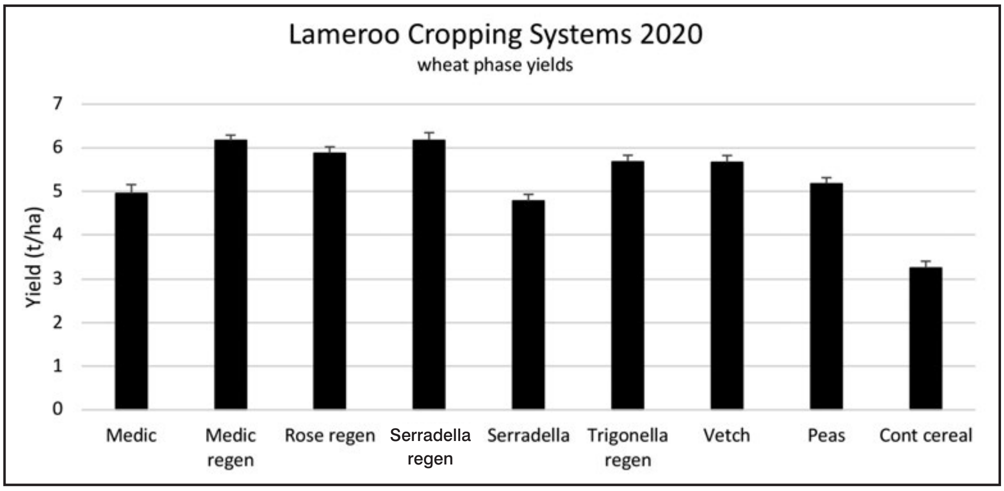

Figure 2: Wheat grain yield (t/ha) in 2020 following 2019 treatments of either sown or regenerating (regen) legumes compared against a continuous cereal control (LSD 0.38 at P=0.05).

There were significantly more broad-leaf weeds and background medic in the twin- and summer-sown plots compared to autumn-sown plots (data not shown) and weed competition in these non-grazed plots was an issue throughout the growing season.

Legume Break Effect

In the 2020 cropping season regenerating medic pasture benefits to subsequent wheat in the southern Mallee were in excess of 90% with up to 2.9 t/ha of extra wheat yield, while a single year harvestable legume option (vetch) offered a 2.4 t/ha benefit (Figure 2). The pastures that were regenerating in 2019 offered a significantly higher break effect than those that were sown in 2019 but all offered benefits in excess of 45% extra wheat yield.

What does this mean?

Legume species have a critical role to play for both pasture and cropping production on mixed farming operations in the Mallee environment. Alternative establishment methods have demonstrated potential in the Mallee, however they are not suitable for all pasture legume species and many are challenged in low rainfall environments such as Waikerie. There has not yet been a consistent advantage from the alternative establishment methods for a given pastures species across all sites. 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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Dryland Legume Pasture Systems: demonstrations on lower Eyre Peninsula

Andrew Ware

EPAG Research

Demonstration 1 - 2019
Location
Ungarra
Ben Pugsely
Rainfall
Av. Annual: 408 mm
Av. GSR: 316 mm
2019 Total: 269 mm
2019 GSR: 260 mm
Yield
5.1 t/ha dry matter
Paddock history
2018: Wheat
Soil type
Sandy clay
Plot size
12 m x 800 m
Trial design
Demonstration: 12 m air seeder non-replicated plots
Yield limiting factors
Nil
Livestock
Enterprise type: Lambs brought in to fatten
Type of stock/breed: Various

Demonstration 2 - 2019 Pastures/2020 Wheat
Location
Butler
Clinton Charlton
Rainfall
Av. Annual: 363 mm
Av. GSR: 278 mm
2019 Total: 269 mm
2019 GSR: 229 mm
2020 Total: 340 mm
2020 GSR: 263 mm
Yield
2019: 5.3 t/ha dry matter
2020: 2.9 t/ha wheat
Paddock history
2018: Barley
Soil type
Loam
Plot size
2 m x 10 m
Trial design
Complete randomised block design - 3 replicates x two blocks - sandy and heavy soil

Key messages

- **At Ungarra in 2019 vetch produced high volumes of high value pasture in a system aimed at producing feed for sheep purchased in spring.**
- **At Butler in 2019 a range of pasture species performed well on a loamy (heavier) soil type, but all species evaluated performed similarly on the sandier soil. This site had high levels of broadleaf weeds, suggesting that if new pasture species are to be successful then broadleaf control options must be part of a targeted agronomy package.**
- **Wheat planted across the 2019 pasture plots at Butler found no differences in yield or quality performance as a result of the 2019 pasture sown.**
- **A trial planted at Lipson in 2020 found no benefit in terms of biomass production and feed quality of planting pasture species in mid-May if a poor self-regenerating pasture establishes.**

Why do the trial?

- This article will report on findings from three pasture trials conducted on Lower Eyre Peninsula in the 2020 and 2021 growing seasons.
- These trials are part of the demonstration component of the Dryland Pasture Legume Systems (DLPS) project developed with the LEADA committee to answer several questions about how pasture performance could be improved in the region.

Demonstration 1:
Evaluation of pasture species to improve spring grazing in systems on Lower Eyre Peninsula.

Some growers on Lower Eyre Peninsula buy stock annually during spring to graze pastures before being turned onto crop stubbles, then sold in summer/autumn. Typically, vetch-based pastures are used for this, however there are no local comparisons to determine if this is the most appropriate species.

How was it done?

- Five unreplicated strips of differing crop species/mixtures were established at Ungarra using the grower's airseeder on 30 May 2019 after they had completed their seeding program. Each strip was approximately 1 ha. The pastures were sprayed to remove grasses and stock was introduced in September.
- The pasture species established were Volga vetch, Sultan-SU barrel medic, Margarita French serradella, Rasina vetch and Rasina vetch + Tillage radish.
- Soil tests were conducted prior to seeding the trial (see Table 1). Biomass cuts and feed value tests were undertaken prior to the stock being introduced.

What happened?

In this demonstration the biomass produced from the medic and serradella species didn't match the production from the vetch or vetch/tillage radish mixtures. Feed value tests also indicated that the quality of the feed in the vetch-based pastures was superior to the medic and serradella (Table 2).

Yield limiting factors
Broadleaf weeks
Livestock
Enterprise type: Sheep
Type of stock/breed: Various

Demonstration 2 - 2020 Pasture
Location
Lipson
Andrew Bates
Rainfall
Av. Annual: 309 mm
Av. GSR: 235 mm
2020 Total: 317 mm
2020 GSR: 279 mm
Yield
2020: 3.8 t/ha dry matter
Paddock history
2019: Wheat
Soil type
Loamy Sand - loamy clay
Plot size
2 m x 10 m
Trial design
Complete randomised block design - 3 replicates x two blocks - sandy and heavy soil
Yield limiting factors
Broadleaf weeks
Livestock
Enterprise type: Sheep
Type of stock/breed: Various

What does this mean?

- From this demonstration vetch pasture appears to be more productive than medic and serradella and better suited to this type of farming system.
- Adding the tillage radish to the seeding mix, in this instance appeared to produce at least equivalent biomass of similar/ better feed value.
- It should be noted that as this demonstration was sown without replication of seeding strips, scientifically valid interpretation of relative difference between treatments isn't possible.

Demonstration 2:

What is the best pasture species/ mix of species to plant in paddocks with differing soil types?

Background: Paddocks across the region often have soil types that vary; i.e. changing from heavier flats to sandier rises, with pH varying from below 6 to above 8 (Table 3). Getting pasture species established and maintaining good production levels across this landscape is often challenging.

How was it done?

These trials, in the Butler area, investigated which pasture species was best able to perform on differing soil types, by sowing two replicated pasture species in different parts of the same paddock, one on a sandy rise and one a heavier flat. A total of 16 pasture species/ mixes were sown in each of the trials. The pastures were sown in 2019, with the same plots oversown to wheat in 2020. Establishment counts and peak biomass cuts were taken from the pasture species in spring, 2019, grain yield and quality were measured in 2020.

Analysis of collected data was undertaken using Genstat 18.

Table 1. Soil test results - pre-sow 2019 at Ungarra, 2019.

Depth	Texture	pH (water)	pH ($CaCl_2$)	OC (%)	P (Cowell)	PBI
0-10	sandy clay	6.9	6.2	1.94	46.1	32.2
10-30	sandy clay	7.3	6.6			
30-60	sand	9.2	8.2			
60-90	sandy loam	9.5	8.4			
90-150	loamy sand	9.6	8.6			

Table 2. Emergence, dry matter, and feed quality of different pasture species at Ungarra, 2019.

Pasture species	Emergence plants/m²	Dry Matter t/ha	Crude Protein % of DM	Acid Det. Fibre % of DM	Net. Det. Fibre % of DM
Vetch - Volga	35	4.68	30.4	26	36.8
Sultan-SU barrel medic	60	2.34	23.9	21.9	37.8
Margarita French serradella	67	1.58	18.6	22.6	43.6
Rasina vetch	35	3.19	30.5	25.1	35.8
Rasina vetch + (Tillage radish)	30 (7)	5.11	26.9	22.3	33.9
Pasture species	**Digestibility (DMD) (% of DM)**	**Digestibility (DOMD) (% of DM)**	**Est Met. Energy (MJ/kg DM)**	**Fat (% of DM)**	**Ash (% of DM)**
Vetch - Volga	73.8	69.4	11.1	4.4	11.6
Sultan-SU barrel medic	70.8	66.8	10.6	4.2	11.1
Margarita French serradella	63.9	60.9	9.4	3.8	11.2
Rasina vetch	75.0	70.3	11.3	4.4	11.8
Rasina vetch + Tillage radish	79.5	74.2	12.1	4.3	10.7

Table 3. Soil test results – pre-sow 2019 and 2020 at Butler.

Soil Depth (cm)	2019						2020			
	Texture	Phosphorus (Colwell) (mg/kg)	PBI (Colwell P corrected)	pH (1:5 water)	pH (1:5 $CaCl_2$)	OC (W&B) (%)	Available N 0-60cm (kg/ha)	Available N 0-60cm Biserrula (kg/ha)	Available N 0-60cm Vetch (kg/ha)	Available N 0-60cm Sultan Medic (kg/ha)
Heavy 0-10	clay loam	60.9	33	7.4	6.9	1.03	120.0	88.0	103.0	92.0
10-30	light clay			8.8	8.0					
30-60	light clay			9.4	8.3					
Sandy 0-10	loamy sand	26.3	9	7.0	6.7	0.74	83.0	66.0	78.0	73.0
10-30	sandy clay			8.8	8.0					
30-60	loamy sand			9.0	8.1					

Table 4. 2019 Establishment and biomass yields from Butler pasture trials.

Variety/ species	Heavy Flat			Sandy Rise		
	Establishment (plants/m²)	Biomass (t/ha)	Ungrazed	Establishment (plants/m²)	Biomass (t/ha)	Ungrazed
Bindaroo button medic	30	1.06	1.50	25	4.03	5.34
Sultan-SU barrel 2.5	51	1.09	2.36	15	2.47	3.48
Bartolo bladder clover	43	1.31	2.20	41	3.31	3.88
SARDI rose clover	37	1.38	2.86	29	1.80	4.94
Clover	60	1.55	2.44	43	3.50	2.22
Biserrula 5	59	1.61	2.30	29	1.52	1.24
Scimitar spineless burr medic	84	1.86	1.70	53	3.53	3.56
Margurita French serradella 7.5	131	2.00	3.60	89	2.95	4.82
Casbah biserrula	28	2.02	2.04	47	3.13	3.58
Prima gland clover	66	2.03	1.46	41	2.37	4.30
Toreador disc medic 7.5	59	2.23	3.40	53	2.81	3.62
Timok vetch	37	2.25	3.74	50	3.28	5.10
Sultan-SU barrel medic 10	84	2.50	3.26	59	2.48	5.58
Sultan-SU 10 + Vetch 10	84	2.55	3.88	53	2.81	4.16
PM-250 strand medic	106	3.24	3.00	52	2.95	4.04
Vetch 40	64	3.53	4.74	37	3.24	4.70
LSD (P=0.05)		*1.04*			*ns*	

What does this mean?

On the heavier soil type the growth of the well-established vetch and medic species produced improved pasture production, in terms of biomass production, over some of the newly evaluated species.

The sandy site showed no significant benefit of growing any one species over any other, indicating that none of the evaluated species has specific adaptation to this soil type. While there was no significant benefit in growing any one species on the sandier soil type there was also no reduction in biomass production through choosing the worst performer either.

Capeweed grew well in this environment, and particularly well on the sandier soil type, indicating that an adapted pasture species needs to have herbicide tolerance to a product that will allow the control of this weed and possibly other broadleaf weeds.

Soil testing for mineral N levels conducted prior to the 2020 growing season found that Nitrogen levels were slightly higher on plots where vetch was planted in 2019 than where medic was planted.

Table 5. 2020 wheat grain yield and quality following 2019 pasture.

2019 Pasture Species	Heavy Flat				Sandy Rise			
	Wheat Yield (t/ha)	Protein (%)	Test Weight (kg/hl)	Screenings (%)	Wheat Yield (t/ha)	Protein (%)	Test Weight (kg/hl)	Screenings (%)
Bartolo bladder clover	2.01	10.9	78.6	1.5	2.82	10.9	78.6	1.5
Bindaroo button medic	2.01	10.7	78.7	1.4	2.72	10.7	78.7	1.4
Biserrula 5	2.24	12.1	78.2	1.3	2.52	12.1	78.2	1.3
Casbah	2.03	11.4	78.6	1.6	2.70	11.4	78.6	1.6
Clover	2.27	12.4	78.0	1.2	2.52	12.4	78.0	1.2
Margurita biserrula 7.5	2.17	12.7	77.9	1.4	2.18	12.7	77.9	1.4
PM-250 strand medic	2.24	12.9	77.5	1.1	2.21	12.9	77.5	1.1
Prima gland clover	2.00	11.0	78.9	1.5	2.70	11.0	78.9	1.5
SARDI rose clover	2.23	11.0	78.6	1.4	2.66	11.0	78.6	1.4
Scimitar spineless burr medic	2.07	12.3	78.3	1.3	2.55	12.3	78.3	1.3
Sultan-SU barrel medic 10	2.20	12.9	78.1	1.0	2.38	12.9	78.1	1.0
Sultan-SU 2.5	2.21	12.8	77.8	1.3	2.44	12.8	77.8	1.3
Sultan-SU vetch	2.16	12.3	78.3	1.5	2.20	12.3	78.3	1.5
Timok vetch	2.03	10.9	78.8	1.5	2.85	10.9	78.8	1.5
Toreador 7.5	2.13	12.7	77.8	1.2	2.34	12.7	77.8	1.2
Vetch 40	2.14	12.5	78.4	1.0	2.58	12.5	78.4	1.0
LSD (P=0.05)	*ns*				*ns*			

Table 6. 2020 Pre-sowing soil tests, Lipson.

Site	Texture	Phosphorus (Colwell) (mg/kg)	OC (W&B) (%)	pH (1:5 water)	pH (1:5 $CaCl_2$)	Available N 0-60 cm (kg/ha)
Hill	Loam	31	1.17	6.6	7.5	89.6
Flat	Loam	30	0.6	5.9	6.8	67.2

Table 7. Plant establishment and biomass production, Lipson 2020.

Species	Variety	Emergence (plants/m^2)		Early Biomass 5 July (t/ha)		Spring biomass 11 Sept (t/ha)	
		Flat	Rise	Flat	Rise	Flat	Rise
Medic	Sultan-SU barrel	45	35	0.89	0.49	1.50	1.45
Vetch	Timok	46	44	3.11	2.30	3.31	3.11
Serradella	Margarita French	54	39	0.48	0.43	1.33	1.71
Regenerated (medic)		32	27	3.81	3.67	3.38	2.14
LSD (P=0.05)				*0.72*	*0.69*	*0.58*	*0.61*

Pastures

Table 8. Feed quality from September biomass cuts, Lipson, 2020.

	Flat				Rise			
	Margarita	Sultan	Re-gen	Timok	Margarita	Sultan	Re-gen	Timok
Crude Protein (%)	20.2	16.5	12.7	16.7	18.8	15.9	13.3	17.1
Acid Detergent Fibre (%)	24.6	30.1	27.6	30.6	22.2	30.6	25.1	32.6
Neutral Detegent Fibre (%)	41.5	45.2	44.1	41.9	43	48.3	42.2	44.8
Digestibility (DMD) (%)	70	65.8	67.4	71	65.4	61.6	69.4	67
Digestibility (DOMD) (%)	66.1	62.5	63.9	67	62.2	59	65.6	63.6
Est Met. Energy (MJ/kg DM)	10.4	9.7	10	10.6	9.6	9	10.3	9.9
Fat (%)	3.9	3.6	3.7	3.7	3.7	3.5	3.5	3.6
Ash (%)	5.7	3.4	5.3	6.2	8.1	3.5	4.1	6.5

Demonstration 3:

Regenerating species

Why do the trial?

Typically, some pasture paddocks relying on regenerating species experience poor establishment, resulting in unproductive paddocks for the remainder of the season. Sometimes it is difficult to forecast when a paddock will establish poorly and it can be 3 weeks after the break in the season when this can be determined. If a regenerating pasture paddock has poorly established, is it more profitable to spray off and re-sow a pasture or let what has come up continue?

What was done?

The trial site was selected at Lipson, 305 mm average annual rainfall, in a paddock where regenerating pasture establishment has been less than satisfactory three weeks after the break in season, all germinating plants were removed with a knock-down herbicide. Plots of medic (cv Sultan-SU), vetch (cv Timok), and serradella (cv Margarita French) were sown in two differing soil types in the same paddock on 14 May, 2020. Each pasture species block consisted of 5 x 2 m x 10 m blocks of plots, replicated three times in each of the heavy and sandier soil types. A further plot of self-regenerating pasture (left upsprayed) was also included in a randomised complete block design. Establishment, early biomass, late biomass, and feed value will be measured. This will be over-sown with wheat in 2020.

What does this mean?

While the self-regenerating pasture appeared at both sites in the paddock to have experienced very poor establishment and didn't appear very productive in mid-May, dry matter production and feed quality were of similar quality (measured in July and September) to the pastures that were sown in mid-May.

Acknowledgements

Gary Miller, Mark Saunders, and Ashley Flint of EPAG Research for their technical assistance. Ben Pugsley and family, Clinton Charlton and family for providing the land for the trials.

Identifying improved pasture legume options for the Victorian Mallee

Roy Latta and Michael Moodie
Frontier Farming

Location
Piangil, Eastern Mallee, VIC
Rodney Hayden
Rainfall
Av. Annual: 300 mm
Av. GSR: 210 mm
2019 Total: 235 mm
2019 GSR: 187 mm
Yield
Potential: 50 kgDM pasture/mm plant available water = 5-10 tDM/ha
Actual: Annual medic 4.7 tDM/ha on 100 mm
Paddock history
2019: Wheat
Soil type
Sandy loam over clay
Soil test
0-10 cm; pH 7.7 $CaCl_2$ SOC 0.6%, EC 0.11 dS/m, Colwell P 9 mg/kg
10–100 cm; pH 8 – 8.5 $CaCl_2$, EC 0.13-0.46 dS/m
Plot size
11 entries x 3 replicates, 18 m x 1.68 m plots
Livestock
Enterprise type: Multipurpose hay, grain graze

Location
Speed central Mallee, VIC
Munro Bros.
Rainfall
Av. Annual: 337 mm
Av. GSR: 223 mm
2019 Total: 416 mm
2019 GSR: 276 mm
Yield
Potential: 50 kgDM pasture/mm plant available water = 5-10 tDM/ha
Actual: Serradella 7.6 tDM/ha on 175 mm
Paddock history
2019: Wheat
Soil type
Deep sand over sandy clay loam

Key messages

- **Serradella provides a productive multi-purpose legume option sown with farm produced seedpod segments on soils where lupins have been grown successfully in the Mallee.**

Why do the trial?

To understand the regional adaptation, seed harvestability and crop benefits provided by different pasture legumes. The 2020 trials were part of an ongoing study that has previously identified serradella as a well-adapted productive break crop on Mallee slightly acidic to mildly alkaline, deep sands. The studies have found that serradella seedpod segments can be sown up to 12 months prior to the pasture phase (EPFS 2016 Summary, p 155 and 2019, p 230). However, on-farm seedpod harvesting and further testing of their subsequent establishment need to be demonstrated to help support the commercial uptake of a serradella package.

How was it done?

Two new trials were established in 2020, Trial 1 on an alkaline sandy loam at Piangil (23 April) and Trial 2 on a slightly acidic deep sand at Speed (17 April). They measured legume establishment (plants/m^2), productivity (from cut and dried quadrats), maturity (flowering date), harvested seed yields (plot header) and seed left behind (post-harvest quadrat sampling). The legume entries are presented in Tables 1 and 2.

Seeding rates were based on germination tests and seed size to achieve plant densities that would support similar early biomass production. In Trial 1 the trigonella, bladder and rose clover targeted plant densities were 300 plants/m^2, annual medics, serradella and astragalus 200 plants/m^2 and vetch 30 plants/m^2. In trial 2 the same seeding rates were used, apart from the annual medic pod aimed at 100 plants/m^2 and vetch 45 plants/m^2.

Trials were sown with 50 kg of Granulock Z MAP fertiliser. All legume species were inoculated with their specific rhizobia group. Both sites received a grass selective herbicide with an insecticide included in July. The Piangil site had broad-leaf weed control with Broadstrike applied to all but the vetch and astragalus entries, they and all Trial 2 plots were hand weeded. Site 1 Piangil had glyphosate applied to increase rate of senescence on 12 November in preparation for machine harvest on 9 December, and at Speed on 11 December.

A third trial fully described in EPFS 2019 Summary, p 230 was sown to wheat on 28 April 2020. It produced grain yields in response to the 2019 sown legumes, including serradella, annual medic and green manured vetch. Where measurement comparisons were applicable ANOVA's were completed as fully randomised blocks using Genstat 5.

Soil test
0-10 cm; pH 6.4 $CaCl_2$ SOC 0.37%, EC 0.075 dS/m, Colwell P 20 mg/kg
10-100 cm; pH 8.1 - 8.2 $CaCl_2$, EC 0.11-0.146 dS/m
Plot size
7 entries x 3 replicates,
8 m x 1.68 m plots
Livestock
Enterprise type: Multipurpose hay, grain graze

What happened?

The Piangil trials received approximately 80% of their average annual and growing season rainfall with a dry (27 mm) May to July period. The Speed trial approximately 125% of growing season and annual rainfall and no periods of deficiency.

