Eyre Peninsula Farming Systems Summary 2018

2018

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GRDC Foreword

On behalf of the Grains Research and Development Corporation (GRDC), it is a pleasure to present to you this 2018 Eyre Peninsula (EP) Farming Systems Summary. This annual publication is a valuable resource that consolidates local research, development and extension (RD&E) activities, providing information and insights to build knowledge and 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 GRDC, the South Australian Research and Development Institute; the University of Adelaide; the South Australian Grain Industry Trust; Commonwealth Scientific and Industrial Research Organisation; EP Agricultural Research Foundation; 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 therefore of real value to local farmers and advisors, helping inform decision making that impacts business performance and profit.

Season 2018 presented the region's farmers with variable conditions and unfortunately, for many, profitability was challenged due to below average rainfall, persistent strong winds and in some cases frost. But in a year of mixed fortunes, others, particularly in parts of the lower Eyre Peninsula, achieved average or above average yields and hence were able to capitalise upon generally strong commodity prices.

A season such as this serves as a reminder as to both how far we have progressed and yet how many challenges still remain. The widespread adoption of farming systems based around harvesting and conservation of water, low disturbance seeding systems, appropriate varietal selection and crop sequencing, improved nutrient management and good crop agronomy have been instrumental in the quest for higher and more stable yields. But now, more than ever, there is a need to find ways to ensure farming systems are more robust and resilient to address the volatility in seasonal conditions, declining terms of trade, increasing global competition, greater regulation and challenges surrounding right to farm.

All of these challenges, critical to the enduring profitability of grain growers, require ongoing yet focused investment in RD&E. 'More of the same' will no longer be sufficient and hence there is a need to explore transformational new approaches to address these problems head-on. This intent is at the heart of the GRDC's new five-year RD&E plan. Now well into the first year of the 2018-23 plan, the GRDC and its valued research partners are working hard to address the plan's priorities for investment in RD&E. If you wish to know more about the plan, go to https://grdc.com.au/about/corporate-governance/strategic-rd-plan or make contact with one of the GRDC Southern region team members on 08 8198 8400.

This EP Farming Systems Summary is an important mechanism for capturing and delivering the latest knowledge from regionally-based research ahead of the coming season. Many of the trials detailed within this publication are also catalogued on the GRDC's Online Farm Trials web portal (www.farmtrials.com.au) which provides open and free access to on-farm or field-based cropping research trial data and information. If you haven't done so already, I encourage you to visit the site and make good use of the reports and data available.

Congratulations are extended to all those involved in preparation and production of this summary – a milestone 20th edition – particularly the SARDI staff involved in collation of the content.

I wish all involved in farming on the EP all the very best for a prosperous and safe 2019 season. Happy reading.

Craig Ruchs, GRDC Senior Regional Manager – South

Eyre Peninsula Farming Systems Summary 2018

Editorial Team

Naomi Scholz	SARDI, Minnipa Agricultural Centre, (MAC)
Amanda Cook	SARDI, MAC
Jessica Crettenden	SARDI, MAC
Fiona Tomney	SARDI, MAC
Nigel Wilhelm	SARDI, MAC/Waite
Fabio Arsego	SARDI, MAC/Port Lincoln
Brett Masters	Rural Solutions SA, Port Lincoln

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

This manual was compiled by The Printing Press

March 2019

Front Cover: Main Photo: Reefinator in action.
Left to right: Launch of DLPS project at MAC field day, pregnancy scanning sheep, farewell to Ken Webber.

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

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Minnipa Agricultural Centre update

Naomi Scholz
SARDI, Minnipa Agricultural Centre

Welcome to the twentieth Eyre Peninsula Farming Systems Summary. This summary of research results from 2018 is proudly supported by the South Australian Grains Industry Trust (SAGIT) and the Grains Research & Development Corporation (GRDC) through the Eyre Peninsula Farming Systems projects.

We would like to thank SAGIT, GRDC and EPARF for their contribution to Eyre Peninsula for research, development and extension and for enabling us to extend our results to all farm businesses on EP and beyond in other low rainfall areas. All articles since 2010 are also available on the EPARF website www.eparf.com.au. Many of the trials are also catalogued in the GRDC Online Farm Trials Database, www.farmtrials.com.au, which is an excellent searchable resource for finding trials and research outcomes from across Australia.

2018 was the final year for several larger projects, including the *Maintaining profitability in retained stubble systems* (or GRDC Stubble Initiative for short), and the SAGIT funded project *Identifying the causes of unreliable N fixation by medic based pastures.* Several new projects in which MAC and/or EPARF is a partner will commence in 2019, including: National Landcare Program/GRDC Mixed Cover Crops, Soils CRC Herbicide Residues Carryover, GRDC Soil and Tissue testing for P and N, Rural R&D for Profit Dung Beetle Ecosystem Engineers and GRDC Mixed Farming sheep production workshops.