The annual medics were well adapted to the alkaline sandy loam soil type with similar or higher total biomass production than all other entries. Compared to vetch only the bladder clover with low plant density had less total September biomass.

Although Jaguar and Cheetah were observed to retain more pod on the vine than the other medic entries, their canopy height was insufficient for successful header pod collection. The bladder clover and astragalus produced high seed yields but the seed was not available to the header due to lack of biomass and/or height. The rose clover seed heads were collected by the header but due to low unit weight were lost straight over the straw walkers.

The serradella and trigonella, with their more erect growth habits, allowed 30% of total seed production to be collected by the header. The header with crop lifters attached and belt delivery collected more than 80% of the total vetch seed yield.

Table 1. Legume entries, establishment (plants/m²), total biomass (tDM/ha), machine harvested and post-harvest plot retained seed (kg/ha) for Trial 1 at Piangil (sandy loam).

Entries	Variety	10 May (plants/m²)	8 September (tDM/ha)	Seed yield (kg/ha)	
				Harvest	Retained
Vetch	Volga	21	3.1	1200	260
Strand medic	PM 250	135	4.2	0	680
Strand medic	Jaguar	201	3.6	30	620
Barrel medic	Sultan-SU	130	3.3	0	640
Barrel medic	Cheetah	131	4.7	20	640
Burr medic	Scimitar	140	3.9	0	690
French serradella	Margurita	153	2.7	220	440
Bladder clover	Bartolo	90	1.5	10	860
Trigonella	SA-5045	384	2.5	120	220
Astragalus	Ioman	146	3.2	0	860
Rose clover	SARDI	143	2.5	10	390
LSD (P=0.05)			*1.46*		

Table 2. Legume entries sown as seed or seedpod, establishment numbers (plants/m²), total biomass (tDM/ha), machine harvested and post-harvest plot retained seed (kg/ha) for Trial 2 at Speed (deep neutral sand).

Entries	Variety	4 May (plants/m²)	16 October (tDM/ha)	Seed yield (kg/ha)	
				Harvest	Retained
Vetch	Volga	45	7.1	2200	820
Strand medic	PM 250 seed	165	4	0	1500
Strand medic	PM 250 pod	77	4.9	0	1690
french serradella	Margurita seed	199	7.5	1030	800
French serradella	Margurita and Eliza pod	154	7.6	990	800
Rose clover	SARDI seed	193	3.5	0	600
Rose clover	SARDI pod	83	3.1	0	700
LSD (P=0.05)			*2.43*		

Table 3. 2019 legume entries and biomass (tDM/ha), and subsequent 2020 wheat yields (t/ha) and grain protein content (%).

2019 Entries	Variety	(tDM/ha) 2019	Wheat yield (t/ha)	Protein (%)
			18 November 2020	
Vetch*	Volga	2.5	2.68	12.7
Barley	Spartacus	3.1	1.80	10.7
Strand medic	PM-250	2.0	2.53	12.2
French serradella	Margurita	1.6	2.79	12.3
Bladder clover	Bartolo	1.6	2.68	12.1
Trigonella	SA 5045	1.2	2.77	12.2
Rose clover	SARDI	1.9	2.76	12.3
LSD (P=0.05)		*0.38*	*0.13*	*0.25*

** Green manure treatment August 2019.*

The vetch established at 100% its potential density, the medic and serradella pods at 75% versus 80 and 100% for their respective seed. The rose clover at 30% establishment when sown as unprocessed seed was not disadvantaged in biomass or seed yield. The serradella produced more biomass than the annual medic or rose clover and similar to the vetch. More than 50% of the serradella seedpod was collected by the harvester, 70% of the vetch.

Wheat yield and protein content was lower following 2019 barley than all other treatments. The wheat yield following the PM-250 strand annual medic was lower than following the other legume entries irrespective of the annual medic producing similar or higher biomass than all other entries in 2019. Grain protein contents following the legumes were similar, apart from the 2019 green manured vetch being higher. However, the vetch does not provide a direct variety comparison as it is an August 2019 green manure treatment compared to the other treatments being maintained through to maturity.

2020 data not presented in Table 3 include pre-seeding total soil N and soil water content (0 - 100 cm). The total N trial mean 100 kgN/ha was an increase from approximately 55 kgN/ha at the commencement of the trial. Soil water means of all treatments showed a 5 mm reduction over growing season. Statistically both sets of results were similar at the 5% level.

SARDI DLPS research team at Piednippie/Wirrulla demonstration site, 2020.

What does this mean?

If the success of the alternative legume is as a one-year pasture phase then their establishment, total production and seed harvestability comparison with vetch is the key. Supporting their prospective value are the wheat yields comparison in response to the 2019 legume options. To assess the success of the alternative legumes to persist over a cropping phase the continuation of the study into 2021 will provide regeneration data.

Entries established at 30 to 100% of projected levels, from seed or seedpod, but there was no perceived disadvantage in low plant densities in total production or seed yield most likely due to early season rainfall and time of sowing. Serradella was the only entry which produced comparable biomass and flowering dates to the "early season" vetch variety Volga at both sites. However, it falls short in an annual medic comparison being less productive on the alkaline soils. In terms of harvesting success vetch, serradella and trigonella produced seed yields. Based on 1000 grain weights, vetch 60 grams, serradella 3 grams and trigonella 1.5 grams approximately 10 times more seed numbers of serradella and trigonella were harvested than the vetch. Harvested serradella provided seedpod for potentially sowing 100 hectares at 10 kg/ha, from each hectare harvested from Trial 2 at Speed, as did the vetch, 100 hectares at 22 kg/ha.

This study continued to support serradella as a multi-purpose (forage, hay, seed) option on deep Mallee sands where lupin has been grown successfully. However, this and previous local studies have shown no clear benefit over vetch in productivity, only in the flexibility in the timing of seeding. As an alternative to the annual medic self-regenerating ley farming system, serradella provides an opportunity for on-farm seed supply and possibly improved productivity on the acidic to mildly alkaline deep sands. Adequate hard seed able to regenerate following a cropping phase, as is the case with annual medic, is uncertain

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Section Editor:
Morgan McCallum and Jessica Gunn
SARDI Minnipa Agricultural Centre

Section 9

Livestock

Maternal melatonin implants improve twin Merino lamb survival

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Location
Minnipa Agricultural Centre
Livestock
Enterprise type: research farm
Stocking rate: 10 ewes/hectare
Type of stock: Sheep, Merino

Key messages

- **High pre-weaning mortality rates are a persistent problem for Australian sheep producers, with minimal improvement seen over the past four decades.**
- **Losses are far greater in twin lambs vs. singletons due to lower birthweight and greater prevalence of prolonged/difficult birth.**
- **Results from intensive medical research over the past decade indicate that melatonin may be beneficial for lambs experiencing compromised pregnancies or prolonged birth.**
- **In our early intensive trials, supplementing twin-bearing Merino ewes with melatonin, either orally or via slow-release implant, improved twin lamb survival to weaning by 12-15%.**
- **The present study examined the effect of treating pregnant ewes with melatonin implants on survival of twin lambs under extensive grazing conditions, and we observed a similar degree of improvement as reported previously (15% above control).**

Why do the trial?

The aim of this trial was to investigate whether supplementing pregnant twin-bearing ewes with one or two melatonin implants at gestational days (d) 70-90 improves lamb survival under field conditions.

High pre-weaning mortality rates cost the Australian sheep industry an estimated $540 million annually in lost production, with losses significantly greater in twin (≥30%) compared with singleton lambs (≥10%). Around 50% of lamb deaths are due to prolonged/difficult birth, with underweight lambs at greater risk of early death. Previous intensive studies demonstrated that supplementing pregnant ewes with melatonin reduces adverse effects of fetal growth restriction and oxygen deprivation on the newborn brain via increased umbilical blood flow, placental efficiency, and antioxidant actions. This was supported by our early intensive trials where supplementing twin-bearing Merino ewes with melatonin, either orally or via slow-release implant, improved twin lamb survival to weaning by 12-15%. The present study examined the effect of supplementing Merino ewes with melatonin implants on the survival of twin lambs under extensive grazing conditions.

How was it done?

Mixed aged Merino ewes (1.5-5.5 years old) were naturally mated with Merino rams for a six week period commencing 1 February 2019. Fetal number and age were determined via ultrasound 70 d after the start of mating, and twin-bearing ewes were selected for inclusion in this trial. Fetal ageing was used to classify ewes as either 'early mated' (pregnant in first cycle) or 'late mated' (pregnant in second cycle). Ewes were stratified on the basis of age, weight, body condition score, mating group, and fetal age, and randomly allocated into three equal treatment groups, which received 0 control (CTL), 1 (M1), or 2 (M2) implants containing 18 mg melatonin (Regulin). Implants were injected subcutaneously at the base of the ear in accordance with manufacturer's instructions, and were administered to 'early mated' and 'late mated' ewes 90 or 107 d after the start of the mating period, respectively. Implant timing was determined such that all ewes received melatonin in the same time range relative to their individual mating (gestational d 70-90).

Ewes were monitored twice daily throughout the lambing period. Lamb survival, weight, and rectal temperature were recorded on the day of birth. Lamb blood samples were taken the following day for serum immunoglobulin G (IgG) analysis as a marker of maternal immune transfer via colostrum consumption. Lamb survival and weight were recorded again at marking (30.6 ± 0.6 d post-birth) and weaning (70.7 ± 0.6 d post-birth). Autopsies were conducted wherever a lamb carcase was found to determine cause of death. Lambs absent at marking or weaning, but for which no carcase was found, were classified 'undiagnosed'.

All data were analysed using SPSS Statistics (version 25). Effects of treatment on lamb survival at each time point were analysed by chi-squared test. Causes of lamb death were analysed by Fisher's exact test. Linear mixed models were used to analyse lamb weights, rectal temperature, and serum IgG with fixed effects of treatment and sex, and random effects of dam ID and sire ID. Probability values <0.05 were considered significant ($P < 0.05$).

What happened?

The proportion of lambs born alive was greater in both M1 and M2 compared with CTL (each $P<0.05$, Table 1), as was the proportion of lambs alive at each time point up to and including weaning (all $P<0.05$). The proportion of lambs that died of birth-related causes (dystocia, stillbirth, or birth injury) was greater in CTL than either M1 or M2 (each $P<0.05$, Table 1). Most lamb deaths across all treatments were attributed to starvation/mismothering, with a low incidence of death by cold exposure. There were no treatment effects on lamb weight at birth, marking, or weaning. Similarly, treatment did not affect lamb rectal temperature or maternal immune transfer.

Table 1. Effects of melatonin treatment on lamb survival from birth to weaning (expressed as % of lambs born) and causes of death (expressed as % of lambs born). 1 (M1), or 2 (M2) implants containing 18 mg melatonin (Regulin). Implants were injected subcutaneously at the base of the ear.

	Treatment			
Survival (%) at:	**Control (n=108)**	**M1 (n=100)**	**M2 (n=106)**	***P-value***
Birth	93.5[a]	100.0[b]	99.1[b]	*0.005*
3 d post-birth	83.3[a]	99.0[b]	95.3[b]	*<0.001*
7 d post-birth	81.5[a]	97.0[b]	93.4[b]	*<0.001*
Weaning	79.6[a]	94.0[b]	92.5[b]	*0.002*
Causes of death (%):				
Birth-related	6.5[a]	0.0[b]	0.9[b]	*0.007*
Starvation/mismothering	10.2	4.0	5.7	*0.202*
Primary cold exposure	0.9	0.0	0.9	*1.000*
Undiagnosed	2.8	2.0	0.0	*0.287*

Values with differing superscripts vary significantly within row ($P<0.05$).

What does this mean?

To the best of our knowledge, the current data provide the first evidence that maternal melatonin supplementation during the second half of pregnancy can improve twin lamb survival in flocks lambing under field conditions. This difference cannot be attributed to any change in fetal growth, as melatonin treatment did not affect lamb birthweight; nor did it affect growth rate, rectal temperature, or maternal immune transfer. The fact that postnatal vitality markers were similar between treatments, together with treatment differences in timing and causes of death, offers a strong indication of when and how melatonin primarily influenced lamb survival. The proportion of birth-related deaths in CTL lambs was consistent with that reported previously, but these causes were almost eliminated in both M1 and M2 groups. This contributed to a marked increase in overall survival to weaning in both melatonin-treated groups, which suggests that melatonin improved lamb survival primarily via neuroprotection.

There is a substantial body of evidence validating the beneficial effects of melatonin treatment during acute oxygen deprivation in lambs, but how this translates to prolonged/difficult birth and newborn vitality has only been recently investigated. In studies on lambs exposed to acute oxygen deprivation via umbilical occlusion at birth, melatonin significantly reduced cell death in white and grey brain matter at three days after birth. This was reflected in marked behavioural improvement compared with untreated lambs, specifically reduced latency to stand and suckle after birth, greater proportion of lambs suckling successfully, and fewer seizures. These outcomes are consistent with the improvements observed in our studies, particularly survival during the critical three day period after birth during which the majority of deaths occur. Importantly, benefits of melatonin treatment on early survival were maintained to weaning, resulting in an additional 25-30 lambs weaned per 100 twin-bearing ewes

Although the present data are promising, this study is limited by small sample size and requires further replication. We also found that one implant conferred equal benefit to two, which is of obvious interest from an economic perspective, though more extensive economic assessment requires further validation of these results.

Further replication involving various environmental conditions and breeds is currently underway. In conclusion, the present data demonstrate that supplementing pregnant twin-bearing Merino ewes with melatonin implants during the second half of pregnancy may be a practical strategy to reduce neonatal mortality and improve weaning rates.

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Morgan McCallum SARDI livestock researcher with MAC newborn triplets, 2020.

MEAT & LIVESTOCK AUSTRALIA

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Government of South Australia
Department of Primary Industries and Regions

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SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE

Virtual fencing as a future paddock grazing management tool for mixed farmers: weed control benefits

Rick Llewellyn, Jackie Ouzman, Caroline Lee, Damian Mowat, Jim Lea, Dana Campbell, Willie Shoobridge

CSIRO Waite

Location
Long Plains SA
Peter Cook
Paddock history
2021: Being sown to wheat
2020: Vetch for hay, grazed regrowth
Plot size
Two equal sized paddocks, one grazed in 4-sub paddocks by shifting a virtual fence 3 times.
Trial design
Experimental: 20 individually monitored animals in a virtually-fenced treatment paddock and 20 individually monitored cattle in an open grazed paddock, separated by an ungrazed buffer. Grazing, vetch and weed populations spatially analysed over time.
Livestock
Enterprise type: Mixed farm grazing
Hereford-based cattle (average initial weight 306 kg)
Stocking rate: 20 cattle per 20 ha over 18 days

Key messages

- **Virtual fencing technology was successful in applying strip grazing to a vetch paddock over 18 days.**
- **Weed damage due to grazing was significantly higher where strip grazing using virtual fencing was applied, with ryegrass seed head density reduced by over 50% compared to an open grazed paddock.**
- **There was no significant difference in the cattle weight gains achieved by the virtually fenced and control group.**

Why do the trial?

Virtual fencing technology is nearing commercial release in Australia. The technology uses automated GPS-enabled, solar-powered neckband devices to train cattle to stay within a virtually fenced boundary using audio cues. There is potential for virtual fencing to benefit mixed farming systems with the ability to better manage grazing pressure, weed populations and ground cover across increasingly large cropping paddocks. While an early stage prototype for experimental use with sheep is in development, trials with the Agersens e-shepherd technology are being conducted to test potential applications on mixed farms using cattle.

The Long Plains trial follows on from a successful trial conducted at Eden Valley in 2019 that demonstrated the ability of virtual fencing to exclude cattle from sensitive paddock areas using a contoured virtual fenceline over a month-long trial period. In this GRDC-supported project the potential for virtual fencing to be applied for improving weed control in mixed cropping systems is being explored. The aim of the trial was to test the ability of virtual fencing to achieve higher levels of grazing pressure on weeds in the spring leading into a subsequent crop.

How was it done?

The trial was conducted on a 70 ha vetch paddock where hay had been cut and removed. Additional fencing was constructed to produce the trial design (Figure 1). Due to spring rain there was substantial vetch and weed regrowth. Weeds present at notable densities were annual ryegrass and sowthistle, with some prickly lettuce. Weeds were typically at or near flowering.

Forty cattle (mainly Hereford; average initial weight 306 kg) were used in the trial, each wearing the latest version of the Agersens e-shepherd device. The cattle entered the trial paddock on October 21 and were removed on November 9. Twenty of the animals were run in an equal area ‘control’ paddock where the devices were used for spatial monitoring, but virtual fences were not applied. The other 20 animals were placed in the virtually fenced treatment paddock with only approximately a quarter of the total area initially available for grazing due to the 1st virtual fence being in place (Figure 1). Each virtual fence was in place for 5-6 days with the final grazing period involving removal of the virtual fence to allow grazing of the remaining area. As animals only had access to one waterpoint (Figure 1), grazed sub-paddocks remained open to animal traffic and return grazing.

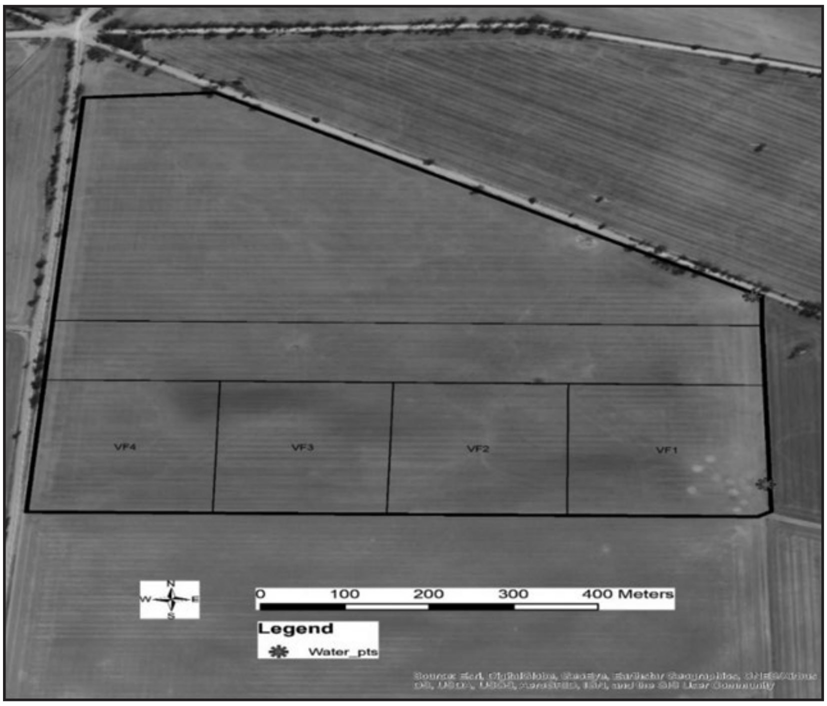

Figure 1. Long Plains trial design showing the sequentially grazed areas VF1 (east) to VF4 (west) in the virtually fenced treatment area; the central ungrazed buffer area and; open-grazed area at top. A single fixed water point was used in the grazed areas.

Cattle were weighed on entry and exit. NDVI-based measures were taken pre and post grazing using CropCircle. Weed counts and quadrat cuts were taken pre and post grazing, including prior to a new virtually fenced sub-paddock being opened up to grazing. Weed plant numbers and seed head numbers, along with weed and vetch biomass were measured across all areas of the paddock. Weed densities will be measured in the wheat crop to be sown in 2021.

What happened?

The virtual fencing was highly effective in containing cattle to the virtually fenced sub-paddocks. Residency maps show not only the efficacy of the virtual fence but the rate at which animals enter the newly opened grazing areas following a virtual fence shift (see example animal residency shift in days following 2nd shift of virtual fenceline shown in Figure 2). Animals were quick to learn to respond to the audio signal with the proportion of audio signals relative to all signals (audio plus electronic) already above 75% over the first day and above 80% after day 3.

There was no difference in weight gain between the virtually fenced animals and the control animals (P=0.4) with an average weight gain of approximately 1.4 kg/day.

A range of NDVI-based data output from CropCircle technology from pre- and post-trial paddock measures was spatially analysed. Post-trial results show the large differences in resulting green groundcover between the virtually fenced areas, including the area only opened for grazing in the final days of the trial (VF4), the open grazed area, and the ungrazed buffer area (Figure 3).

There were no significant pre-trial differences in average weed density found between the different paddock areas (*P>0.4*) but the virtual fence strip-grazing treatment resulted in over 50% less ryegrass plants (*P=0.01*) and ryegrass heads (*P=0.03*) post-trial. Ryegrass plant density was 2/m^2 in the virtually-fenced area and 6/m^2 in the openly grazed area. Ryegrass seed head density was 10/m^2 in the virtually fenced area and 23/m^2 in the control open grazed area.

Post grazing sowthistle density was insufficient to detect differences between treatments. Further weed impact analysis is being conducted using biomass and weed density measures in the 2021 wheat crop.

What does this mean?

The eShepherd technology can effectively contain young cattle in sub-paddock zones and enable fence line shifts for strip grazing (or targeted grazing pressure). The ability to utilise sub-paddock virtual fencing within a cropping paddock can be used to effectively increase grazing pressure on weeds while managing groundcover, in this case leading to significantly reduced ryegrass at seed set without reducing cattle weight gains compared to an open grazed control paddock.

The effectiveness of virtual fencing for managing zonal grazing in a dual-purpose crop to optimise ground cover, weed control and crop yield potential will be assessed with cattle in 2021. Following the 2021 cattle trials, field testing will begin using a prototype research device adapted for use with sheep.

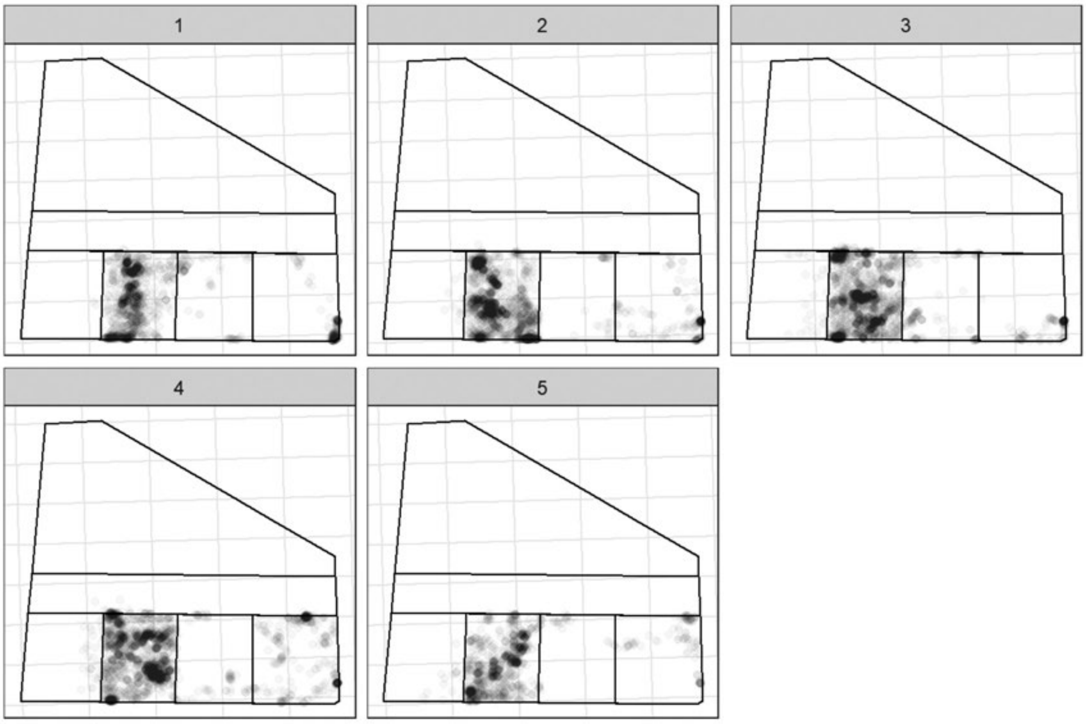

Figure 2. Animal residency over days 1-5 following shift of virtual fence from 2nd position (VF2) to third position (VF3) on day 1. Darker shading represents more frequent residency.

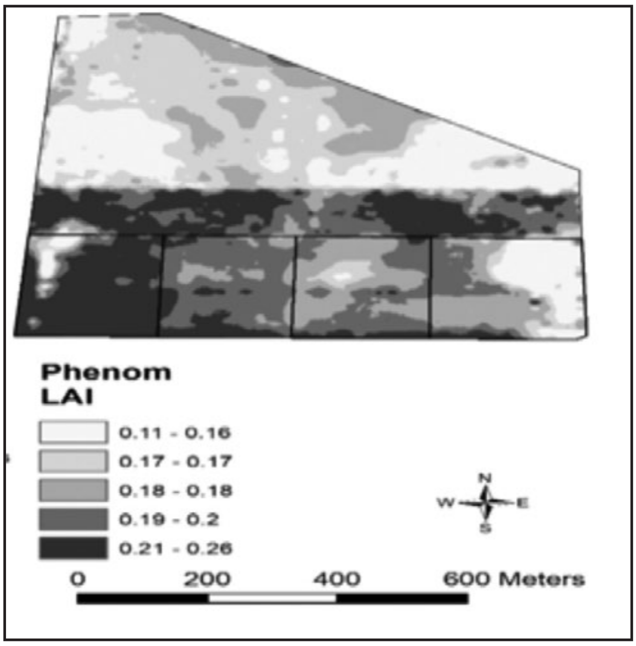

Figure 3. Post-trial NDVI-based maps of LAI estimations from post-trial CropCircle Phenom measurements.

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Managing standing crops for grazing

Alison Frischke
BCG (Birchip Cropping Group)

Key messages

- **Grow and manage the standing crop as if it's for harvest.**
- **Feed test for nutrient value and manage protein requirements for livestock.**
- **Be adaptable in management and make decisions for the long term.**

Why do the trial?

Boosting productivity and providing flexibility on farm

Establishing cereal crops for grazing to finish lambs has been implemented by several farmers across the southern region of Australia, achieving greater economic returns than managing livestock and cropping separately.
Many farm enterprises manage both livestock and cropping, however there is often separation of the two in terms of management. By understanding livestock nutritional requirements and crop management, the two enterprises can be integrated to increase productivity and profitability of less productive land.

Grazing standing crops does not limit land use, rather it provides increased flexibility for a mixed farming system. The following case studies are examples of how this management can be implemented on farm.

How was it done?

Petering's - Murtoa, VIC

Running a mixed farming enterprise of 1100 breeding ewes, Petering's set aside 265 hectares of the farm dedicated to establishing crops for grazing. This area is made up of smaller paddock sizes and is typically less productive land relative to the rest of the cropping paddocks.
Since sowing cropped area for grazing in 2016, Petering's have been able to increase productivity of land and returns from lamb production that was typically regenerating pasture.

A benefit that comes with establishing a crop for grazing is the flexibility offered if seasonal conditions are favourable and feed is in excess. Bailey Petering explains, "The key thing is to treat it [the crop] as if it's for harvest. Manage everything properly and don't skimp on things like fertiliser." In 2019, the area sown for grazing provided more than required, so some was cut for hay while other areas were followed through and harvested for grain.

The 250 hectares on Petering's property that is set aside for grazing crops is managed on a two-year rotation. In year one, crop is established with paddocks sown to Spartacus CL barley to allow for better grass control.

Depending on the season, ewes can be held in containment while the crops establish, then enter the crops to lamb during July. In September-October, lambs are weaned and placed straight back into the crops, that are now beginning to develop grain in the heads. Lambs remain on the crop while grain matures.

As the crop matures (from vegetative to flowering and early grain fill), there is a natural decline in feed value and a protein supplement is needed to meet the higher protein demands of growing lambs. Petering's manage this by providing seconds lentils in a paddock feeder. Lambs remain on the crop until they meet target weights for sale, and any remaining lighter, tail-end lambs moved to a lentil stubble to finish.

Bailey Petering standing in Spartacus CL sown for grazing 2019

Tips from Petering's:

- *Treat the crop as if it's for harvest*
- *Know the feed value and manage protein requirements*
- *Be flexible*

Livestock

Grain harvest production economics – Summer 2019/2020

Barley sown for grain harvest	Total cost ($/ha)
Spartacus seed	16.00
Seed coating- Systiva	12.96
Fertiliser	98.85
Herbicide/insecticide	59.70
Operations Excl. harvest	64.27
Harvest Incl. insurance & freight	74.11
Total costs	**$325.89**

Gross Margin - Grain for harvest	
Establishment cost	$251.78
Harvest cost	$74.11
Yield potential (t/ha)	1.86
Grain value ($/t)	$280
Gross income/ha	520.80
Gross margin/ha	**$194.91**

Ewes and lambs grazing Spartacus CL crop, October 2019.

In the second year, volunteer crop and clover are allowed to regenerate and bulk up. They're grazed by lambing ewes until just prior to seed set, then either sprayed out or cut for hay.

As the season progresses, the best decision for the crop end-use can be made using the season outlook and stored soil moisture, expected production and commodity price figures. Establishment costs for a grazing crop are the same as establishing a crop for harvest.

Below is an example process for calculating economics of both production options. The (ungrazed) harvested area in Petering's poorer performing paddock sown to standing crops for grazing averaged 1.86 t barley/ha, whereas better crop paddocks yielded 4.9 t/ha in 2019.

For this paddock, the return on grazing by lambs was greater than if harvested - and would be higher if the grazing value by ewes for 3 months was added.

Petering's have now successfully grazed cereal crops with lambing ewes and lambs over several, varied seasons. However, there have been important things to consider and learn along the way.

Timing is important when introducing stock to graze a standing crop. Crop chemical with-holding periods must be adhered to - be mindful when they're applied and control stock movements around them.

Similarly, if stock will be introduced to the crop when grain has ripened, to avoid acidosis risks they will need to be adapted to grain prior to entering the crop. If sheep are placed on the crop prior to ripening and remain on the crop while grain ripens, health issues are avoided as sheep rumens will adapt gradually to the changing plane of nutrition.

Build-up of disease in a grazing standing crop system can be managed by understanding the disease profile of the cereals used. In Petering's two-year grazing rotation and the abundant crop biomass, disease pressure was high in 2019 even with the use of fungicide. Sheep will consume the diseased crop, but it could result in lost biomass and feed value. Depending on how seasons roll, Petering's will modify the system to reduce disease pressure when needed.

Ewes and lambs are moved from standing crop paddocks once most of the grain in cereal heads has been consumed, and in time to leave adequate residue to protect the soil over late summer and early autumn.

Despite, these challenges, Petering's are positive about the system providing productive feed across all seasons. "We have enough area set out so that if it is a dry year or a wet year we can manage that; whether it be through providing feed at a time when there is typically a gap, or jumping at hay or harvest opportunities that present themselves in a wet year", Bailey Petering said.

Bennett's - Lawloit, VIC

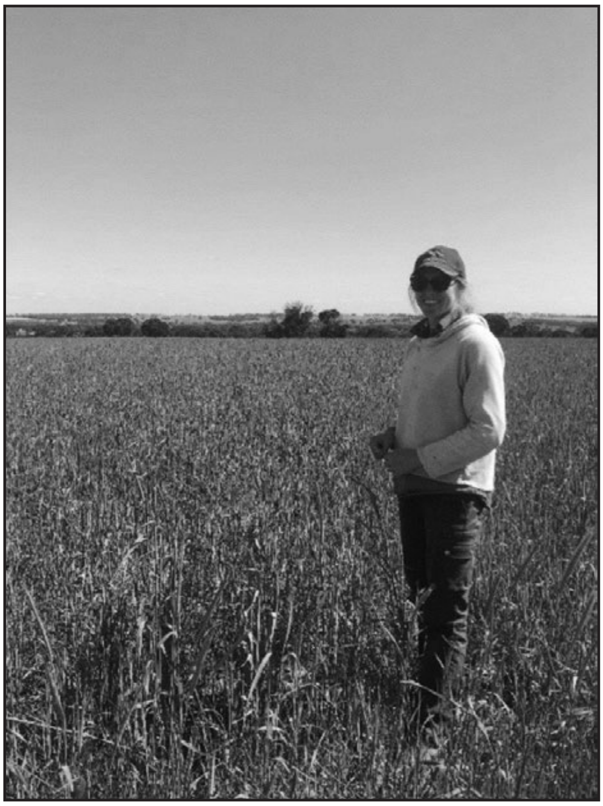
The Bennett's run a mixed farming enterprise consisting of 6000 self-replacing Merino ewes and 1000 cross bred lambs in the medium rainfall zone of western Victoria. As well as their regenerating pasture areas they have been using crops sown for grazing to expand their sheep enterprise, but are adaptable with management of the crops considering seasonal conditions and other aspects of the system that may need to be prioritised.

Over a time of business growth and risk management, Bennett's have been increasing the area managed for stock. Different soil types and rainfall environments across the property are managed for their needs and limitations.

Towards the southern end of the property, soils are heavier and there is a large amount of well-established lucerne used for lambing. Cropping in this area of the property involves a canola-wheat-bean rotation. Grazing of bean stubbles and standing crops are used to finish lambs.

Ewes and lambs grazing Spartacus CL crop, October 2019.

> *"It's a great pasture system because it makes management so much easier. Once the crop is on, I know there will be abundant feed to wean lambs on to in August and October and they can stay there comfortably for 8-10 weeks".*
>
> *- Alan Bennett*



Ellen Bennett in a Fathom barley and serradella pasture sown into a cereal rye stubble for grazing, October 2019.

Northern areas of the property fall on lighter soil types with lower rainfall. This area is managed for grazing using crops and lucerne. Care is taken to allow lucerne to establish well and recover after each graze. The choice of cereal rye and fathom barley for grazing has been beneficial due to their suitability to lighter soils.

In general, Bennett's manage a standing crop for grazing across one season. Crop is established as it would be if it were intended for harvest, with the standard seed treatment and fertiliser regime. It is then grazed by lambs starting in August and October for eight to ten weeks.

Grazing barley for lamb production economics – Summer 2019/2020

Barley for grazing prime lamb (35kg → 45kg liveweight)	
Dry matter production	**kg/DM/ha**
Total DM Year 1	7000
Available for grazing	6000
Residual	1000
Cost of establishment	**$251.78/ha**
Cost of production	**$41.96/t DM**
	kg/head/day
Barley	0.5
Lentil	0.3
Roughage- standing barley crop	0.8
PN Dry feed energiser	0.02
Lime and salt 80/20	0.01
Total	1.63
Total feed – cost/tonne	**$130.60**
Total feed - cost/head/day	**$0.21**
Expected daily rate of gain	132g
Starting average weight	35kg
Target average weight	45kg
Number of days to feed	75
Total feed cost/head	**$15.75**

Costs - lambs	**Cost $/head**
Purchase price	114.80
Drench	0.31
Vaccination	0.36
Crutching and shearing	6.00
Water and repairs	0.50
Transport to market	2.50
Commission on sale (5.6%)	9.62
Levies (2.1%)	3.61
Total feed cost	15.75
Total cost/head	**$153.45**

Returns - lambs	
Average carcase weight	20.7kg
Carcase price ($8.30/kg)	$171.81
Skin price	$3.00
Wool clip (grow 1kg)	$8.00
Total returns/head	**$182.81**
Profit/loss per head	$29.36
Stocking rate (lambs/ha)	12.00
Gross margin/ha	**$352.32**

In general, Bennett's manage a standing crop for grazing across one season. Crop is established as it would be if it were intended for harvest, with the standard seed treatment and fertiliser regime. It is then grazed by lambs starting in August and October for eight to ten weeks.

In the past, Bennett's have sown Moby barley for grazing, but switched to Fathom barley when they found it to also be a high biomass variety, that yields more grain than Moby. This gives flexibility to either graze the grain or harvest in a good season. It also meant they could simplify the number of different grain types they needed to store as Fathom was already part of the cropping program.

The decision to include cereal rye for grazing was made after seeing the success by other local growers with growing and grazing rye, and its suitability for their system. The Bennett's have found cereal rye to be a safe crop for grazing, with high fibre content reducing likelihood of sheep scouring.

Bennett's value the feed availability that standing crops provide, making livestock management easier. Heading towards harvest, having a large abundance of feed on offer means Bennett's can comfortably graze ewes and lambs on these paddocks without experiencing a feed gap over the harvest period.

What happened?

Protein in cereal crops changes as the crop moves through different growth stages. A vegetative cereal crop will have 25-30% protein, during flowering it drops to 8-11%, but then rises again in mature grain to 11-16.5% depending on the cereal type, variety and season (2019 BCG report). Likewise, energy also declines from 12-12.5 MJ ME while vegetative to 8-9.5 MJ ME during flowering, then rises back to 12-14.5 MJ ME/kg DM in grain.

This means protein and energy will meet sheep maintenance requirements (8% protein, 8 MJ ME/kg DM) during flowering, but a protein supplement is needed to support growth in lambs (18-20% protein for lambs growing at 200g/day). By sowing cereal crops into a lucerne, medic, clover or serradella pasture base, or providing legume hay or grain, protein requirements can be met.

Table 1. Feed test results and biomass from mixed pasture and grazing crop paddocks, 15 October 2019.

Paddock/ crop	Crude Protein (%)	Neutral detergent fibre (%)	Digestibility (DMD) (%)	Metabolisable energy (MJ/kg DM)	Water soluble carbohydrates (%)	Biomass (t DM/ha)
Pasture (clover, lucerne, ryegrass)	17.5	55.6	70.0	10.4	3.5	2.61
Standing Fathom barley	12.3	60.1	63.5	9.3	11.6	8.44

The mid-October feed value of one of Bennett's mixed pasture paddocks and a pure sample of a Fathom barley standing crop is below. As expected at this time of year, the standing crop has lower protein than the mixed pasture, but the amount of feed on offer is four times that of the mixed pasture paddock. This paddock was under sown with serradella, which added protein to the sheep diet. The paddock was grazed with ewes in this instance due to leased paddock fenceline conditions.

The Bennett's are adaptable in the management of their grazing across the property, adapting to the market and making decisions on opportunities to increase returns. Crops will be cut early for hay or sprayed out if weed issues are experienced. If grain prices are low and sheep prices are high, they will allow total grazing of standing crops. If grain prices increase, they may choose to harvest a larger area to sell or retain for feed grain if supplementary feeding is required in drier seasons.

A long-term perspective on management is important for the Bennett's - being adaptable plays a big role in achieving this. Sustaining ground cover is a long-term priority for the Bennett's and is managed through monitoring and moving stock when required. In a dry season, more crop stubbles will be grazed, but if groundcover is compromised sheep can be moved into containment yards until pasture growth resumes and is ready for grazing.

Bennett's have increased their feed on offer, particularly in periods across autumn and late spring when a feed gap is more common. Sowing crops for grazing has helped to fill these feedgaps and maintain condition and growth on stock. Alan Bennett said, "Mixed livestock is a complex system. You need to be adaptable in management and make decisions for the long term. We have seen many positive effects of grazing crops on our property".

Acknowledgments

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Livestock

Australian Government

BCG shared solutions

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Section 10

Disease

Cereal variety disease guide summary of 2020 season and implications for 2021

Hugh Wallwork and Tara Garrard
SARDI Waite

Season summary

The 2020 season started well and provided good conditions for fungal diseases to become established in crops. Below average rain through winter then delayed development of most diseases and in particular the rain-splash dispersed diseases like septoria. This combination of wet and then dry conditions is however favourable for crown rot infection and subsequent growth in moisture-stressed plants.

By the end of the season the level of disease in cereal crops on the Eyre Peninsula was generally low although crown rot will be a disease to look out for in 2021. Consider avoiding sowing cereals into heavily infected stubbles.

Net form net blotch

Net form net blotch established early in crops on the Far West Coast and developed rapidly, including in crops treated with Systiva. Sampling of some of these crops between Streaky Bay and Elliston and subsequent DNA testing at Curtin University confirmed that the NFNB in most of the samples was resistant to the SDHI fungicide in Systiva. For this reason, it is recommended that Systiva not be used to treat barley seed for the 2021 season throughout the western region of the EP.

The growing of barley in infected barley stubbles from the same variety will have greatly sped up the development of fungicide resistance and virulence on that variety. Diversifying the varieties grown and the fungicides used to treat them is a practical and common-sense approach to slow the development of fungicide resistance and variety susceptibility.

It is worth noting that resistance to Systiva has been found in a population of SFNB in Western Australia.

Rusts

Stripe rust made a reappearance in SA after a few seasons' absence. This time we had a mix of strains and included the new 198 strain not previously recorded in SA which has increased virulence on Emu Rock⦶ and Trojan⦶ but decreased virulence on many varieties including Mace⦶, Scepter⦶, and Chief CL Plus⦶.

Leaf and stem rust were mostly absent from SA wheat crops and barley leaf rust was present only at low levels.

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 resulted in resistance to strobilurins and some DMI products developing in the mildew population on the Upper Yorke Peninsula. Fungicide trials run by Sam Trengrove in the area in 2020 showed that strobilurins were still providing useful control of mildew. With continued reliance on fungicides their effectiveness will diminish over time.

Crown rot

Crown rot was a serious problem for cereal crops which had received good opening rains early in 2020 and had low and intermittent rainfall during winter through to grain filling. These favourable conditions promoted crown rot development causing yield loss in durum and wheat crops.

Lower rainfall in previous seasons has also meant that breakdown of infested cereal residues will have been slow. Increased expression of the disease in 2020 will leave cereal crop residues with high inoculum levels. 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 2021.

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.

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.

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.

Where a range is given, that would usually indicate that the more resistant score is more common, but that more virulent strains of the pathogen have been detected either in a limited geographic area or in previous seasons. In other situations, data may be more limited and a definitive rating cannot be provided.

Disease identification

A diagnostic service is available to farmers and industry for diseased plant specimens. Samples of all leaf and aerial plant parts should be kept free of moisture and wrapped in paper, not a plastic bag. Roots should be dug up carefully, preserving as much of the root system as possible and preferably kept damp.