MAC is also involved in a new major project that began in 2018, *"Boosting profit and reducing risk of mixed farms in low and medium rainfall areas with newly discovered legume pastures enabled by innovative management methods"*, or Dryland Legume Pasture Systems (DLPS) for short. 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 SARDI, Murdoch University, CSIRO, the WA Department of Primary Industries and Regional Development, and Charles Sturt University, as well as grower groups. The aim of the project is to 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.

We are also currently working on new project submissions on topics such as crop competition for weed control, improving productivity on grey calcareous soils, a new mixed farming extension program and EP farmer resilience, with numerous collaborators and funding sources. Fingers crossed that we are successful on at least some of these!

Staff

In 2018 we welcomed new casual staff Steve Jeffs, Ashley White and Bradley Hutchings, and farewelled Rochelle Wheaton, Brett Hay and Lauren Cook.

Students/work experience

Emma Doudle, year 10 student from Navigator College in Port Lincoln completed work experience at MAC in June 2018.

Visitors

Minister Tim Whetstone, Minister for Primary Industries & Regions and Peter Treloar MP attended an EPARF meeting at MAC on 27 June.

His Excellency the Honourable Hieu Van Le AC - Governor of South Australia and Mrs Van Le, visited MAC on 13 August. Staff gave a presentation of the history and role of Minnipa Ag Centre, and provided a tour of the facilities.

Michael Crawford, CEO and Paul Greenfield, Board Chair of the Soils CRC, visited MAC on 11 July.

SAGIT Board members visited MAC on 20-21 August.

Events

A range of events were held or attended by MAC staff, with details listed in the following article *Minnipa Agricultural Centre Events in 2018.*

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

We look forward to seeing you all at farming system events throughout 2019, and wish you all the best for a more productive and profitable season!

Projects

Project name	Funder	Summary
EPARF Sponsored Projects		
Regional Agriculture Landcare Facilitator service delivery	EPNRM	Providing a central contact point for farmers, industry, and community groups. Collection of regional intelligence - understanding the needs of the agricultural community and keeping abreast of emerging challenges, issues or threats that may affect the agricultural sector in the region. Supporting agriculture groups to develop new projects and seek grant funding. End: June 2023
Warm and cool season mixed cover cropping for sustainable farming systems	NLP2/GRDC *4-60A5VY4*	The performance of a broad range of cover crops will be evaluated in targeted field trials across the southern region to answer two key questions: What are the new and emerging plant species/varieties, summer and winter active, most suited to different environments across the region? What are the most effective strategies and timings to terminate a cover crop for achieving the optimum benefits for subsequent crops and soil health? End: June 2022
Developing knowledge and tools to better manage herbicide residues in soil	Soils CRC *4.2.001*	Development of tools to enable in-field assessment of risk of herbicide carry-over to the crop. End: June 2022
Using soil and plant testing data to better inform nutrient management and optimise fertiliser investments for grain growers	GRDC *9176604*	Work with 5 EP growers x 6 paddocks = 30 paddocks on EP. Soil testing of 2 sites per paddock, with fertiliser test strips in 3/6 paddocks sampled on their property. In-season tissue testing (GS30) in the paddocks where test fertiliser strips are located and biomass cut. Field day/workshop to be held at one of the test strip sites in-season. Discussion of soil testing, nutrition and determining fertiliser rates. At the end of the season need to obtain the yield map data from the growers. End: June 2022
Dung Beetle Ecosystem Engineers - enduring benefits for livestock producers	Rural R&D for Profit *RnD4Profit-16-03-016*	The project aims to improve soil in grazing systems, reduce the spread of diseases and insect pests, such as bush flies, increase pasture health and reduce nutrient run-off into waterways by introducing new dung beetle species and expanding the distribution of existing species. End: December 2021
Using soil water information to make better decisions on Eyre Peninsula	SAGIT *EP216*	To use an existing network of soil moisture probes across Eyre Peninsula to provide growers across the region with information on how data the soil moisture probes collect can be converted into easily utilized decision support tools that will assist them in targeting yield potential and tailoring inputs to match. End: June 2019
Eyre Peninsula Farming Systems Summary 2016 - 2018	SAGIT *EP116*	This project will support the cost of printing Eyre Peninsula Farming Systems Summaries 2016, 2017 and 2018, enabling the free distribution to all growers on Eyre Peninsula. End: June 2019
Maintaining profitable farming systems with retained stubble - upper EP	GRDC *EPF00001*	To produce sustainable management guidelines to control pests, weeds and diseases while retaining stubble to maintain or improve soil health, and reduce exposure to wind erosion. Increased knowledge and skills allowing farmers and advisers to improve farm profitability while retaining stubble in farming systems on upper EP. End: June 2018
SARDI Projects		
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. End: June 2022