Send your samples to:

SARDI Diagnostics
Plant Research Centre,
Gate 2B 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	SVS	SVS	S	MS	MRMS	S	SVS	MRMS	MS	S	MS	MS	MS	AH
Ballista	RMR	MSS	S	SVS	MRMS	MSS	S	SVS	-	-	S	MS	SVS	-	AH
Catapult	MR	MRMS/ SVS	S	MSS	R	MRMS	S	S	S	MS	S	MS	MS	MSS	AH
Chief CL Plus	MR	S	MR	MSS	MS	MRMS	S	SVS	MRMS	MSS	MSS	MS	SVS	MS	APW
Cobra	MR ^	MSS	MR/S*	MSS	MS	MRMS	S	MSS	MSS	MSS	S	MS	S	MSS	AH
Cutlass	R	MS	RMR	MSS	MR	MSS	S	S	MSS	MSS	S	MS	MS	MS	APW
Emu Rock	MS	S	SVS	SVS	S	MRMS	MSS	MSS	MSS	S	MSS	MS	MS	MSS	AH
Grenade CL Plus	MR	MRMS	S	S	R	S	S	MS	MSS	S	S	MS	MR	MSS	AH
Hammer CL Plus	MR	MS	S	MSS	MRMS	MRMS	S	MSS	-	-	S	MSS	RMR	-	AH
Mace	MRMS	SVS	MSS	S	MRMS	MRMS	S	MSS	MS	MS	S	MS	S	MRMS	AH
Razor CL Plus	MR	MS	S	SVS	MR	MSS	S	MSS	S	MRMS	S	MSS	RMR	MS	ASW
Rockstar	MR	MRMS/S	S	MSS	MSS	MRMS	S	SVS	MRMS	MRMS	SVS	MSS	VS	MS	AH
Scepter	MRMS	MSS	MSS	S	MRMS	MRMS	S	SVS	S	MSS	S	MS	MSS	MS	AH
Sheriff CL Plus	MS	MS/SVS	SVS	S	MS	MRMS	S	SVS	MRMS	MRMS	S	MSS	S	MS	APW
Trojan	MRMS	SVS	MR/MS	MS	MS	MSS	MS	S	MSS	MSS	MS	MS	SVS	MS	APW
Vixen	MRMS	MRMS/ SVS	SVS	S	MSS	MRMS	S	SVS	MRMS	MS	S	MSS	SVS	MSS	AH

‡ - 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^	MR/MS	RMR	MRMS	MS	MRMS	–	S	MS	MR	VS	MS	MRMS	MS	Durum
Aurora	RMR	MR	R	MR/S	MSS	MRMS	S	MSS	MRMS	RMR	VS	MSS	R	MS	Durum
Bitalli	RMR	MS	MR	MRMS	MSS	MR	–	S	MSS	RMR	SVS	MS	R	MS	Durum
Saintly	MR	MS	MRMS	S	MS	MRMS	MS	MSS	MRMS	MR	VS	MS	R	MS	Durum

Triticale	Rust			*Septoria tritici* blotch	CCN Resistance	Yellow leaf spot	Eyespot	Powdery mildew	Root lesion nematodes		Crown rot	Common root rot	Flag smut	Black point ‡	Quality in SA
	Stem	Stripe	Leaf						*P. neglectus*	*P. thornei*					
Fusion	R	RMR	RMR	MR	R	MRMS	MS	R	RMR	MSS	MS	S	R	MSS	Triticale
Goanna	R	SVS	RMR	MRMS	R	MR	–	R	MRMS	SVS	S	–	R	–	Triticale
KM10	R	MRMS	MR/S	MR	S	MR	–	R	MR	MS	MS	MRMS	R	MRMS	Triticale
Kokoda	R	RMR	RMR	RMR	R	MR	–	R	–	–	MS	S	R	–	Triticale
Normandy	R	RMR	RMR	RMR	R	MR	–	R	–	–	MR	MS	R	–	Triticale
Wonambi	R	MR^	R	RMR	MS	MR	–	R	MR	MS	MSS	MSS	R	–	Triticale
Joey	S	MRMS/ MSS	RMR/MS	RMR	MS	MR	–	R	MRMS	MSS	MRMS	MRMS	R	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

Disease

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	S	MS-SVS	R ^	R mlo	–	R	MSS	MR	MR	MRMS
Banks	MR-S	R-MR	S	R-SVS	S	MRMS	–	MSS	MSS	MR	MR	MS
Beast	MR-SVS	MR-S	MS	MS-SVS	MR	–	–	R	S	-	MR	MSS
Bottler	MR-MS	R-MS	S	MS-VS	S	R	–	RMR	MS	-	RMR	MRMS
Commander	MS-S	S-VS	MSS	MSS-SVS	R	MRMS	–	RMR	MSS	MRMS	MRMS	MSS
Commodus CL	MS-SVS	MR-MS	MSS	MR-SVS	R	MS	-	R	S	-	-	-
Compass	SVS	MR-S	MS	MR-SVS	R	MRMS	MS	R	MS	MRMS	MR	MSS
Fathom	MRMS-S	MSS-VS	RMR	R-S	R	MRMS	MRMS	MR	MSS	MRMS	MR	MSS
Laperouse	MRMS-SVS	MR-MRMS	MR-MS	MSS-SVS	S	MRMS	–	R	MSS	MR	MR	MSS
La Trobe	MRMS-S	MR-S	MSS	R-SVS	R	MSS	MRMS-S	MS	S	MRMS	MRMS	MSS
Leabrook	MS-SVS	MR-MS	MS	R-SVS	MR	MSS	–	R	MS	MR	RMR	MSS
Maximus CL	MS-S	R-MS	MRMS	R-S	R	MS	–	MS	S	–	MR	MSS
Oxford	R-MS	MR-VS	MS-S	MS-SVS	S	MS	MRMS	MRMS	MSS	MR	MR	MR
RGT Planet	MR-MS	MR-S	SVS	R-MSS	R	R mlo	S	R	MSS	MRMS	MR	MRMS
Rosalind	MR-MS	R-MRMS	MS-S	MR-S	R	MS	MS	MRMS	S	MR	MR	MSS
Scope	MS-SVS	R-MR	MS-S	MRMS-SVS	S	RMR	MS	MS	MS	MRMS	MRMS	MS
Spartacus CL	MR-S	S-SVS	S	R-SVS	R	MS	MS	MS	MSS	MRMS	MRMS	MSS
Westminster	R-MRMS	R-S	S	R-S	–	R mlo	–	MR	MSS	MRMS	MS	MRMS
Traveler	RMR-MR	R-MS	S	R-S	R	RMR	–	MRMS	S	-	MR	MS

R = Resistant, MR = Moderately Resistant, MS = Moderately Susceptible, S = Susceptible, VS = Very Susceptible, – = Uncertain
* Due to multiple strains of these pathogens, the table provides a range of reactions that may be observed. Different ratings are separated by a -
mlo - These varieties carry durable resistance

Oats	Rust		CCN		Stem nematode		Bacterial blight	Red leather leaf	BYDV*	*Septoria avenae*	End Use
	Stem*	Leaf*	Resistance	Tolerance	Resistance	Tolerance					
Bannister	S	MS	MR	I	MS	I	MR-S	MS-SVS	MS	S	Grain
Bilby	S	MR	VS	–	S	MI	S	MR-S	MR-MS	S	Grain
Brusher	MS-S	MS-S	R	MI	S	MI	MR-MS	MR-MS	MS	MS	Hay
Durack	S	MS	R	MI-MT	S	MT	MR-S	S-VS	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	MT	R	MR	MR-S	MR	Hay
Koorabup	R-S	S	S	–	S	I	MR-MSS	SVS	MS-S	MR	Hay
Kowari	MR-S	R	VS	–	S	MI	MR-MSS	MR-S	S	S	Grain
Mitika	MR-S	MS-S	VS	I	S	MI	MR-MSS	R-SVS	MS-S	S	Grain
Mulgara	MS	MR-MS	R	MT	R	MT	MR	MS-S	MS	MS	Hay
Tungoo	MS-S	MS	R	MT	R	T	MR	RMR	MR-MS	MR	Hay
Wallaroo	S	S	R	MT	MS	MI	S	MR-VS	MS	S	Hay
Williams	MR-S	R-S	S	I	S	MI	MR-MSS	MR-MS	MR-MS	MR-MS	Grain/Hay
Wombat	MS-SVS	SVS	R	T	MS	MT	MS-S	S	MR	MS	Grain
Wintaroo	S	S	R	MT	MR	MT	MR-MS	MR-S	MR-MS	MR-MS	Hay
Yallara	S	S	R	I	MS	MI	MR-MSS	SVS	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 -

Disease

Eyre Peninsula cereal and pulse disease survey 2020

Sara Blake and Marg Evans
SARDI Waite

Key messages

- **There were low disease levels in cereals but high disease levels in 50% of pea crops in spring 2020.**
- **Powdery mildew was present at significant levels in one wheat crop (susceptible very susceptible variety) on Lower Eyre Peninsula despite two foliar fungicide applications. Consider selecting the most resistant locally adapted variety available to manage this disease.**
- **Disease severity in field pea crops ranged from very low for downy mildew to moderately high for ascochyta blight. There was no association of observed disease levels with seed dressing, foliar fungicides or rotation history. Pre-sowing inoculum was not measured as part of this survey but may explain the observed disease levels.**
- **Dry conditions favoured spot form net blotch in barley and this disease affected all barley crops sampled in 2020.**
- **No high priority exotic plant disease was found.**

Why do the survey?

- To determine the incidence and severity of endemic leaf diseases of cereal and pulse crops in South Australia.
- Contribute to "proof of area freedom" from five high priority exotic grain diseases. This provides confidence that the region is free of those exotic diseases.

How was it done?

Number of crops to be sampled per region were based on the area sown of each crop type and using this as a guide, a comprehensive list of agronomists and independent consultants was compiled. A stratified random sampling approach was then applied when inviting participation in the survey. Paddock information was collected, including property owner contact details, GPS coordinates, sowing date, 2020 crop type and variety, 2020 fungicide applications (products and timing), and a three-year paddock history.

Paddocks were sampled at flowering to mid grain filling for cereals and at early pod development for pulses. A paddock sample consisted of 100 plants collected along a single transect (most pulses) or four transects (cereals and some pulses). Transects started a minimum of 50 m away from the fence line with a whole plant collected approximately every 10 m. Plants were transferred back to the laboratory for disease rating.

Biosecurity protocols were followed to ensure no transfer of pests, weeds or diseases from one paddock to the next. This included not taking vehicles into paddocks and boot disinfection between each paddock.

Presence/absence of major endemic and priority exotic diseases (Table 1) and disease severity on the whole plant was assessed visually. For pulses, % whole plant area diseased was recorded and for cereals, particular attention was paid to disease expression on the flag leaf and the leaf below the flag (flag leaf-1).

What happened?

A total of 102 crops (62 cereals and 40 pulses) were surveyed during the spring period across the five main growing regions in SA: lower-mid-upper Eyre Peninsula (L-M-UEP), lower-mid-upper Yorke Peninsula, lower-mid-upper North, Mallee and upper-lower South East. For the whole of the EP, 14 wheat, five barley and four field pea crops were sampled (Table 2), with wheat and barley crops assessed on LEP, MEP and UEP, and field pea crops assessed on UEP only (Figure 1). The number and distribution of pulse crops surveyed for this region was small due to the small area of peas grown in the region relative to the whole state.

In general, low rainfall during the 2020 growing season meant that leaf disease expression was limited on the MEP and UEP, with more expression in the higher rainfall region LEP.

Table 1. Diseases selected for assessment in crops on Eyre Peninsula.

Crop Type	Diseases Assessed
Wheat	*Septoria tritici* blotch, powdery mildew, stripe rust, stem rust, leaf rust, yellow leaf spot, wheat stem rust UG99 [e]
Barley	Net form net blotch, spot form net blotch, powdery mildew, scald, leaf rust, barley stripe rust [e]
Field pea	ascochyta blight (syn. blackspot), downy mildew, bacterial blight, botrytis grey mould, *sclerotinia*

[e]=high priority exotic disease

Table 2. Number of crops sampled per crop type and region.

Regions	Wheat	Barley	Field pea	Faba bean	Lentil	Chickpea
Eyre Peninsula	**14**	**5**	**4**			
Mallee	6	4				
North (lower-mid-upper)	9	6	6	5		5
South East	4	4		4		
Yorke Peninsula	6	4			10	6
TOTAL per crop type	**39**	**23**	**10**	**9**	**10**	**11**

Cereal disease summary

Wheat (14 crops sampled):

Powdery mildew and *septoria tritici* blotch (STB) were present only on crops in the LEP. The number of plants affected by these diseases was low. For STB, disease expression was limited and unlikely to cause yield loss.

Powdery mildew expression was of more concern as lesions were present on the flag leaf and flag leaf-1 in both of the affected crops and heads were affected in one of those crops. Both of the affected paddocks were sown to varieties with a SVS (susceptible-very susceptible) rating for powdery mildew and had two foliar fungicide applications prior to being surveyed. Powdery mildew is notoriously difficult to manage with fungicides in a very susceptible variety. Varietal resistance is likely to be the best management tool for the future.

Yellow leaf spot was present in 60% of samples from MEP and UEP at low levels unlikely to have affected yield. Leaf rust was present at very low levels in two samples (one each from UEP and MEP) and again would not have affected yield. Crown rot was present at low levels in 60% of wheat crops assessed. Stripe rust and stem rust (including the exotic strain UG99) were not detected.

Barley (five crops sampled):

Spot form net blotch (SFNB) was favoured by the dry 2020 conditions and was present in all crops, with two crops having significant levels of this disease. SFNB can cause yield losses of around 20% in susceptible/very susceptible varieties such as Spartacus, where inoculum levels are high and infection occurs early and continues to occur during the season. Avoiding high intensity barley cropping and selecting less susceptible varieties are the best options for managing SFNB.

Scald was present in three paddocks, with one paddock having significant levels of this disease. Leaf rust was present in one sample, with some pustules on the flag leaf. Neither of these barley diseases were present at levels that would have affected yield.

Net form net blotch, powdery mildew and barley stripe rust were not detected.

Pulse disease summary

Of the four field pea paddocks surveyed on the Eyre Peninsula, 100% of plants in all four paddocks were infected with ascochyta blight (AB; syn. blackspot). Plant severity was moderate and ranged between 17-38%. This was comparable to the results in the survey of other regions. Severe downy mildew had been reported widely across the state in seedling crops early in the season, however only two crops (50%) surveyed on the EP had infected plants (two plants in one paddock, one plant in the other) and severity was very low (<1%). Warm and dry spring conditions likely restrained downy mildew. There was no bacterial blight, botrytis grey mould or sclerotinia detected in the survey, either on the Eyre Peninsula or in the rest of the surveyed paddocks in other regions. There were no high priority exotic diseases detected during the survey.

Outside of the survey, the SARDI Pulse Pathology lab only received five other pulse samples with disease from the Eyre Peninsula: two field pea samples with AB, one lupin sample and one canola sample with *sclerotinia*, and one faba bean sample with chocolate spot. The low number of samples received by the Pulse Pathology Lab with a disease caused by a primary foliar pathogen reflects the dry season in 2020.

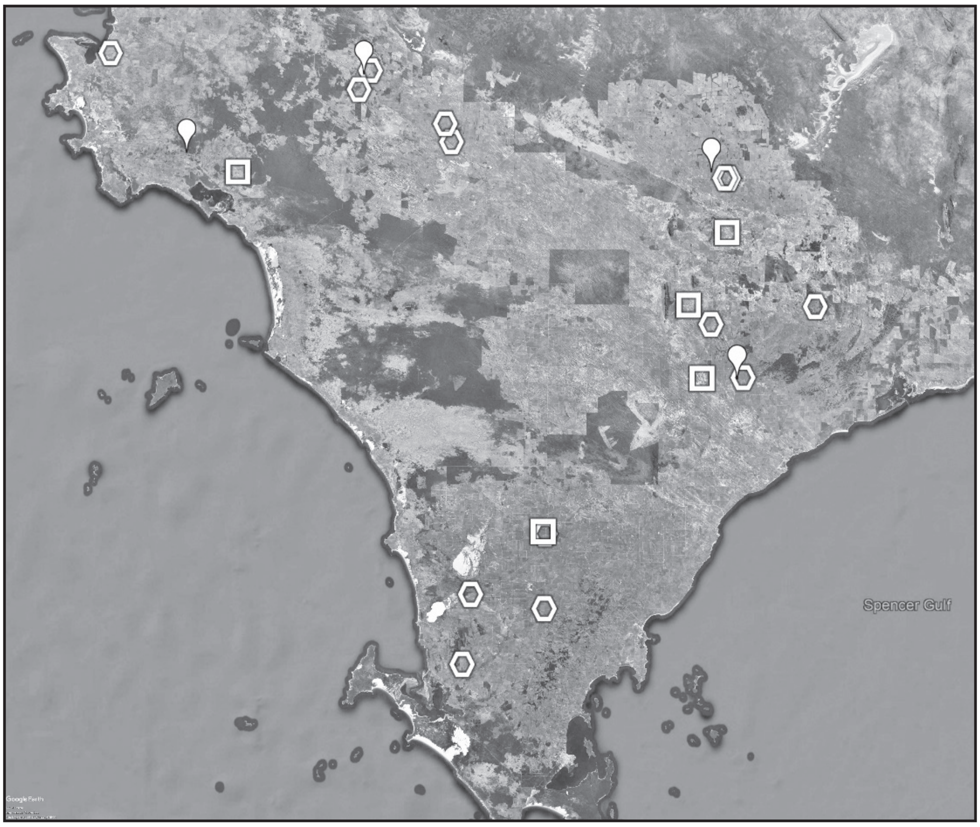

Figure 1. Location of wheat (hexagon), barley (square) and field pea (bulb) crops surveyed for leaf diseases on Eyre Peninsula in 2020.

What does this mean?

- The 2020 season was characterised by dry conditions, particularly in July, and produced low levels of disease across most regions and crops including parts of the Eyre Peninsula.
- No high priority exotic plant pathogens were detected during the survey.
- Future disease surveys undertaken in seasons with more typical (i.e. higher) rainfall will be beneficial to understand the presence and severity of disease in wetter years.
- Growers are encouraged to proactively monitor their crops for signs of disease and to report disease observations to SARDI pathologists.

Acknowledgements

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Root diseases in pulses - a constraint to production?

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Key messages

- **Root diseases are common in pulses and appear to be causing varying levels of yield loss.**
- **Across 2 years of a national survey (3 years in SA), *Pythium* spp., root lesion nematode, *Phoma pinodella* and *Rhizoctonia solani* AG8 were common across a range of pulses.**
- **Less common but potentially more damaging *Aphanomyces* and *Phytophthora* spp. continue to be detected - these are found across Australia but infrequently at this stage.**
- ***Fusarium* species are more common. Isolates vary in pathogenicity, but little is known about their role in causing root disease in Australian pulses.**
- **Partial control of root disease in 2020 corresponded with yield increases of up to 0.62 t/ha.**
- **Pulse root diseases have potential to cause significant yield losses across Australia.**

Why do the trial?

This research is investigating the causes and effects of root diseases in pulse crops.

Growers are increasingly incorporating legumes into rotations for benefits such as nitrogen fixation, grass weed control and disease break effects. More recently, high prices for food legumes such as lentil and faba bean have driven high frequency pulse cropping (e.g. wheat-lentil). However, despite an eagerness to grow more legumes, growers remain wary due to poor performance and occasional crop failure.

Poor performance of pulses is likely due to multiple factors. Many obvious above-ground issues have been resolved through resistance breeding and the development of insecticide and fungicide strategies and products. However, unexplained poor performance continues to be an issue, with soil abiotic and biotic constraints implicated.

Experience in North America and Europe indicates that soilborne diseases become important as pulse cropping frequency increases. Priority targets for international research include *Aphanomyces euteiches*, *Fusarium* spp. and *Phoma pinodella*. *Phytophthora* spp. appear more common in Australia and have a history of significance in pasture legumes and chickpea.

This paper summarises the findings of surveys of pulse roots diseases (three years in SA and two years nationally) and preliminary results of yield loss trials conducted in 2020.

How was it done?

Pulse Survey

Since 2018, SARDI has encouraged growers and agronomists to submit root and lower stem samples from poor performing legume crops in SA. In 2019, the survey expanded nationally in collaboration with AgVic, NSW DPI, DPIRD (WA) and USQ (QLD).

In 2020, 533 samples were processed, including 43 from the Eyre Peninsula (EP). Samples were scored for root health, photographed, and DNA was extracted. A suite of qPCR tests was used to quantify known pulse pathogens in the DNA extracts, and next generation sequencing (Illumina® MiSeq®) used to identify potentially important pathogens for which SARDI does not have qPCR tests. Three DNA libraries were prepared using primer pairs that target oomycetes (e.g. *Aphanomyces*, *Phytophthora* and *Pythium* spp.) and fungal species (e.g. *Fusarium* and *Sclerotinia*). The 2020 samples are currently being sequenced and the results will be reported later.

What happened?

The survey is providing insight into previously unexplained crop symptoms including poor establishment, reduced vigour or early/uneven senescence as seen in Figure 1.

The most common pathogens detected nationally using qPCR were *Pythium* spp., *Pratylenchus* spp. (root lesion nematodes), *Rhizoctonia solani* AG8, and *Phoma pinodella* (Figure 2). Of the 42 samples from the EP, 38 contained *Pythium* clade F, with 22 above >100 pgDNA/g root, 30 samples contained *R. solani* AG8 (10 >100 pgDNA/g root), 23 contained *P. pinodella* (10 >100 pgDNA/g soil), 38 contained *P. neglectus* (5 >100 nematodes/g root). DNA levels in root tissue have not been correlated to yield loss, however experience over the course of the survey suggests a threshold of 100 pgDNA/g root often correlates with moderate root damage.

Disease

Figure 1. Poor establishment and vigour in a lentil crop near Kimba, Eyre Peninsula in 2020. The roots contained DNA of multiple pathogens, predominately* Rhizoctonia solani *AG8, a likely cause of symptoms.

Pythium and *Pratylenchus* spp. have broad host ranges, *R. solani* AG8 prefers cereals but will infect other plants. *Phoma pinodella* along with *Didymella pinodes* causes blackspot of field pea, but it has a much broader legume host range.

There were infrequent detections of *Aphanomyces* and *Phytophthora* nationally. Aphanomyces root rot causes severe and widespread losses in pulses in Europe and North America, while Phytophthora root rot has long been identified as a constraint to both pasture legume and chickpea production in Australia, with certain species also known to limit pea production in Europe.

In 2020, *Aphanomyces euteiches* was detected in six faba/broad bean samples from SA and NSW and 1 lentil sample from Victoria; the agronomists reported significant yield loss in many of these paddocks. There were no detections of *Aphanomyces* from the EP.

Four *Phytophthora* species were detected nationally. *Phytophthora medicaginis* was detected in 26 (25 chickpea, 1 faba bean) samples from northern NSW, where it is known to cause substantial losses. *Phytopthora megasperma* was detected in 33 faba bean, lentil and chickpea samples from across Australia, including from one lentil crop on the EP. *Phytophthora drechsleri* (tentative identification), was detected in 14 samples, mostly lupins, from WA, southern NSW, Vic and SA. Investigations are underway to confirm identification of this species.

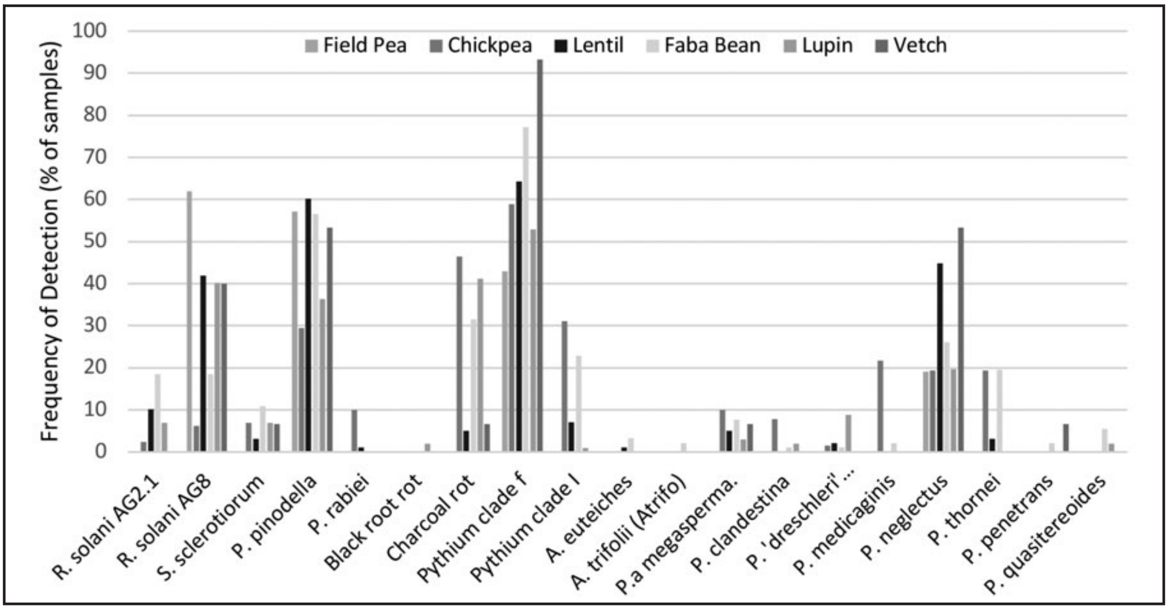

Figure 2. Frequency of root pathogens detected by qPCR in 2020 national pulse root health survey.

DNA samples were also sequenced (next generation sequencing) to identify pathogens not detected by current qPCR tests. Three primer pairs were developed to amplify gene regions selected to identify different pathogen groups.

Sequencing identified *P. megasperma*, *P. "drechsleri"*, a range of *Aphanomyces* and *Fusarium* species, *Sclerotinia trifolorium* and *Thielaviopsis basicola*. *Fusarium* spp., including *F. avenaceum*, are suspected to be important in north America and Canada. Some species have a wide host range.

Yield Response Trials

In 2020, SAGIT project SUA920 commenced field studies to investigate yield losses caused by soilborne diseases of pulses. A mixture of pesticides was used to suppress root disease in 20 trials collocated with the GRDC Southern Pulse Agronomy program, including 6 sites on Eyre Peninsula.

At each site, two locally suited legume crops were sown with seed and soil-applied pesticides to control multiple fungal/oomycete/nematode targets. At Hart, only one crop type (lentil) was sown. Pathogen inoculum at each site was characterised through replicated soil samples, tested using the Pulse Research test panel (26 qPCR tests) developed for the survey. At each site, 6 treatments were applied, including 'untreated' and 'full treatment' (combination of 3 products), as well as 4 other individual or combination treatments. Treatments are all currently unregistered across the range of pulse crops used in these experiments. For simplicity, only the visual disease scores for the 'untreated' and 'full' treatments are presented here. Root disease was scored (0 to 5 scale) for 15 plants per plot in early spring.

Plant samples (~15 per plot) were visually assessed and DNA was extracted from the roots of those samples and tested using the Pulse Research test panel. Trials were harvested to measure yield effects. Preliminary results are presented in this paper, data analysis is progressing.

What happened?

A summary of the qPCR results of pre-sowing soil samples are presented in Table 1 for EP sites. This table does not include pathogens e.g. Fusarium spp., for which qPCR tests have not been developed. DNA sequencing is underway to identify other potentially important pathogens present in diseased roots.

The sites were selected without prior knowledge of disease risk. Wudinna had high levels of *Phoma* and *Rhizoctonia*, Stokes had high levels of *Pythium* and *P. pinodella*, and Tooligie 1 had high levels of *P. pinodella.*

Table 1. Initial density of pathogens detected in soil samples from 2020 field sites on EP. Fungi results are reported as pgDNA/g soil. Pratylenchus neglectus and P. thornei are reported as nematodes/g soil.

Site	*Rhizoctonia solani AG2.1*	*Rhizoctonia solani AG8*	*Phoma pinodella*	*Macrophomina phaseolina*	*Pratylenchus neglectus*	*Pythium clade f*	*Pythium clade I*
Kimba	8	60	35	10	2	12	5
Stokes	29	49	103	1	2	239	0
Tooligie 1	0	0	167	6	9	17	0
Tooligie 2	56	75	75	12	1	28	2
Wudinna	0	128	150	1	12	10	3
Yeelanna	0	0	84	20	20	50	19

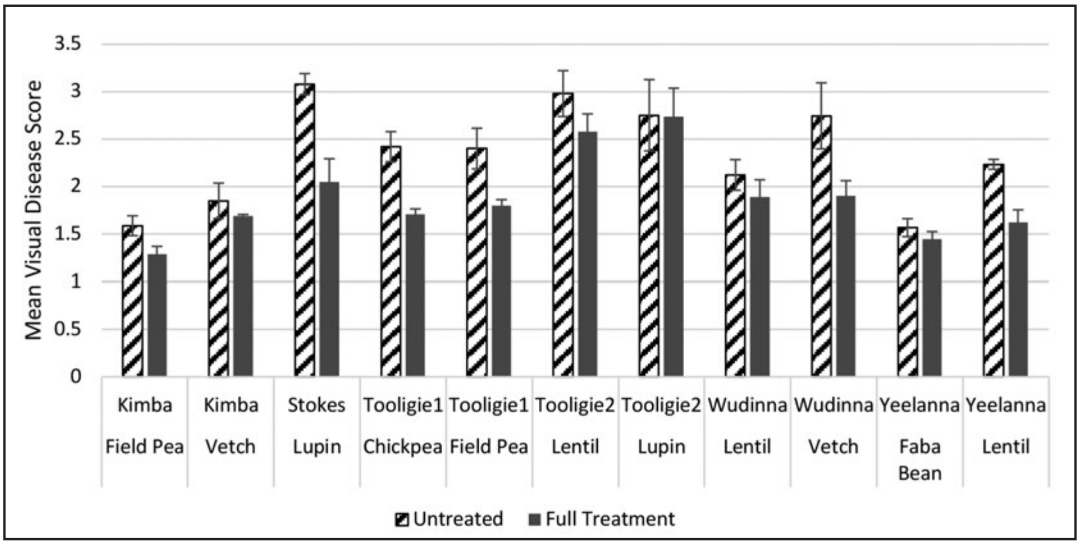

Figure 3. Root disease score of pulses either untreated or treated with a combination of pesticides selected to control fungi, oomycetes and nematodes in disease response trials located on the Eyre Peninsula in 2020.

Disease

*Table 2. Mean yields and standard error (SE) of treatments applied to suppress soilborne diseases at trial sites on Eyre Peninsula, 2020. Treatments coded: O = to control oomycetes (***Pythium & Phytophthora***), F1 = to control* **Rhizoctonia** *and* **Phoma***, F2 = to control* **Fusarium** *and N = to control nematodes. Wudinna lentil yields were affected by harvest issues and are not included. 'Treatment difference' (t/ha) is indicated where a yield response was significant and is calculated as the difference between lowest and highest yielding treatments. Lowest yielding treatment was not always the Nil (untreated), with phytotoxicity from other treatments suspected.*

Crop	Site	Treatment yields (t/ha)						SE	*p-value*	Treatment difference
		Nil	O	N	O + F1	O + F1 + N	O + F1 + N + F2			
Lentil	Yeelanna	4.55	4.12	4.74	4.15	4.61	4.75	0.24	*0.035*	0.63
	Tooligie 2	1.39	1.37	1.35	1.44	1.44	1.09	0.11	*0.023*	0.35
Faba bean	Yeelanna	5.36	5.22	5.29	5.55	5.32	5.38	0.08	*<0.001*	0.33
Field Pea	Tooligie 1	0.71	0.76	0.78	0.86	0.64	0.77	0.06	0.261	ns
	Kimba	0.63	0.55	0.56	0.56	0.61	0.60	0.10	0.752	ns
Lupin	Stokes	2.21	2.26	2.12	2.40	2.28	2.33	0.11	0.318	ns
	Tooligie 2	0.92	0.83	0.86	0.82	0.95	0.88	0.20	0.427	ns
Chickpea	Tooligie 1	0.97	0.95	0.90	0.95	0.93	1.07	0.06	*0.027*	0.17
Vetch	Kimba	0.84	0.78	0.91	0.81	0.88	0.72	0.07	*<0.001*	0.19
	Wudinna	0.43	0.37	0.39	0.39	0.42	0.37	0.08	0.812	ns

Severity of root diseases varied between sites. Sites with the most root disease included Stokes (lupin) and Tooligie 2 (lentil and lupin), both had root disease scores of around 3 in untreated plots (Figure 3). Sites with the least root disease included Yeelanna (faba bean) and Kimba (field pea), with scores around 1.5 in untreated plots. Most sites root disease scores were greater than 2 across a range of crop types.

The full treatment reduced root disease scores compared to untreated at Stokes (lupin), Tooligie1 (chickpea and field pea), Wudinna (vetch) and Yeelanna (lentil).

Complete disease control was not achieved at any site, indicating that either the method of application was limiting and/or the product range was inadequate or poorly effective. For example, at Stokes the full treatment only reduced root disease severity by one unit (3 to 2) of the 0-5 scale.

Yield responses were observed at 5 of the 10 sites (Table 2). At Yeelanna the full treatment and the oomycete + fungicide treatment yielded 0.2 t/ha more in faba beans than the untreated. The full treatment also produced the best yield in chickpeas at Tooligie 1. However, in vetch at Kimba, the full treatment had the lowest yield. At some sites the full treatment may have been phytotoxic, adversely affecting the rhizobia or the treated crop suffered greater moisture stress during grain fill.

Yield responses of up to 0.62 t/ha were observed at other sites in SA in 2020. Sites with the greatest yield increases were in the higher rainfall zones including Tarlee in the mid-north and Bool Lagoon in the south-east of SA.

What does this mean?

Surveys undertaken by this project show root disease is common in Australian pulse crops, including those on the Eyre Peninsula. Pathogens are generally present as complexes of several types. Some pathogens are very common across grain legume regions and crop types i.e. *P. pinodella*, *P. neglectus*, *Pythium* spp., *Fusarium* spp. and *Rhizoctonia solani* AG8.

Several pathogens were detected, including Aphanomyces euteiches and Phytophthora spp., that have caused substantial yield loss in isolated crops. These pathogens are favoured by wet conditions and can cause large losses in wet seasons. However their distribution appears to be limited to higher rainfall zones and soils prone to short term waterlogging.

Yield losses of up to 0.62 t/ha in faba beans at Bool Lagoon, associated with partial control of root diseases assessed as moderate-high in September, is an indication that soilborne diseases can be a significant constraint to pulse yields. Smaller responses such as at Yeelanna indicate that there is potential for yield increases even where pathogen loads and environmental conditions are not highly-conducive for expression of disease.

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2020 Foliar pulse disease seasonal update

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Paper presented at GRDC Update, 2021

Key messages

- **Two new chickpea varieties were released in 2020, CBA Captain^A and PBA Magnus^A, are rated S and MS to ascochyta blight (AB) respectively.**
- **In one chickpea AB trial at Kingsford, different fungicide products gave varying levels of disease control in the very susceptible variety Howzat, but these products demonstrated equivalent disease control in MS varieties.**
- **There are no changes to AB for lentil or faba bean for 2020. Two pathotypes of each pathogen are now recognised and growers are advised to monitor closely for infection and manage disease proactively.**
- **Two new lentil varieties are available for 2021. GIA Leader^A has provisional ratings of RMR to both AB pathotypes and MR to botrytis grey mould (BGM). PBA Kelpie XT^A has a MRMS rating to both AB pathotypes and a RMR rating to BGM.**
- **SARDI annual testing of *Ascochyta lentis* isolates in 2020 included the highly resistant newly released variety PBA Highland XT^A for the first time. Of the 20 isolates tested, collected in 2019, 25% of these were able to infect PBA Highland XT^A indicating that there are isolates present in the pathogen population that can overcome the variety's resistance. 100% of the tested isolates infected PBA Hurricane XT^A.**
- **In a trial at Bool Lagoon, PBA Amberley^A had less chocolate spot than both PBA Kareema^A and PBA Bendoc^A. Multiple fungicide applications significantly reduced disease severity particularly in PBA Bendoc^A and PBA Kareema^A.**

2020 Pulse Disease Seasonal Update, Diagnostics and Surveillance

Despite generally good opening rains and average spring rainfall for most regions, the dry conditions in June or July contributed to low levels of disease across most regions and crops.

SARDI Pulse Pathology received 78 plant samples for disease diagnosis from lentil, faba bean, chickpea, field pea, lupin, vetch and canola crops. Over 40% (33 of 78) had no disease and symptoms were attributed to abiotic causes e.g. weather or chemical damage. The main disease diagnosis was AB in 7 (9%) samples. Other primary foliar diseases diagnosed included CS and cercospora leaf spot (CLS) in faba bean, and sclerotinia in lupin. 22 specimens (28%) were also assessed for root disease (refer B. Gontar's EPPS 2020 Summary p 235). Virus testing in some of the pulse specimens also identified Cucumber mosaic virus (CMV) in lentil and lupin, Alfafa mosaic virus (AMV) and Bean leaf roll virus (BLRV) in lentil as well as Turnip yellows virus (TuYV) in lentils, faba bean and chickpea.

Disease Surveillance

A survey of 40 pulse crops across the major growing regions in South Australia for endemic and notifiable exotic diseases was conducted in spring 2020. Crops were selected with assistance from regional agronomists and represent proportional crop type per region. 100 plants per paddock were sampled and whole plant percent disease severity rated. Results would have been affected by fungicide regimes and by seasonal conditions. Overall there was a low level of disease in all crop types, with some regional differences, likely due to the 2020 winter being drier than average for most regions. No sclerotinia or notifiable exotic diseases were found in the paddocks surveyed.

In the 11 **chickpea** paddocks surveyed, 55% of crops were infected with AB but at very low severity (2% or less) and the number of plants per crop with AB lesions (i.e. disease incidence per crop) ranged between 1-44%. BGM was identified in only 1 crop, on the Yorke Peninsula, but severity was almost zero (0.002%) and the disease incidence was also very low (1%).

Lentil crops surveyed on the Yorke Peninsula had very low levels of AB (less than 1% plant area diseased) in 30% of the crops surveyed and the disease incidence per crop was also very low (ranging from 3-4%). 2 crops showed BGM symptoms at a very low severity (4.3-5.7%) although disease incidence was high at 83-88% in those two crops.

In the 9 **faba bean** paddocks surveyed, 56% were infected with AB but at very low severity (2% or less) and the disease incidence, ranging from 3-12%, was also low. 44% of crops were infected with CS ranging in severity between 0.6 to 53.9% whole plant disease, and disease incidence was high at 49-100% in those crops. All surveyed crops in the South East were infected with CS. No CLS detected, possibly due to the timing of survey.

In the 10 field pea paddocks surveyed, 100% were infected with AB with plant severity ranging between 15-58%. Severe downy mildew had been reported widely across the state in seedling crops early in the season, and in the spring survey 4 of 10 crops were infected but at a very low severity (0.02-1.6%) with 1-50% disease incidence. Warm spring conditions likely restrained downy mildew. No bacterial blight, BGM nor sclerotinia were detected in these crops.

Ascochyta Blight in Chickpea, Lentil and Faba Bean: fungicide trials, variety trials, and pathogenicity testing

Chickpea

All current commercial varieties of chickpea are rated moderately susceptible (MS) or susceptible (S) to AB. This includes two new releases in 2020: CBA Captain[A] rated S to AB, and PBA Magnus[A], rated MS to AB.

Economic management strategies in chickpea to control ascochyta blight and maximise yield

AB in chickpea causes significant grain yield loss and economic losses through the need for multiple fungicide applications. Two replicated split plot trials at Kingsford were sown on the 6 June to measure yield loss from AB in commercial varieties and advanced breeding lines of chickpea and assess fungicide management strategies. A variety trial was sown to 6 varieties and 3 advanced breeding lines and received 3 fungicide treatments (Table 1). A separate fungicide trial was sown to two varieties (Howzat[A], Genesis™090) and one advanced breeding line (CICA1454) and received five fungicide treatments (Table 2). Fortnightly chlorothalonil sprays commenced on 14 July. A maximum of 4 strategic sprays were applied ahead of rain fronts on September 3 & 16, Oct 1 & 21. Trials were inoculated with AB infested stubble six weeks after sowing. Disease was assessed on 15 October as % plot severity during podding.

Fortnightly chlorothalonil sprays reduced disease to zero in all varieties and both trials (Table 1 and 2). In the unsprayed plots of the variety trial, lowest disease scores were in CICA1454, Genesis™090 and PBA Royal[A] (11.3 – 13.8% plot severity). CBA Captain[A] (22.5% plot severity) had statistically similar disease levels to Genesis™090 and PBA Royal[A], but more than CICA1454. Highest disease scores were in Howzat, PBA Monarch[A] and PBA Magnus[A] ranging from 58.5 to 81.3% plot severity (Table 1). Veritas® fungicide sprays reduced disease to one or two thirds of that in unsprayed plots so that plot disease severity ranged from 3.3% in the less susceptible lines but up to 45-50% in the more susceptible lines (Table 1).

In the fungicide trial, all treatments reduced disease to less than 4% plot severity in the moderately susceptible Genesis™090 and in CICA1454 (Table 2). However, in the very susceptible Howzat[A], disease severity was significantly lower in the plots treated with Miravis Star® (5.5% plot severity) compared to those treated with Veritas® or AviatorXPro® (20.8 and 24.3% plot severity respectively).

Table 1. Mean ascochyta blight disease (% plot severity) in Kingsford chickpea variety trial.

Variety	AB rating	Square Root % plot severity (Raw data in parentheses)		
		Fortnightly chlorothalonil	Strategic Veritas®	Nil fungicide
Howzat[A]	S	0.0 (0.0)	7.1 (50.0)	9.0 (81.3)
PBA Monarch[A]	S	0.0 (0.0)	6.4 (45.0)	8.5 (72.5)
CICA1352 (PBA Magnus[A])	MS	0.0 (0.0)	3.2 (10.8)	7.6 (58.8)
PBA Striker[A]	S	0.0 (0.0)	3.7 (13.8)	6.5 (42.5)
PBA Slasher[A]	S	0.0 (0.0)	2.9 (9.3)	5.1 (26.3)
CICA1521 (CBA Captain[A])	S	0.0 (0.0)	2.5 (6.3)	4.7 (22.5)
Genesis™090	MS	0.0 (0.0)	2.0 (4.3)	3.7 (13.8)
PBA Royal[A]	MS	0.0 (0.0)	1.7 (3.3)	3.7 (13.8)
CICA 1454	-	0.0 (0.0)	1.9 (3.8)	3.2 (11.3)
LSD (P<0.001) fungicide x variety = 1.13				

Table 2. Mean ascochyta blight disease (% plot severity) in Kingsford chickpea fungicide trial.

Treatment	Rate of fungicide application (L/ha)	Square Root % plot severity (Raw data in parentheses)		
		Howzat[A]	Genesis™090	CICA1454
Nil	0	8.2 (67.5)	3.6 (14.3)	2.6 (7.5)
Strategic Veritas®	1 L/ha	4.4 (20.8)	1.7 (3.8)	1.3 (1.8)
Strategic AviatorXPro®	600 mL/ha	4.8 (24.3)	1.7 (3.8)	1.6 (3.0)
Strategic Miravis Star®#	600 mL/ha	2.2 (5.5)	1.5 (2.5)	0.9 (1.0)
Fortnightly chlorothalonil	2 L/ha	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
LSD (P<0.001) = fungicide x variety = 1.14				

#registration pending for June 2021.

Disease Management of Ascochyta Blight in Faba Bean and Lentil

AB disease management trials were established in low, medium and high rainfall zones at Port Broughton, Maitland and Riverton respectively. The aim was to determine the potential yield loss in faba bean and lentil associated with the new resistance breaking isolates of each pathogen, *Ascochyta fabae* and *A. lentis* respectively. Maitland and Riverton were sown on 26 May and Port Broughton on 14 May. Varieties and their AB resistance categories included in the trial are shown in Tables 3 & 4. Ratings were current at the time of trial inoculation but may have since changed due to the NVT Pulse Disease project ratings review. The trials were sown as a replicated split block, with fungicide as the main block and varieties randomised within each block. Two treatments were included in the trials viz. (1) chlorothalonil foliar fungicide sprayed every two weeks or (2) no fungicide.

Unsprayed plots were inoculated with a mixed spore suspension of six different pathotype 2 isolates of *A. fabae* collected from South Australia between 2013 and 2018, and nine different pathotype 2 isolates of *A. lentis* collected from South Australia between 2018 and 2019 (concentrations between $5x10^5$ and 1×10^6 spores per mL). Pathotype 2 of *A. fabae* is widespread in the southern growing region and is virulent on Farah[A] faba beans and a range of other varieties. Pathotype 2 of *A. lentis* is common in lentil growing areas of South Australia and is virulent on previously resistant varieties including PBA Hurricane XT[A] and a range of other varieties. Plants were inoculated with a backpack sprayer, 1 L per plot, on three separate occasions (2 July, 22 July and 18 August) in overcast conditions ahead of a rain front to be conducive to infection. Percent disease per plot of each trial was rated on 1 September. All trials were harvested at maturity and grain yield of each plot calculated.

Low to average rainfall conditions occurred in May and June, and July was extremely dry, limiting disease infection and spread. Rainfall was average in August and September allowing a low to moderate levels of disease to establish at Maitland and Riverton trials. Higher than average rainfall occurred in October when plants were maturing but seed infection levels were not available at the time of publication.

Results faba bean trials

Moderate levels of disease established in the Maitland and Riverton trials but very little in the low rainfall trial at Port Broughton. The three-way interaction between site x fungicide x variety for disease severity assessed on September 1 was not significant but there were significant differences (*P<0.001*) between varieties for disease severity which was consistent across sites (Table 3). The two-way interaction for site x fungicide treatment was also significant (*P<0.001*). The plots treated with fortnightly foliar fungicide across the three sites had zero disease (data not shown) while disease severity in untreated plots ranged from an average 2.4% plot severity at the low rainfall site to an average 8.3% plot severity at the high rainfall site. Highest disease severity was recorded in untreated plots of the susceptible variety Farah[A] (16.7% plot severity) and the MRMS variety PBA Marne[A] (11.7% plot severity) at Riverton. In the other varieties the disease severity averaged across sites and fungicide treatments ranged from 2.7% to 1.3% plot severity.

There are no changes to AB disease ratings for faba bean varieties for 2020 however isolate pathogenicity testing in controlled environment conditions on a differential host set was not conducted for faba bean this season. The last examination of the *A. fabae* population in 2019 of 2018-collected isolates indicated a possible third pathotype emerging in the population that is aggressive on PBA Samira[A] (Blake *et al*. 2020). PBA Amberley[A], PBA Bendoc[A] and PBA Marne[A] have not been assessed against a suite of current isolates in this manner. Continued monitoring will be critical to confirm if any further shifts are occurring in the pathogen population.

Disease

Table 3. Ascochyta blight disease severity (square root % plot severity) in untreated faba bean plots trials at three sites in South Australia 2020, incorporating 6 varieties. Raw data is in parentheses.

Site	**Fungicide treatment**	**Varieties (pathotype 2 AB rating)**					
		Farah[A] (S)	**PBA Marne[A] (MRMS)**	**PBA Samira[A] (MR-R)**	**Nura[A] (MR-R)**	**PBA Amberley[A] (MR-R)**	**PBA Zahra[A] (MRMS)**
Port Broughton	Nil	2.2 (5.0)	1.8 (3.3)	1.5 (2.3)	1.0 (1.0)	0.3 (0.3)	1.6 (2.7)
Maitland	Nil	2.8 (8.3)	2.7 (7.7)	2.2 (5.0)	1.6 (2.7)	1.4 (2.0)	1.1 (1.3)
Riverton	Nil	4.1 (16.7)	3.4 (11.7)	2.4 (6.0)	2.7 (7.7)	2.3 (5.3)	1.6 (2.7)
LSD (P<0.001) for variety = 0.35					*LSD (P<0.001) for site x treatment = 0.46*		

Table 4. Ascochyta blight disease severity (square root % plot severity) in untreated plots in lentil trials at three sites in South Australia 2020 incorporating 6 varieties. Raw data is in parentheses.