Project name	Funder	Summary
Nutrient Responses	GRDC *UQ00082*	This project is developing critical levels for commercial soil tests of N, P, K and S for the major break crops. Two trial sites have been set up on the EP. One is at Minnipa to calibrate Colwell P for canola on a red sandy loam. The other is at Mt Hope on a gravelly sand over limestone and is to calibrate the deep mineral N test for canola. End: June 2022
Improving production on sandy soils in low and medium rainfall areas	GRDC *CSP00203*	There are opportunities to increase production on deep sands by developing cost effective techniques to diagnose and overcome the primary constraints to poor crop water-use or by reducing the impact of constraints with modified practices. Commonly recognised constraints that limit root growth and water extraction on sands include compaction (high penetration resistance), poor nutrient supply and low levels of biological cycling and poor crop establishment. The project has set up trials at Murlong to investigate both low cost modified agronomy (e.g. use of wetters) and high cost interventions (e.g. spading incorporation of OM). End: June 2021
Extension of knowledge and resources to manage risk and exploit opportunities to improve whole farm profit through successful integration of cropping and livestock enterprises	GRDC/MLA *9175516*	The aim of this fourth phase is to support farmers and advisors with information, training and tools to tackle the complexity associated with successfully integrating crops and livestock in a farming business. The focus is on understanding the opportunities, synergies and trade-offs in mixed farming, using the knowledge, experience and calculators created in previous phases of the Grain and Graze program. End: June 2020
Swathing for barley grass weed seed collection and applying drone technology	SAGIT *S117*	Swathing cereal crops with problem weed issues early (between 20 and 40% grain moisture) for grass weed seed capture into windrows, followed by harvest and using a chaff cart for weed seed collection may provide farmers with another tool for integrated weed management. Testing the use of UAV (drone) technology to assess barley grass weed density in crop. End: June 2020
Water Repellency	GRDC *DAW00244*	The main focus of this project is to explore management techniques that promote water infiltration into non-wetting soils and increase crop production and profitability. A trial has been conducted at Wharminda since 2015 investigating the impact of wetting agents and near-row seeding on crop establishment and performance. End: June 2019
Application of CTF in the low rainfall zone - MAC Research Site	GRDC via ACTFA *ACT00004*	Adoption of Controlled Traffic Farming (CTF) in the LRZ is very low (eg SA/Vic Mallee, 4%) compared to other zones in the Region (eg Vic HR, 26%). This is believed to reflect scepticism about its benefits in many LRZ environments when weighed up against the cost of adopting the practice. The project will evaluate whether or not this scepticism is justified. End: June 2019
Maintaining profitable farming systems with retained stubble -Component 1 Coordination Support	GRDC *DAS00145*	Coordination Support provided by Naomi Scholz, SARDI. The role includes organisation of national meetings, facilitate sharing of resources and communication between Component 2 grower groups and Component 1 research, and ensuring guidelines and other project products are accessible to growers across Australia now and in the future. End: December 2018
Identifying the causes of unreliable N fixation by medic based pastures	SAGIT *SARDI1515*	Assess the impacts of current weed control chemicals, adjuvants and rhizobial inoculants on N fixation by medics under field conditions typical of the upper EP and other low rainfall mallee systems. Also assess the impact of nutrition (esp N and P) on N fixation by medics under field conditions and investigate their effects on tolerance to current weed control chemicals. End: June 2018

Project name	Funder	Summary
National Variety Trials	GRDC	Yield performance of cereal & break crop varieties at various locations across upper EP.
Crop Improvement Trials	Various	Various trials including district variety trials, product trials, species trials.

MAC staff and roles 2018

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

DATES TO REMEMBER

GRDC/EPARF Spray Workshops: 27-28 March 2019

EPARF Member Day: mid-year 2019

MAC Annual Field day: Thursday 19 September 2019

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

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Eyre Peninsula Agricultural Research Foundation Annual Report 2018

Simon Guerin
Chairperson, EPARF

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

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

Vision

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

Values

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

Purpose

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

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

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

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

EPARF Board Members

<u>Farmer elected members:</u>

Simon Guerin, Bryan Smith, Shannon Mayfield, Dion Trezona, Greg Scholz, Wes Matthews

<u>Special Skills and Experience representatives:</u>

Andy Bates, Mark Stanley

<u>SARDI representative:</u> Dr Kathy Ophelkeller, Research Chief

<u>University of Adelaide representative:</u> Prof Jason Able, Head Department Agricultural Science

At the September AGM, two new farmer members were elected to the Board, Matthew Cook and Jerel Fromm.