Site	**Fungicide treatment**	**Varieties (pathotype 2 AB rating)**					
		PBA Flash[A] (MS)	**PBA Hallmark XT[A] (MRMS)**	**PBA Hurricane XT[A] (MRMS)**	**PBA Highland XT[A] (MR)**	**PBA Ace[A] (R)**	**PBA Jumbo2[A] (R)**
Port Broughton	Nil	2.3 (5.3)	2.2 (5.0)	1.9 (4.0)	1.3 (1.7)	1.6 (2.7)	0.3 (0.3)
Maitland	Nil	2.9 (8.7)	2.7 (7.7)	1.8 (3.3)	0.0 (0.0)	0.8 (1.0)	0.3 (0.3)
Riverton	Nil	4.2 (18.3)	3.1 (9.3)	2.6 (7.0)	1.8 (3.7)	1.3 (1.7)	1.4 (2.0)
LSD (P=0.03) for site x treatment x variety = 1.1							

Results for lentil trials

A moderate level of AB disease established in the trials at Maitland and Riverton but very little in the low rainfall site at Port Broughton. The three-way interaction for site x variety x fungicide treatment was significant (*P=0.03*) for disease severity. All plots treated with fortnightly foliar fungicide across the three sites had zero disease (data not shown). In the plots with no fungicide, most disease (18.3% plot severity) was recorded at the high rainfall site (Riverton) on the moderately susceptible variety PBA Flash[A]. Medium levels of disease (5 - 9.3% plot severity) were recorded at the medium (Maitland) and high (Riverton) rainfall sites on the MRMS varieties *viz*. PBA Hurricane XT[A] and PBA Hallmark XT[A], and on PBA Flash[A] at the low rainfall site (Port Broughton). The moderately resistant and resistant varieties (PBA Ace[A], PBA Highland XT[A] and PBA Jumbo2[A]) had zero to low disease levels (3.7% plot severity) at all three sites (Table 4).

Annual Pathogenicity Testing of Ascochyta lentis on Lentil

SARDI's annual testing of *A. lentis* isolates included the 2019-released lentil variety PBA Highland XT[A] for the first time, in place of elite line Indianhead. PBA Highland XT[A] is rated MR to both pathotypes of AB and is likely to be widely sown across South Australia in 2021. Due to the dry season and lower AB disease pressure in 2019, fewer isolates were collected in the 2019 season thus less isolates were available for controlled environment testing in 2020.

In 2020, twenty isolates of *A. lentis* collected each in 2018 and in 2019 from lentil field trials and commercial crops (36 from SA, 4 from Victoria; n=40) were tested in controlled environment conditions on a differential host set that included Nipper[A], PBA Hurricane XT[A] and PBA Highland XT[A] (Table 5a & 5b). Of the isolates tested, 5 of 20 (25%) collected in 2018 and 7 of 20 (35%) collected in 2019, were capable of infecting PBA Highland XT[A] at a low level. This indicates that there are isolates present in the pathogen population that can overcome the resistance in that variety and may become selected for over time in intensive lentil cropping systems. PBA Hurricane XT[A] was infected by all 2019-collected isolates at a low to high level in this test confirming that the MRMS rating in SA in under threat. The number of isolates capable of infecting PBA Hurricane XT[A] has steadily increased since first tested from 28% in 2016, 50% in 2018 and 67.5% in 2019 (Blake *et al*. 2020; Blake *et al*. 2019a, Blake *et al*. 2019b, Blake *et al*. 2017). The elite line ILL7537, a source of resistance used in the breeding program, remains resistant to all isolates tested.

The newly released lentil variety, GIA Leader[A], has been released with a provisional rating of RMR to foliar AB in SA and has shown excellent resistance to both the Nipper-virulent (pathotype 1) and Hurricane-virulent (pathotype 2) strains in controlled environment testing (tested as GIA1701L).

Table 5a. Twenty **Ascochyta lentis** *isolates collected in 2018 were inoculated onto a lentil host differential set in controlled environment conditions in 2020. Entries in the table are the number of isolates per category.*

Test reaction	Cumra (susceptible check)	Nipper[A]	PBA Hurricane XT[A]	PBA Highland XT[A]	ILL7537 (resistant line)
R	0	4	7	15	20
MR	0	9	2	3	0
MRMS	4	3	7	2	0
MS	8	2	3	0	0
S	8	2	1	0	0

Note: R = resistant, MR=moderately resistant, MRMS = moderately resistant-moderately susceptible, MS = moderately susceptible; S = susceptible

Table 5b. Twenty **Ascochyta lentis** *isolates collected in 2019 were inoculated onto a lentil host differential set in controlled environment conditions in 2020. Entries in the table are the number of isolates per category.*

Test reaction	Cumra (susceptible check)	Nipper[A]	PBA Hurricane XT[A]	PBA Highland XT[A]	ILL7537 (resistant line)
R	0	5	0	13	20
MR	0	10	2	7	0
MRMS	3	5	7	0	0
MS	8	0	10	0	0
S	9	0	1	0	0

Note: R = resistant, MR=moderately resistant, MRMS = moderately resistant-moderately susceptible, MS = moderately susceptible; S = susceptible

The other new lentil release, PBA Kelpie XT[A], has been released with a provisional rating of MRMS to both pathotypes of foliar AB in SA. However, ratings for both varieties may be subject to change when more data becomes available. Growers should monitor for AB and if infection is present, plan to spray ahead of rain fronts at podding to protect the developing seed.

Faba Bean Foliar Disease: Chocolate Spot and Cercospora Leaf Spot

Chocolate spot management to maximise yield in PBA Amberley

Chocolate spot (CS; causal pathogen *Botrytis fabae*) in faba and broad beans can cause significant grain yield loss. PBA Amberley[A], released in 2019, is recognised as having some level of resistance to CS and fewer fungicide applications may be required than currently used. To quantify the grain yield losses caused by chocolate spot in PBA Amberley[A] compared to other varieties, and to develop an economic fungicide regime for this variety, a trial was conducted at both Bool Lagoon and Yeelanna. Each replicated block trial was sown to three varieties with different reactions to CS and received 4 fungicide treatments as follows; (1) nil, (2) minimum = tebuconazole (350 mL/ha) 6 weeks after sowing (WAS), (3) low cost = tebuconazole 6 WAS and at early flowering, and (4) standard = tebuconazole 6 WAS plus carbendazim (500 mL/ha) at early flowering plus additional sprays of carbendazim or procymidone (500 mL/ha) ahead of spring rain fronts (four additional sprays at Bool Lagoon and 2 additional sprays at Yeelanna). Disease was assessed three times at Bool Lagoon as % plot severity and analysed using Repeated Measures ANOVA (Table 6).

Extensive chocolate spot developed at Bool Lagoon, but no disease developed at Yeelanna, most likely due to higher rainfall at the former site, which enabled disease infection and spread. In the nil fungicide treatment, PBA Amberley[A] has less disease than both PBA Kareema[A] and PBA Bendoc[A] in the first two assessments (Table 6). By the third disease assessment, the standard fungicide treatment had significantly reduced disease severity in PBA Amberley[A] compared to the nil fungicide. No other treatments reduced disease severity in this variety. The standard treatment significantly reduced disease severity in PBA Kareema[A] compared to nil fungicide in all three assessments, while the low cost treatment (two tebuconazole sprays) also reduced disease below the nil treatment but only in the first assessment. In PBA Bendoc[A] all three fungicide treatments reduced disease compared to nil fungicide in the first assessment, while in the second assessment the standard and low cost treatments significantly reduced disease but the minimum treatment (tebuconazole at 6 WAS) was ineffective at this stage.

Table 6. Chocolate spot disease severity assessed at Bool Lagoon 2020.*

Variety	Chocolate spot disease rating	Treatment	% plot severity Individual Analysis of Variance per assessment			% Plot Severity Repeated Measures ANOVA
			23 Sept	13 Oct	27 Oct	3 assessments
PBA Amberley[A]	MR[#]	Standard	1.7 a	4.2 a	28.3 a	11.4 a
		Low cost	2.0 ab	9.3 ab	46.7 bcd	19.3 bc
		Minimum	2.3 ab	8.0 ab	38.3 abc	16.2 ab
		Nil fungicide	3.3 abc	10.5 ab	47.3 bcd	20.4 bc
PBA Kareema[A]	MS	Standard	3.7 abc	10.8 ab	34.0 ab	16.2 ab
		Low cost	4.0 bc	13.8 bc	46.7 bcd	21.5 bcd
		Minimum	6.5 de	13.3 bc	45.0 bcd	21.6 bcd
		Nil fungicide	7.7 e	20.8 cd	50.0 cd	26.2 de
PBA Bendoc[A]	S	Standard	3.3 abc	15.0 bc	50.0 cd	22.8 cde
		Low cost	5.2 cd	20.0 cd	55.0 d	26.7 de
		Minimum	5.0 cd	25.8 de	51.7 d	27.5 ef
		Nil fungicide	10.0 f	30.8 e	56.7 d	32.5 f
LSD (P<0.007)			*2.2*	*8.1*	*13.4*	*5.6*

 # provisional rating
**Different letters represent significant differences.*

By the third assessment there were no significant differences in disease across the treatments for PBA Bendoc[A]. In the repeated measures analysis, averaged across the three assessments, the standard treatment significantly reduced disease severity below the nil treatment in all three varieties. The low cost treatment also significantly reduced disease in PBA Bendoc[A]. Grain yield and seed staining levels were not available at the time of publication.

Cercospora leaf spot in faba bean

All current commercial varieties of faba beans are susceptible to cercospora leaf spot (CLS) and this disease developed in the chocolate spot trial at Bool Lagoon. Disease severity of CLS was assessed in late September. In the unsprayed plots PBA Kareema[A] had significantly more CLS than the other two varieties. The low cost and standard treatments in PBA Kareema[A] and PBA Amberley[A] had less CLS than the untreated and minimum treatments, while CLS severity did not vary in the PBA Bendoc[A] plots (Table 7).

A helpful guide for growers and agronomists to identify common faba bean diseases can be found here: http://communities.grdc.com.au/field-crop-diseases/spot-the-difference-identifying-faba-bean-diseases/. Correct identification is important as different fungicides are used to manage different fungal disease.

Disease samples of ascochyta blight and sclerotinia sought

Diseased samples of pulses with ascochyta blight or sclerotinia are sought by SARDI for GRDC-funded projects monitoring pathogen populations and changes in variety resistance. If you can help, please contact Sara Blake (email sara.blake@sa.gov.au) for a collection kit that includes sample envelopes and a return Express Post envelope.

Crop protection products

There are often changes to permits for the use of fungicides in pulse crops. See Pulse Australia's website (www.pulseaus.com.au) for current information on Crop Protection Products including Minor Use Permits, or the APVMA (www.apvma.gov.au).

Useful resources seasonal disease reports

Subscribe to SA CropWatch e-newsletter http://pir.sa.gov.au/research/services/reports_and_newsletters/crop_watch

GRDC GrowNotes:

- Chickpea: https://grdc.com.au/resources-and-publications/grownotes/crop-agronomy/chickpea-southern-region-grownotes
- Faba bean: https://grdc.com.au/resources-and-publications/grownotes/crop-agronomy/faba-bean-southern-region-grownotes
- Field Pea: https://grdc.com.au/resources-and-publications/grownotes/crop-agronomy/field-pea-southern-region-grownotes
- Lentil: https://grdc.com.au/resources-and-publications/grownotes/crop-agronomy/lentil-southern-region-grownotes

2021 SA sowing guide: https://grdc.com.au/resources-and-publications/all-publications/publications/2020/2021-south-australian-crop-sowing-guide.

Table 7. Cercospora leaf spot severity assessed at Bool Lagoon.

Variety	Treatment			
	Standard	Low cost	Minimum	Nil
PBA Amberley[A]	4.3 a	4.3 a	9.3 bc	10.0 bc
PBA Kareema[A]	5.0 a	8.3 ab	6.5 c	13.3 d
PBA Bendoc[A]	6.0 ab	6.0 ab	8.3 ab	9.3 bc
LSD (P<0.007) = 4.1				

**Different letters represent significant difference*

New pulse variety releases:

- CBA Captain[A] chickpea: https://www.pbseeds.com.au/docs/CBA%20Captain%20key%20advantages%20Victoria.pdf
- PBA Magnus[A] chickpea: https://www.pbseeds.com.au/docs/PBA%20Magnus%20kabuli%20chickpea%20brochure.pdf
- PBA Kelpie XT[A] lentil: https://www.seednet.com.au/sites/seednet/files/2020-11/documents/PBA-KelpieXT-lentil-Nov2020.pdf
- GIA Leader[A] lentil: http://grainsinnovation.com/
- GIA Ourstar[A] field pea: http://grainsinnovation.com/wp-content/uploads/2020/12/OURSTAR-AND-KASTAR-brochure-AUG-21.pdf
- GIA Kastar[A] field pea: http://grainsinnovation.com/wp-content/uploads/2020/12/OURSTAR-AND-KASTAR-brochure-AUG-21.pdf

Diagnostic plant samples can be sent by Express Post to Pulse Pathology Plant Diagnostics SARDI, Locked Bag 100, Glen Osmond, 5064. Dig up whole symptomatic and asymptomatic plants and send with roots wrapped in damp (not wet) paper towel. Send at the beginning of the week, so the parcel does not get held up in the post. Send an email to PIRSA.SARDIPulsepathology@sa.gov.au to inform that the plants are coming.

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Section 11

Pests

Establishment pests in 2020, and how to manage risk

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Key messages

- **Unusually high populations of redlegged earth mite and migratory moth/caterpillar pests attacked establishing crops on Eyre Peninsula in 2020.**
- **Don't chase this year's pest issues next year - make decisions on merit each year, as every season is different.**
- **Assess risk first, make informed decisions, then monitor.**

Why do the trial?

In 2020, unusually high populations of some insect pests attacked crops on Eyre Peninsula during establishment. This paper discusses factors that contributed to these issues, then provides advice on how to assess pest risk in advance and manage pests strategically in future years.

Crops are attacked by two broad categories of invertebrate pests:

1) **Resident pests** live within paddocks or paddock edges throughout their lifecycle, in association with the soil. Their populations are present in similar locations but varying densities from year to year. Resident pests are flightless and include earth mites, lucerne flea, weevils and other beetles, millipedes, earwigs, slaters, slugs and snails. A range of *resident beneficial* insects attack these pests, including carabid beetles, rove beetles, spiders and predatory mites.
2) **Transient pests** live on short-lived host plants within or outside paddocks, either nearby or long distances away. They are highly mobile and move into crops from alternative host plants. Transient pests include migratory moths (caterpillars are the damaging stage), and aphids. A range of *transient beneficial* insects move into crops and attack these pests, including ladybirds, hoverflies, lacewings, and parasitoid wasps. These become most abundant in spring.

Resident and transient pests require slightly different approaches to management. However, the key to all successful pest management is assessing risk first and making informed decisions. Blanket pest management approaches are unsustainable, often ineffective and not recommended.

What happened?

The crop establishment period in 2020 on Eyre Peninsula was characterised by high populations of several moth/caterpillar pest species attacking crops and pastures, and high densities of redlegged earth mite attacking emerging crops on Lower Eyre Peninsula.

The common moth/caterpillar pests (migratory) were:

- **Native budworm**, *Helicoverpa punctigera*, attacked early sown crops around Upper Eyre Peninsula. This insect is a major pest of pulse and canola crops in spring but crop damage early in the season is relatively uncommon.
- **Weed web moth**, *Achyra affinitalis*, was particularly widespread attacking medic pastures, emerging cereals and canola crop on northern Eyre Peninsula. Some pastures required treatment to control caterpillars in early May. Larvae were fast-moving and spun webs in foliage.

- **Pasture webworm**, *Hednota* sp., attacked some pastures and canola. This pest resides in silk-lined tunnels in the soil and emerges at night to feed, when they chew off leaves and drag them back to their tunnels. This pest is usually only problematic in paddocks following pasture phases but was more widespread this season.
- **Pink/brown cutworm**, *Agrotis munda*, attacked cereal crops from northern to central Eyre Peninsula. Larger larvae (>25 to 40 mm) chewed off leaves and stems near ground level, primarily crops sown into paddock areas with heavier stubble. Paddocks grazed or windrow-burned suffered less damage. Female moths prefer to lay eggs into stubble. This species is relatively common during crop establishment on Eyre Peninsula.
- **Herringbone cutworms** were observed at lower densities in canola, recognisable by their variegated colour patterns. They are less damaging than pink cutworm.
- **Armyworms** damaged some vegetative cereal crops on Eyre Peninsula during winter, causing patches of missing plants. Larger larvae (>25 mm to 40 mm) cause defoliation and sever plant stems near ground level.

These species commonly occurred in mixed populations with two or more species. The larvae feed mostly at night and are more difficult to find during the day.

The common establishment pests (resident) were:

- **Redlegged earth mite** (RLEM),*Halotydeus destructor*, occurred in unusually high densities in crops and pastures around Lower Eyre Peninsula from late May onwards, but lower densities further north. Pastures that received a well-timed TimeRite® insecticide treatment in spring 2019 experienced substantially lower densities than untreated pastures and crops. Whilst a good decision last spring, this should not be used as a basis for implementing TimeRite® across the whole farm in 2020/21! In most years, crops following a relatively weed-free crop rotation will not require TimeRite®. We discuss risk assessment further below.
- **Bryobia (clover) mites**, *Brobyia* spp., occurred early in canola crops at typical densities. This mite moves from weeds onto seedlings during warmer conditions of early autumn.
- **Vegetable weevil**, *Listroderes difficulus*, and spotted vegetable weevil, *Steriphus diversipes*, damaged canola crops in patches around the West Coast. Capeweed is a preferred host for vegetable weevil.
- **Russian wheat aphid** (RWA), *Diuraphis noxia*, remained at low overall densities in most of SA following the dry summer. In parts of northern Eyre Peninsula, the area south of Port Augusta and parts of the mid north, populations were slightly higher in spring due to a combination of factors. It was thought that significant rainfall in February 2020 in these areas caused an increase in RWA green bridge species, such as barley grass. When this green bridge matured during June and July, aphids migrated and colonized some drought-stressed crops. The effects of seed treatments had subsided, and some growers had to spray RWA when populations were above thresholds levels.

Low RWA populations on young plants will not cause significant yield loss unless there is a significant build-up of populations in spring. An economic threshold calculator for RWA is now available based on aphid observations at GS30 (See Useful Resources). Thresholds for RWA were developed by SARDI and cesar through the GRDC investment, "Russian Wheat Aphid Risk Assessment and Regional Thresholds" (UOA1805-018RTX).

What does this mean?

Moths/caterpillars (transient pests):

Unusually high moth and caterpillar activity in early 2020 is thought to have resulted from significant moth migration events in early autumn. This can occur when rainfall in inland source areas causes growth of insect host plants, warm temperatures support population build-up and flight, and suitable wind systems transport the insects into cropping zones. Evidence for migration included the sudden appearance of several migratory moth species in crops around the same time. Large flights of weed web moth and other species were recorded on Eyre Peninsula, Adelaide and the South East region in late March and early April.

Weed web moth is a native insect and although little is known of its biology, is likely to feed on native plants. Large populations of weed web moth caterpillars were reported attacking crops in southern and central NSW in March 2020. This followed significant rainfall in parts of southern Queensland and NSW during February, which likely supported population growth and migration of this insect. Weed web moths observed on Eyre Peninsula in April had tattered wings, suggesting they originated from pastoral zones some distance away. These same wind systems likely transported the other moth species, including native budworm, cutworms, webworms and armyworms, and possibly some Russian wheat aphid, into cropping areas.

Redlegged earth mite (resident pest):

Large populations of RLEM in early 2020 may have resulted from suitable weather conditions in spring 2019 and autumn 2020, both important times in the RLEM lifecycle. RLEM typically undergoes three generations during the winter cropping season. In the third generation, mites produce over-summering diapause eggs, which are retained in the body of the female. This occurs around the predicted TimeRite® spray date (15 September at Cummins). Over-summering diapause eggs hatch the following autumn when suitable conditions occur: at least 5 mm rainfall coinciding with mean daytime temperatures under 16°C for 10 days.

Parts of the Eyre Peninsula received substantial rainfall in spring 2019 (Figure 1). Moisture around the TimeRite® date can lengthen the spring growing season and lead to production of more over-summering mite eggs. In autumn 2020, high rainfall coinciding with cool temperatures occurred in late April across parts of Lower Eyre Peninsula (Figure 1), expected to have caused a synchronous hatching of RLEM during crop emergence. In years with a less synchronous autumn break, RLEM hatching occurs in a more staggered fashion, leading to lower initial densities and allowing crops to out-grow some early damage.

Recommended future approach

The key message is not to assume pest issues in 2021 will be the same as those experienced in 2020. While it can be tempting to implement blanket and/or widespread control measures following a higher pest pressure year, chasing last year's pest problems the following season is rarely successful. Every season brings different pest issues and blanket approaches are not sustainable. We advise making strategic decisions by assessing risk on a seasonal basis.

New resources are available to assist growers assess risks before sowing and throughout the season. Best Practice Management Guides were recently developed for redlegged earth mite, green peach aphid and diamondback moth, each including a Risk Assessment Guide and podcast (see Useful Resources). Growers and agronomists are encouraged to familiarise themselves with the guides and incorporate them into pre-season farm/paddock planning.

Some general factors that contribute to seasonal risk of establishment pests include:

- Green bridge vegetation during February to May, driven by rainfall, supports aphids and diamondback moth (DBM), as well as some resident pests. In general, more green bridge increases risk of aphid/DBM risk, and scarce green bridge leads to low risk for these pests.
- For resident pests, paddock history (i.e. previous pest problems, crop rotations, weed control, insecticide use and seasonal conditions) all contribute to seasonal risk. See the pest guides in Useful Resources.

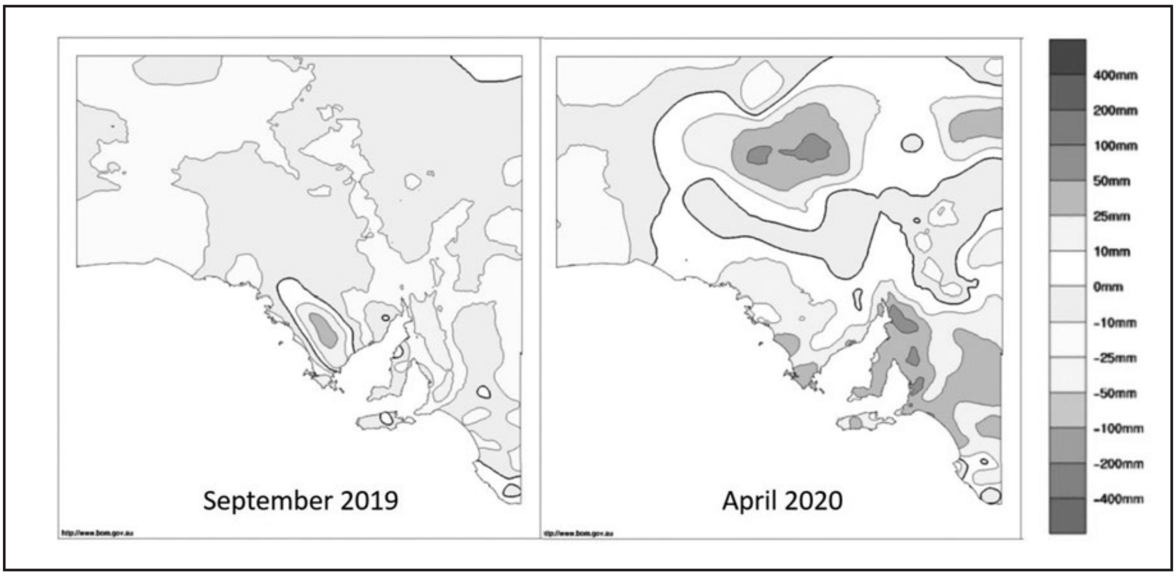

Figure 1. Monthly rainfall anomalies showing above-average rainfall on parts of Eyre Peninsula during spring 2019 and April 2020. This contributed to high populations of redlegged earth mite in autumn 2020. Colour maps can be sourced from the Australian Bureau of Meteorology http://www.bom.gov.au/climate/maps/

Moth/caterpillars and aphids

Transient species are difficult to predict in advance but easy to manage if detected early. Standard insecticides can be applied to infested areas as warranted. Moth flights are a prompt to monitor crops for caterpillar activity several weeks later. Early detection can be achieved by keeping an eye out for moth flights, monitoring emerging crops, and subscribing yourself (and/or your advisor) to free regional notification services such as PestFacts South Australia newsletter. This service relies on your reports.

Will the moth/caterpillar pests be a problem again in 2021? By their very nature, issues with transient pests are transient. Migratory species tend to occur in boom/bust cycles. Typically, they arrive suddenly in large numbers, breed locally through a generation, then new adults disperse elsewhere. Immigrant moth populations generally do not persist locally in any substantial numbers beyond a single generation, as their primary habitat occurs in inland source areas. Migrations would need to occur again in 2021 for these pests to be problematic. While migrations of the scale observed in 2020 are relatively uncommon, monitoring and early detection is the key to successful management.

For aphids, the abundance of green bridge vegetation is important. Lack of green bridge during late summer and autumn indicates low seasonal risk. Under these conditions, seed treatments for RW aphid control in cereals are not warranted in most instances. If RW aphid build-up occurs after emergence, this pest can be easily controlled using registered insecticides. If there is substantial green bridge, there is a higher risk of RW aphid and green peach aphid (see Useful Resources).

Redlegged earth mite

By contrast, resident pests can be more easily predicted in advance. The keys are assessing paddock risk before sowing, monitoring emerging crops, and correctly identifying species before deciding on control. Different earth mite species have differences in tolerance to insecticides. TimeRite® is effective only on redlegged earth mite and is not effective for other mites or lucerne flea.

For RLEM, risk of high mite populations depends on last year's crop/pasture type, weed status, seasonal conditions and RLEM numbers, and the susceptibility of the next planned crop. A well-timed spring spray according to the TimeRite® strategy can be effective but should be reserved only for high-risk situations (e.g. planting canola after a legume-based pasture). Some crops, such as lentils and chickpeas, are poor RLEM host plants and in weed-free paddocks, low RLEM numbers can typically be expected the year following these rotations. Plan autumn insecticide strategies according to paddock risk, using the RLEM Risk Assessment Guide (Useful Resources). Avoid pre-emergent insecticides in low risk situations. Monitor susceptible crops closely in the first 3-5 weeks after emergence. If insecticides are warranted, follow guidelines in the Resistance Management Strategy for Redlegged earth mite.

Every season brings different pest management challenges. The key to successful pest management is assessing and managing risk. It is important to avoid chasing this year's pest issues next year - assess each season on its own merits.

Acknowledgements

We thank GRDC for their continued support, and agronomists and growers for their observations. GRDC Project codes: UOA1805-018RTX, CES1904-002RTX

Useful resources

- PestFacts South Australia e-newsletter, and Twitter @PestFactsSARDI https://www.pir.sa.gov.au/research/services/reports_and_newsletters/pestfacts newsletter
- Redlegged earth mite, Best Management Practice and Risk Assessment Guide https://grdc.com.au/news-and-media/audio/podcast/using-all-our-tools-for-pest-management-redlegged-earth-mite
- Redlegged earth mite, Resistance Management Strategy
- https://grdc.com.au/FS-RLEM-Resistance-strategy
- Green peach aphid, Best Management Practice and Risk Assessment Guide https://grdc.com.au/news-and-media/audio/podcast/using-all-our-tools-for-pest-management-green-peach-aphid
- Diamondback moth, Best Management Practice and Risk Assessment Guide: https://grdc.com.au/news-and-media/audio/podcast/using-all-our-tools-for-pest-management-diamondback-moth
- Economic threshold calculator for Russian wheat aphid
- https://pir.sa.gov.au/research/services/pest_management/rwa_action_threshold_calculator

Russian wheat aphid thresholds - insect density, yield impact and control decision making

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Paper presented at GRDC Update 2021

Key messages

- **Russian wheat aphid (RWA) risk from 'natural invasion' (as opposed to inoculated insect pressure) was non-significant in all 28 trials in 2018 and 2019.**
- **RWA yield impact is 0.28% yield loss per percent of tillers with RWA (%TwRWA).**
- **After GS30 (start of stem elongation), the number of tillers with RWA doubles about every 35 days, thus doubling %TwRWA.**
- **The RWA action threshold calculator is now available on-line and supports adoption of an IPM approach.**

Why do the trial?

This project studied the risk of infestation by the Russian Wheat Aphid (RWA, *Diuraphis noxia* Kurdjimov) and its effect on yield to develop best management practices in an Australian context of winter cropping of short cycle cereals (e.g. spring wheat). Risk of yield loss depends on aphid invasion, subsequent pest development and sensitivity of the crop to the pest.

How was it done?

Previously, there were no data available for quantitative and qualitative yield effects of RWA and the development of intervention thresholds in Australian cereal growing conditions. Overseas data, from North America and South Africa, where RWA has been present for many decades (Archer and Bynum 1992; Du Toit and Walters 1984; Du Toit 1986; Bennett 1990a,b; Kieckhefer and Gellner 1992; Girma *et al* 1990, 1993, Mirik *et al* 2009, Legg and Archer 1998, Chander *et al* 2006), report a wide range of potential damage levels (yield loss and qualitative losses) and derived economic injury levels. Losses of around 0.5% of yield loss per percentage of RWA infested tillers during stem elongation and grain filling are most frequently reported (Archer and Bynum 1992).

These knowledge gaps were addressed through:

1) 28 natural RWA infestation field trials in 2018 (15) and 2019 (13) in South Australia, Victoria, New South Wales and Tasmania (Table 1).
2) 15 RWA inoculated field trials in 2018 (5) and 2019 (10) where 50 RWA/m^2 (500,000 RWA/ha) were applied at GS15-20 (2-4 leaf stage, Table 1).
3) Green Bridge sampling of grasses during the non-cropping period in both years in all states and extensive continuous sampling of grasses in SA over 26 months (March 2018-May 2020).

What happened?

Risk of RWA invasion of crops: Overall RWA risk was very low during these two (very dry) years with no significant RWA infestation occurring in any of the non-inoculated field trials. This shows that the largely adopted use of prophylactic seed treatments against RWA was not justified.

Yield loss in inoculated trials: Regional and varietal differences were large (Figure 2). In some, but not all, of the inoculated field trials RWA populations reached population levels (maximum observed between GS40 and 50) resulting in yield loss. The best predictor of yield loss of various aphid pressure metrics was the maximum percentage of tillers with RWA present (%TwRWA) and a percentage of the potential yield loss with a 0.28% yield loss observed for every %TwRWA. This simple relationship applied to all the different cereal types (wheat, barley, durum wheat), years and regions (through the adjustment of potential yield), oats did not allow RWA development. This yield impact is significantly lower than described for the USA (0.46-0.48% for every %TwRWA, Archer and Bynum 1992).

From this equation, the economic threshold (the break-even point of yield loss and control measures) can be calculated depending on the costs of control (pesticide, applications costs), the expected yield (region and year dependant) and the farm-gate price of the crop as parameters (Figure 5).

Table 1. Location of trial sites in 2018 and 2019.

Site Name	State	Lat	Long	Inoculation	Irrigation
2018					
Birchip	VIC	-35.9666	142.8242	Y	N
Cummins	SA	-34.3050	135.7189	N	N
Griffith	NSW	-34.1902	146.0920	Y	N
Hillston	NSW	-33.5482	145.4408	N	Y
Inverleigh	VIC	-38.1805	144.0390	N	N
Keith	SA	-36.1299	140.3233	Y	N
Lockhart	NSW	-35.0837	147.3280	N	N
Longerenong	VIC	-36.7432	142.1135	N	N
Loxton	SA	-34.4871	140.5891	Y	N
Minnipa	SA	-32.8398	135.1642	N	N
Nile DRY	TAS	-41.6759	147.3140	N	N
Nile IRR	TAS	-41.6759	147.3140	N	Y
Piangil	SA	-35.0519	143.2758	N	N
Riverton	SA	-34.2193	138.7350	Y	N
Yarrawonga	NSW	-36.0484	145.9833	N	N
2019					
Birchip	VIC	-35.9666	142.8242	Y	N
Bundella	NSW	-31.5851	149.9064	N	N
Cressy	TAS	-41.7854	147.1134	Y	N
Eugowra	NSW	-33.4944	148.3192	N	N
Griffith	NSW	-34.1902	146.0920	Y	N
Horsham	VIC	-36.7432	142.1135	Y	N
Inverleigh	VIC	-38.0497	144.0104	Y	N
Loxton	SA	-34.4871	140.5891	Y	N
Minnipa	SA	-32.8398	135.1642	Y	N
Mildura	VIC	-34.2627	141.8535	Y	N
Pt Broughton	SA	-33.5757	137.9987	Y	N
Thule	NSW	-35.6491	144.3914	Y	N
Yarrawonga	NSW	-36.0484	145.9833	N	N

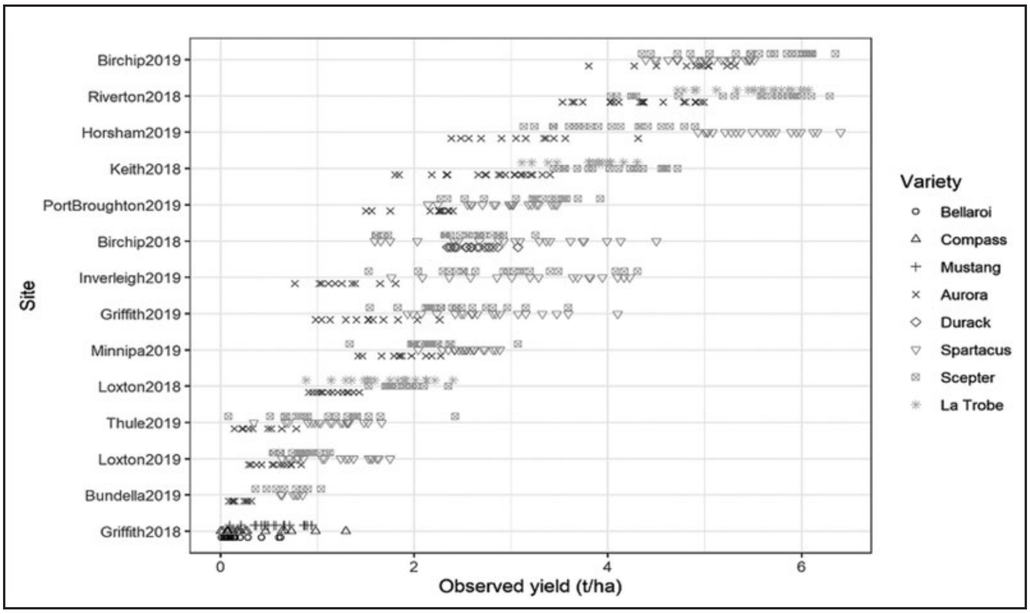

Figure 2. Yield across all trial sites and years with different cereal type/variety denoted by different markers. Varieties used: Barley: Compass; Spartacus CL, La Trobe; Durum wheat: EGA Bellaroi, DBA Aurora; Wheat: Scepter, Mustang; Oat: Durack.

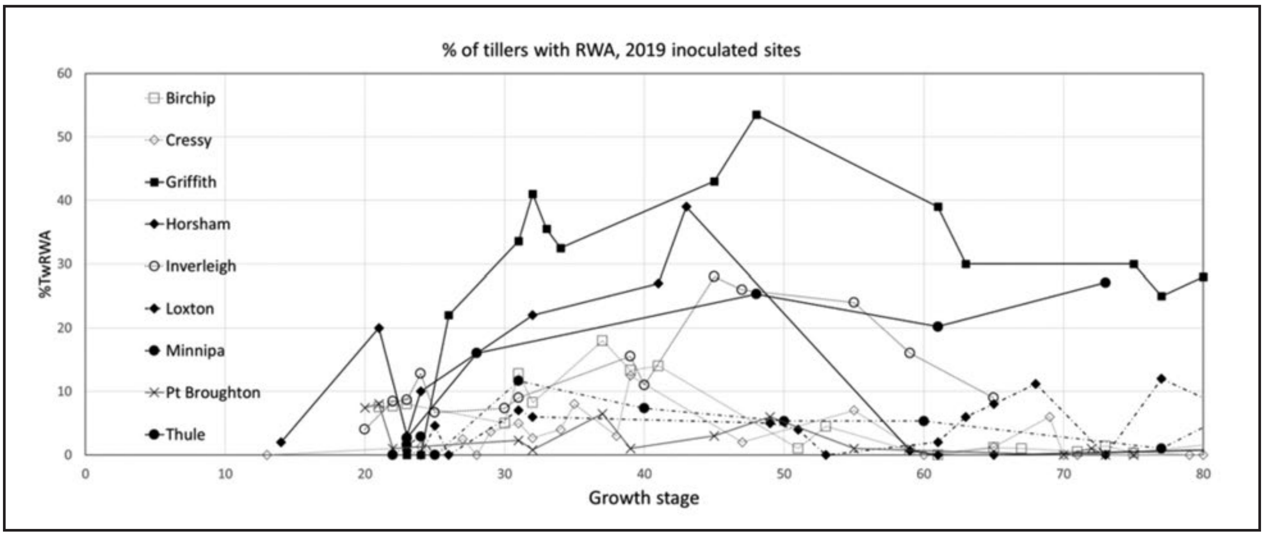

Figure 3. Percentage of tillers with RWA (%TwRWA) against growth stage for the RWA inoculated untreated control plots (AI-UTC) in all inoculated trial sites in 2019.

RWA population development: After inoculation with RWA, the highest RWA populations developed in drier regions, through a combination of increased RWA establishment during inoculation and increased rates of subsequent population increase. Less tillering in dry areas also contributed to a higher %TwRWA. The maximum population of RWA and the maximum %TwRWA was reached between GS40 and 50 (Figure 3) followed by a decrease. Between the end of tillering (GS30) and GS50 an increase in the %TwRWA of 0.021%/day was observed. This would result in a doubling of the %TwRWA every 35 days.

Action threshold calculator: Based on these observations and equations, we propose a decision rule (action threshold, Figure 4) for RWA management using an observation of the percentage of tillers with symptoms and the %TwRWA at GS30. This observation and the expected increase in %TwRWA (based on the expected time to ear emergence GS50), inform the need for management action, which can (if needed) be combined with existing treatments at GS32-35, thus reducing application costs. Growers and advisers are directed to the GRDC calculator (see additional resources) to calculate thresholds for their growing conditions.

Green bridge risk: The environmental conditions over summer that form a 'green bridge' of suitable (grass) habitat between winter crops were expected to determine the risk of early colonisation events.

Field surveys during the spring to autumn periods demonstrated RWA detections being particularly common and with high populations during spring in the warm dry grain growing regions of northern Victoria, southern New South Wales and South Australia. During the summer, growing crops and green vegetation for most grass species disappeared and RWA populations declined (Figure 5). Apart from volunteer cereals (wheat and barley), the majority of RWA detections were on five grass genera (barley grass, *Bromus* sp., phalaris, ryegrass and wild oat).

Barley grass (*Hordeum leporinum*) and (to a lesser extent) Brome grasses (*Bromus* sp.) were the host plants that showed the highest combination of abundance, positive RWA detection frequency and aphid numbers. These introduced species are not summer active in low rainfall areas. In low rainfall areas, the native *Enneapogon nigricans* (bottle-brush) is the most important summer refuge because of its widespread distribution (207 samples collected from 135 sites) and summer growth pattern. Grazing and water availability (irrigation) can make some host grass populations, including prairie grass, couch grass, ryegrass and volunteer cereals, persist in summer. The presence of irrigated crops increased the likelihood of RWA detections 1.6-fold over the green bridge.

Early rainfall in late summer/ autumn, 2-3 months before sowing, could cause RWA population to build up on grasses and cereal regrowth, potentially exacerbating early crop invasions. A 250 mm high rainfall event in the Birchip area (Vic) in December 2018 did cause significant development of a green bridge, but did not seem to result in increased RWA risk. Reports in 2020 from the Port Augusta area (SA), where a significant summer rain occurred on February 1, suggested an increase in RWA pressure.

This shows that observations, especially in early break years and better understanding of aphid population dynamics and migration on the green bridge before and after sowing, are needed to obtain more precision on the impact of the green bridge and the risk and timing of crop invasion.

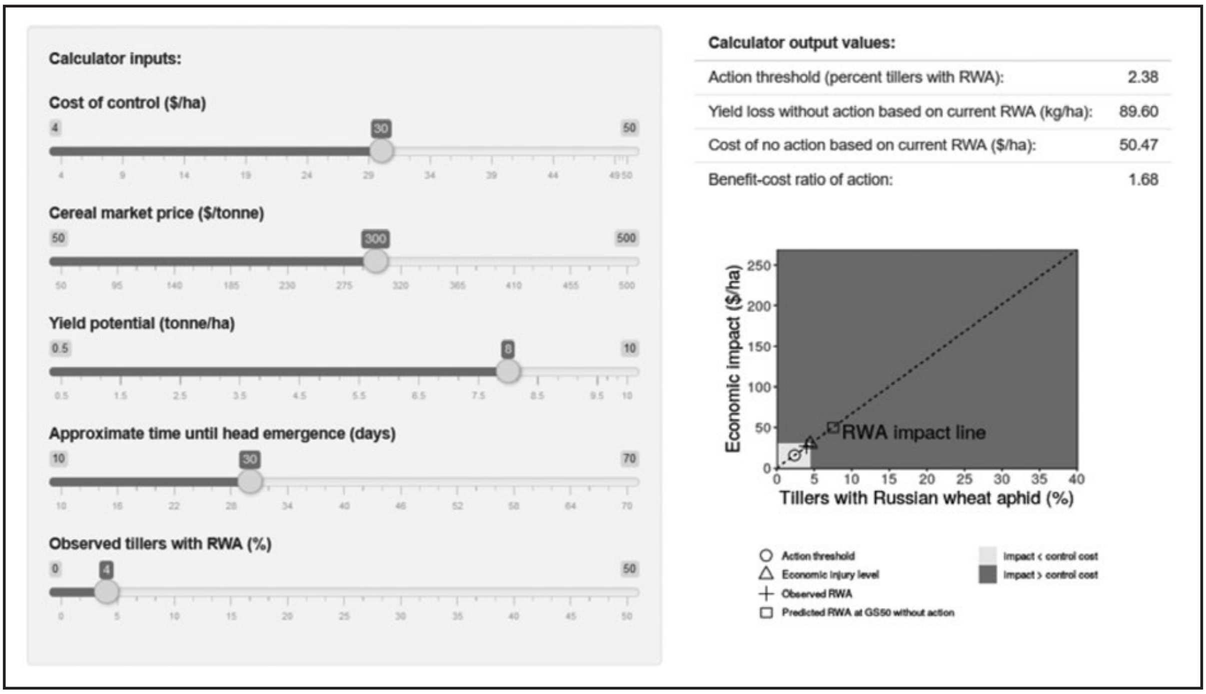

Figure 4. RWA action threshold calculator (example)

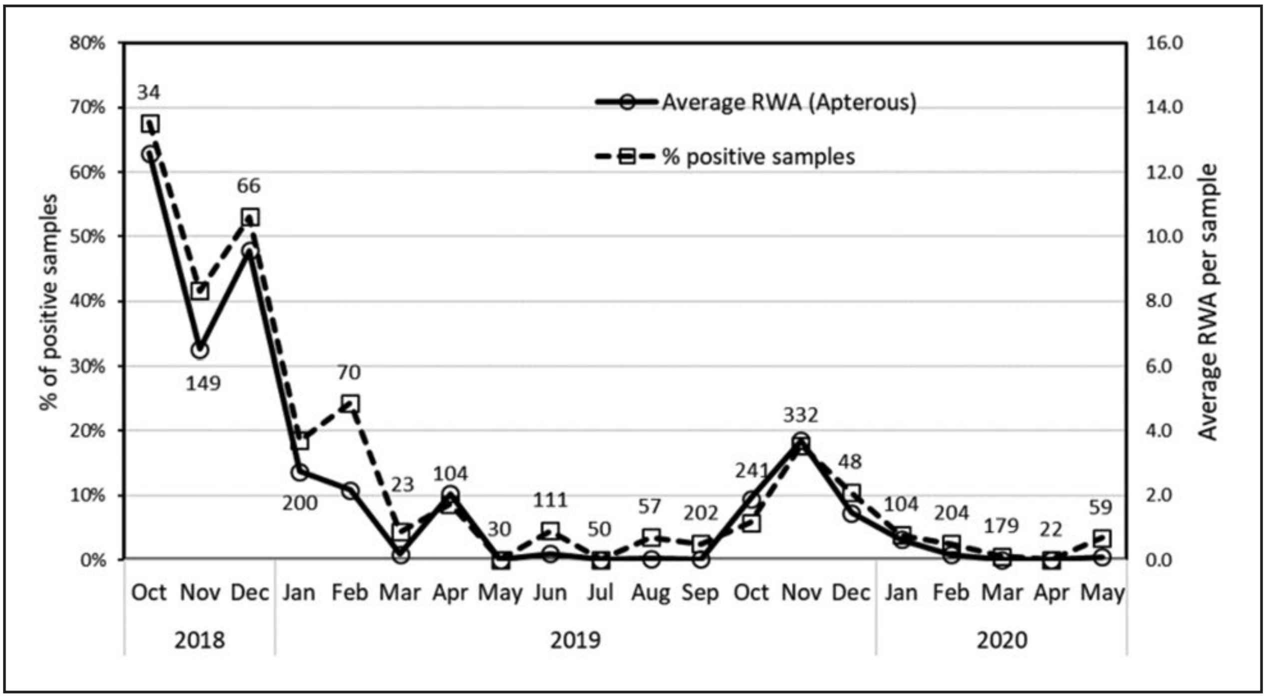

Figure 5. Dynamics of the percentage of positive samples (dotted line, left axis) and average RWA per sample (Solid line, right axis) over time in SA. Samples were 2 litres of grass extracted in a Berlese funnel. Numbers above markers show number of samples taken per month. n = 2285

A 'wetter' year with a higher green bridge, or if immigration of aphids occurs at a higher level for some other reason, might increase aphid colonisation, but will not automatically result in higher impact of RWA. Wetter and colder conditions are less favourable for RWA development in the crop (as can be seen from the Tasmanian trials), through a combination of slowing down population development, improving the crop development which will better resist RWA, and more tillering (diluting the aphid numbers over a lower % of tillers. The two experimental years experienced generally low levels of growing season rainfall, so RWA development in the crop (after inoculation) was probably maximal on these often drought stressed crops.

Crop sensitivity: Similar yield impact and aphid population development was observed for all crops tested, except for oats which is known not to be an RWA host. However, crop and varietal differences in RWA *establishment* are likely to exist and have been reported. Also, the crop condition (growth stage, level of tillering, drought stress, nutritional stage) will play a role in RWA *development* and could change the probability of reaching above threshold populations.

What does this mean?

RWA ecology and yield impact in Australia are now somewhat better understood. This allows growers and agronomists to manage RWA more sustainably and economically. Management based on observations and regionally adapted decision rules, rather than an over-reliance on prophylactic seed treatments, will increase profitability, minimise chemical inputs and reduce off-target risks and resistance development.

The two years during which this study was done were very dry, with hot summers and growing seasons, and were generally unfavourable for RWA survival over summer, but favourable for the development of RWA in the inoculated trials (Baugh and Phillips 1991, De Farias *et al*. 1995). Some anecdotal observations in 2020, and in the few years that RWA is known to be present (since 2016, Ward *et al* 2020, Yazdani *et al* 2018), do suggest that the population levels will be very different (but not necessarily more damaging) with different rainfall patterns. More experience and research are needed to better understand RWA ecology and would enable further improvement to management guidelines.

The geographical distribution of RWA is expected to increase further into northern NSW and Queensland (Avila *et al*. 2019), and RWA was detected in Western Australia in 2020. Different growing conditions (temperature, drought) and presence of other cereal crops, including summer cereals (rice, corn, sorghum, millet), and other grass hosts could alter the risk of RWA in those regions.

SARDI staff undertaking soil characterisations at Mt Dutton, 2020.

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Additional resources:

https://grdc.com.au/resources-and-publications/resources/russian-wheat-aphid

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Varieties displaying this symbol beside them are protected under the Plant Breeders Rights Act 1994.

Movement, breeding, baiting and biocontrol of Mediterranean snails

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Key messages

- **Extensive datasets highlight that baiting programs should be focused during March to June.**
- **Snails move in response to increases in relative humidity at ground level from late summer through autumn, providing early baiting opportunities.**
- **Rule-of-thumb guidelines for movement of vineyard, Italian and small pointed snails were generated from analysis of time lapse video data.**
- **An introduced parasitoid fly, *Sarcophaga villeneuveana*, parasitises up to 48% of conical snails in local areas of SA near favourable species mixes of native vegetation.**

Background

This paper reports findings from GRDC research projects focused on improving molluscicidal control (DAS00160) and biocontrol (UOA1903-014BLX (9177340), CSE00061-PYC106)) of Mediterranean pest snails. Molluscicidal baiting is an important component of integrated snail control but provides variable levels of control despite high cost (Baker *et al*. 2017). An introduced parasitoid fly, *Sarcophaga villeneuveana*, attacks two conical snail species, *Cochlicella acuta* and *C. barbara*, with limited impact to date. Developing improved management tactics for snails remains a priority to improve growers' profitability and reduce market access risks caused by snail contamination of the grain harvest.

The GRDC project, 'Biology and management of snails and slugs in grain crops' (GRDC project: DAS00160, 2017-2020), led by SARDI in collaboration with DPIRD, generated new biological knowledge of pest snails and slugs, specifically their movement behaviour and reproductive activity, to assist growers to optimise the timing of baiting programs. Efficient baiting must target adult snails before most reproduction occurs. Effective baiting to ensure snails encounter pellets requires snail movement, which must be predicted before application. This project investigated the environmental triggers for mollusc movement to provide better predictive capacity. This paper presents the results for snails.

The GRDC project, 'Snail biocontrol revisited - Phase II' (GRDC project: CSE00061-PYC106; 2019 - present), led by CSIRO in collaboration with SARDI, is investigating whether strains of the parasitoid fly, *S. villeneuveana*, sourced from Mediterranean regions more closely aligned with the geographic origins of Australian *C. acuta*, can improve biocontrol of this species. Project results are presented elsewhere. New data generated by SARDI describing existing levels of biocontrol of *C. acuta* by *S. villeneuveana* in SA (SARDI-GRDC project: UOA1903-014BLX (9177340)) are presented here.

This paper summarises selected findings with relevance for management. Comprehensive datasets and analyses are presented elsewhere and in project final reports (Perry *et al*. 2020a, Perry et al. 2020b, Caron *et al*. 2020; see Further Reading).

How was it done?

Snail breeding seasons

The reproductive cycles of three snail species were studied at four SA and four WA locations between 2017 and 2020 for periods from 2-4.5 years. Target species were the vineyard snail (*C. virgata*) at three SA sites and one WA site, the white Italian snail (*T. pisana*) at one SA site, and the small pointed snail (*C. barbara*) at three WA sites (Table 1). Nine-month datasets were collected for *C. virgata* and *C. acuta* at three additional SA sites (for brevity, not presented). Samples of ≈50 adult-sized snails were collected approximately monthly, then measurements of shell height and albumen gland length (after dissection) recorded for each individual snail, yielding observations for 12,914 snails. Snails in a reproductive state have swollen albumen glands.

Snail movement and microclimate

Movement behaviour of snails was studied at ten locations in SA and WA (seven sites in Table 1 with exception of Manoora, plus three other SA sites) between 2015 and 2020 for periods from 9 months to 4.5 years. Time lapse video footage was collected continuously at 1-minute intervals and microclimate variables (e.g. soil water content at 10 cm depth, soil surface wetness, ground level relative humidity and temperature, and others) were logged at 30-minute intervals.

Video footage was analysed using computer vision techniques developed by collaborators at University of South Australia (Ivan Lee *et al*.), yielding 103,228,235 observations of individual movement distance per frame. Manual ground-truthing estimated that autodetection accuracy was ≈85% for the round snail species but <40% for small pointed snails due to greater detection challenges. Movement data were statistically analysed to determine microclimate conditions that best explained low or high snail movement at different times of the year.

What happened?

Snail breeding seasons

The three snail species, *C. virgata*, *T. pisana* and *C. barbara*, demonstrated strongly seasonal reproductive cycles with breeding seasons extending from autumn to spring (Table 1). On average, the main breeding seasons were March to late September for *C. virgata*, late February to late July for *T. pisana*, and March to October, sometimes extending into late November, for *C. barbara* in WA (Table 1). Limited data at three SA sites (4-8 months between July 2019 and March 2020) for the conical snail, *C. acuta*, suggested most breeding commenced sometime after March in 2020.

For each snail species, the timing of reproductive activity varied between seasons and/or locations, reflecting that species' activity depends to some extent on local environmental conditions. However, relationships between reproductive activity and prior rainfall or other measured climate and microclimate variables (such as soil water content, soil surface wetness, and relative humidity and temperature at different heights above ground level) were not always clear, suggesting that reproductive cycles have an underlying seasonal basis. We found no evidence of significant breeding activity from late spring to summer for any snail species during this study, even when substantial movement occurred following spring or summer rainfall.

Snail movement and microclimate

In general, snails became increasingly responsive (moved) to increases in ground level relative humidity from late summer through autumn. Other microclimate variables and interactions between variables were associated with high/low movement, however these relationships were less clear (Perry *et al*. 2020b). For simplicity, rule-of-thumb guidelines for snail movement with respect to relative humidity were generated from the data (Table 2). These guidelines are simply a set of hypotheses generated from the available data and should be tested and refined over time under field conditions. There is greater confidence in the information for the round snails, *C. virgata* and *T. pisana*, than for small pointed snails, based on higher detection accuracy.

Table 1. Breeding seasons by species.

Species	Study location	Study years	Breeding season average	Breeding season range
Vineyard snail, *Cernuella virgata*	SA - Palmer	2015 - 2018	Mar to Sep	Feb/Mar to Jul/Oct
	SA - Manoora	2015, 2017, 2018	Mar to Oct	Mar/Apr to Oct/Nov
	SA - Urania	2018 - 2020	Apr to Sep	Mar/May to Aug/Oct
	WA - Gairdner	2017, 2018	Mar to Oct	Feb/Mar to Oct/Nov
	4 sites	12 years	**Mar to Sep**	
White Italian snail, *Theba pisana*	SA - Warooka	2015 - 2018	Feb to Jul	Jan/Feb to Jul/Aug
	1 site	4 years	**late Feb - late Jul**	
Small pointed snail, *Cochlicella barbara*	WA - Esperance Marshall	2018	Jan to Sep	
	WA - Esperance Perks	2017, 2018	Mar to Sep	Feb/Apr to Sep/-
	WA - Woogenellup	2017, 2018	Mar to Nov	Mar/Apr to Nov/-
	3 sites	5 years	Mar to Oct	

Table 2. Rule-of-thumb levels of relative humidity at ground level associated with the highest observed movement.

Species	Feb	Mar	Apr	May	Autumn
Vineyard snail	>95 %	>90 %	>80-85 %		>85-95 %
Italian snail	>90 %	>90 %	>85-90 %		>88 %
Small pointed snail		>95 %	>95 %	>95 %	>95 %

What does this mean?

Implications for bait timing

All datasets together highlighted that baiting programs targeting *C. virgata*, *T. pisana*, and *C. barbara* should be concentrated during the autumn and early winter period, from approximately March to June, prior to most reproduction, to maximise cost-efficiency. There are several reasons for this recommended timing: (1) Snails showed higher susceptibility to bait toxins during this period than during non-reproductive periods (see Brodie *et al*. 2020, Perry *et al*. 2020); (2) Snails feed voraciously on baits immediately after exiting summer aestivation; (3) Most offspring are produced during the early phase of the breeding season; Targeting adult snails before most eggs are laid minimises offspring production; (4) Baiting prior to crop sowing minimises soil surface obstacles and alternative food sources (e.g. crop seedlings), thereby increasing the chance of bait encounter.

We recommend that growers commence monitoring for baiting opportunities from late summer, approximately February onwards, as snails move opportunistically in response increased moisture or relative humidity at this time. Baiting from January or earlier is likely to be less efficient because: (1) Snails may be less susceptible to bait toxins than during their reproductive periods; (2) Exposure of bait pellets to high temperatures (>35°C) can cause loss of active ingredient (Baker *et al*. 2017); (3) Baiting too early increases the chance of killing some snails that would otherwise die naturally from heat/dry stress (e.g. Perry *et al*. 2020a), wasting bait. We suggest baiting programs should generally cease by mid-winter or earlier as later applications are less efficient. Instead, baits should be used earlier in the season or in the following season during the optimal windows.

Time lapse video showed that initial increases in movement during late summer through autumn occurred mostly overnight (not shown). To detect this movement and confirm whether snails are feeding, growers can deploy small areas of bait in infested areas prior to widespread application.

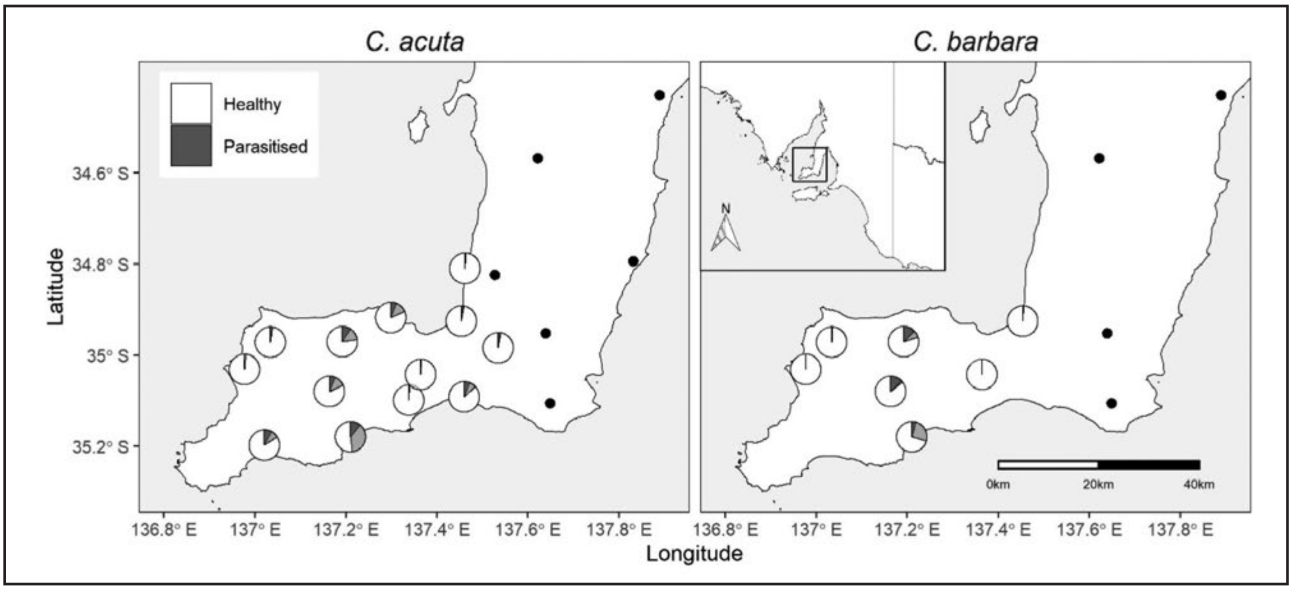

Figure 1. Parasitism levels of conical C. acuta and C. barbara by the parasitoid fly, S. villeneuveana. Pies show the proportion mean overall parasitism (red shading) or maximum parasitism observed on a single sampling date (pink shading) at sites where S. villeneuveana was present, while black dots indicate absence of S. villeneuveana at a sampled site.

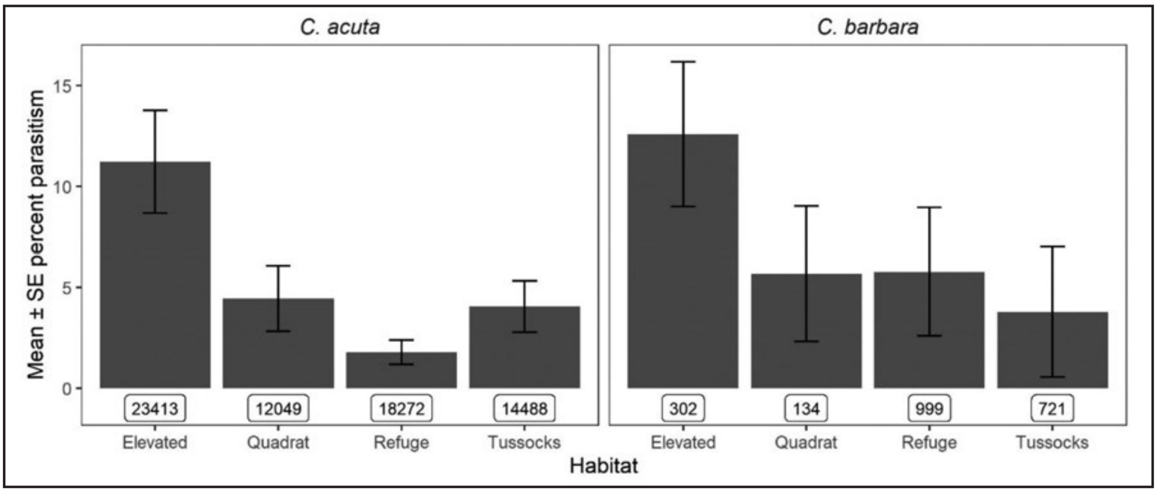

Figure 2. Parasitism of conical snails by S. villeneuveana in four microhabitats in 2019 and 2020. Sample sizes per category are shown in boxes.

Biocontrol of conical snails

The fly, *Sarcophaga villeneuveana*, is a specialist parasitoid of the conical snail, *C. acuta* and small pointed snail, *C. barbara*. Strains of *S. villeneuveana* were sourced from the Montpellier region, France, and introduced into South Australia by SARDI and CSIRO between 2001-2004 for biocontrol of *C. acuta* (Leyson *et al*. 2003). The fly successfully established on southern Yorke Peninsula but exhibited limited spread and impact, with pre-2018 levels of *C. acuta* parasitism estimated at <2% (SARDI unpublished). A current GRDC project (CSE00061-PYC106, 2019-present), conducted by CSIRO and SARDI, has focused on enhancing biocontrol success by introducing *S. villeneuveana* sourced from areas of Spain and Morocco better matching the geographic origins of Australian *C. acuta* (Jourdan *et al*. 2019). In 2020, Moroccan fly strains were imported by CSIRO and reared in quarantine facilities at SARDI for evaluation of host specificity prior to seeking approval for a rear-release program.

To enable assessments of the impact of future fly releases, SARDI generated baseline data on the current level of conical snail parasitism by *S. villeneuveana* (project: UOA1903-014BLX (9177340)). In January and April of 2019 and 2020, *C. acuta* and *C. barbara* were collected from 19 sites on Yorke Peninsula and from four different microhabitats: 1) ground-level, in quadrats; 2) elevated (e.g. on plants, stubble and fence posts); 3) at the base of tussocks, plants and grasses; and 4) under refuges (e.g. logs and rocks). Snails were returned to the laboratory, reared and examined for parasitism.

From 85,673 *C. acuta* and 2,412 *C. barbara* of suitable size (> 5 mm) assessed for parasitism, *S. villeneuveana* was detected in snails from 13/19 sites (Figure 1). At sites where *S. villeneuveana* was detected, overall parasitism was 2.8% for *C. acuta* and 3.4% for *C. barbara*. Mean parasitism rates were significantly higher for *C. acuta* snails on elevated substrates (10.8%) than at the base of plants (4.1%), at ground level (4.4%) or under refuges (1.7%) (Figure 2.). At individual sites and sampling dates, parasitism ranged from 0-48% for *C. acuta* and 0-27% for *C. barbara*. Higher parasitism levels were observed at sites adjacent to native vegetation flowering during periods of fly activity (spring/ summer), suggesting vegetation provides food and/or shelter resources.

Conclusions

Findings from DAS00160 generated a sound evidence base underpinning best practice snail management and provided growers with new information to refine their baiting strategies. Additionally, novel infrastructure (methods, analyses) for mollusc movement studies were also developed for future use. Further development is required to improve computer vision detection accuracy for conical snail species, and to generate deeper understanding of their movement and management. It was discovered that the introduced parasitoid fly, *S. villeneuveana*, performs well in the Yorke Peninsula climate in local areas with suitable habitat. Furthermore, *S. villeneuveana* attacks *C. barbara* at similar rates to *C. acuta* and is therefore suitable for release in other regions (e.g. including Western Australia) for biocontrol of either species.

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Further reading

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Chemical product trademark list

Knock Down + Spikes

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Acronyms and abbreviations

ABA	Advisory Board of Agriculture
ABARES	Australian Bureau of Agriculture and Resource Economic and Sciences
ABS	Australian Bureau of Statistics
ADWG	Average daily weight gain
AFPIP	Australian Field Pea Improvement Program
AGT	Australian Grain Technologies
AH	Australian Hard (Wheat)
AIR EP	Agricultural Innovation and Research Eyre Peninsula
AM fungi	Arbuscular Mycorrhizal Fungi
APSIM	Agricultural Production Simulator
APW	Australian Prime Wheat
AR	Annual Rainfall
ASW	Australian Soft Wheat
ASBV	Australian Sheep Breeding Value
AWI	Australian Wool Innovation
BCG	Birchip Cropping Group
BYDV	Barley Yellow Dwarf Virus
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
DAS	Days After Sowing
DAP	Di-ammonium Phosphate (18:20:00)
DCC	Department of Climate Change
DEWNR	Department of Environment, Water and Natural Resources
DGT	Diffusive Gradients in Thin Film
DM	Dry Matter
DMD	Dry Matter Digestibility
DOMD	Dry Organic Matter Digestibility
DPI	Department of Primary Industries
DSE	Dry Sheep Equivalent
DUL	Drained Upper Limit
EP	Eyre Peninsula
EPFS	Eyre Peninsula Farming Systems
EPL	Eyre Peninsula Landscapes Board
EPR	End Point Royalty
GA	Gibberellic Acid
GM	Gross Margin
GRDC	Grains Research and Development Corporation
GS	Growth Stage (Zadocks)
GSR	Growing Season Rainfall
HLW	Hectolitre Weight
IP	Inclusion Plates
IPM	Integrated Pest Management
LEP	Lower Eyre Peninsula
LSD	Least Significant Difference
LW	Live weight
MAC	Minnipa Agricultural Centre
MAP	Monoammonium Phosphate (10:22:00)
ME	Metabolisable Energy
MED	Molar Ethanol Droplet
MIR	Mid infrared
MLA	Meat and Livestock Australia
MRI	Magnetic Resonance Imaging
NDF	Neutral Detergent Fibre
NDVI	Normalised Difference Vegetation Index
NLP	National Landcare Program
NRM	Natural Resource Management
NVT	National Variety Trials
OM	Organic Matter
PAWC	Plant Available Water Capacity
P	Probability
PBI	Phosphorus Buffering Index
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
UAN	Urea Ammonium Nitrate (42.5:0:0:0)
UNFS	Upper North Farming Systems
WAS	Weeks After Sowing
WP	Wilting Point
WUE	Water Use Efficiency
YEB	Youngest Emerged Blade
YP	Yield Prophet

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