EPARF members thanked Shannon for his six years and Dion four years' service and commitment to the Board.

Membership

280 members.

Activities in 2018

Again 2018 has been a difficult year with some areas having drought like conditions (we can't say drought in South Australia), but in the higher rainfall areas there has been some rain and later rains have been positive. These seasonal conditions seem to come along all too regularly and keep us recognising the need of future research and the value of farming systems that we can implement to remain resilient.

In February, EPARF hosted a 'Pulse Management in low rainfall farming systems' half day workshop with the aim to give farmers more confidence to grow pulses in drier climates and therefore increase the area sown. High quality speakers presented relevant information on growing pulses and break crops with nearly 100 people attending. Evaluation at the event indicated growers had gained a better understanding on pulse production and the management of pulse crops.

The EPARF board invited the new Minister for Primary Industries, Hon Tim Whetstone to MAC and along to the EPARF meeting. This was a good way to show him our strong local farmer support of MAC and SARDI and of the research they perform in our region. He was accompanied by our local member of parliament Peter Treloar, Member for Flinders. After addressing the group they were taken on a MAC farm tour.

During this EPARF meeting we also invited Craig Ruchs (GRDC, Senior Regional Manager, Southern Region) to inform staff and the EPARF board members on GRDC's funding approach of projects going forward into the future.

Strategic planning is always on the agenda for discussion, as a grower group we need to ensure that we continue to be relevant moving forward.

EPARF Projects

- The “Eyre Peninsula Farming Systems Summary” publication, currently funded by SAGIT, is a highly regarded annual summary of the trials conducted on the EP
- Using Soil Water Information to make better decisions (Soil Probe Network), funded by SAGIT
- Maintaining profitable farming systems with retained stubble (EPFS4), funded by GRDC
- Regional Landcare Facilitator (RALF), funded by EPNRM
- Delivery of Pulse Check Discussion Group, funded by GRDC through BCG
- Increasing production on sandy soils in low and medium rainfall areas of the Southern Region, funded by GRDC thought CSIRO
- CRC for High Performance Soils

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Thank you to all sponsors for their generous support.

Sponsorship is a vital link in EPARF being able to provide the services to our members and we hope to be able to continue this relationship.

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

Appreciation and Thanks

Thank you to Ken Webber and his work at Nufarm, for his long-term commitment to the Eyre Peninsula and for supporting all the research at MAC and wish him all the best in his future endeavours.

MINNIPA AGRICULTURAL CENTRE

PO Box 31 MINNIPA SA 5654

Telephone 08 8680 6202 Facsimile 08 8680 5020

ABN 94 833 615 975

www.eparf.com.au

REMINDERS

ANNUAL EPARF MEMBERSHIP

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

Contact Dot Brace 8680 6202 or eparf31@gmail.com

Eyre Peninsula Agricultural Research Foundation Members 2018

Michael	Agars	PORT LINCOLN SA
Terry	Baillie	TUMBY BAY SA
Karen	Baines	UNGARRA SA
Andrew	Baldock	KIMBA SA
Mark	Baldock	KIMBA SA
Graeme	Baldock	KIMBA SA
Heather	Baldock	KIMBA SA
Tristan	Baldock	KIMBA SA
Geoff	Bammann	CLEVE SA
Paul	Bammann	CLEVE SA
Ashley	Barns	WUDINNA SA
Andy	Bates	STREAKY BAY SA
Warren	Beattie	CEDUNA SA
Peter	Beinke	KIMBA SA
Joshua	Beinke	KYANCUTTA SA
Neville	Beinke	KYANCUTTA SA
Brenton	Bergmann	CEDUNA SA
Ian	Bergmann	CEDUNA SA
Bill	Blumson	SMOKY BAY SA
Sam	Boehm	CUMMINS SA
Dion	Brace	POOCHERA SA
Jason	Brace	POOCHERA SA
Reg	Brace	POOCHERA SA
Bill	Brands	MINNIPA SA
Sharon	Brands	MINNIPA SA
Kevin	Brands	MINNIPA SA
Daryl	Bubner	CEDUNA SA
Neville	Buchanan	KIMBA SA
Jason	Burton	RUDALL SA
Brian	Cant	CLEVE SA
Alexander	Cant	CLEVE SA
Shaun	Carey	CHANDADA SA
Peter	Carey	MINNIPA SA
Paul	Carey	CUNGENA SA
Matthew	Carey	CHANDADA SA
Damien	Carey	CHANDADA SA
Mark	Carmody	COWELL SA
Symon	Chase	COWELL SA
Trevor	Cliff	KIMBA SA
Randall	Cliff	KIMBA SA
Trevor	Clifford	KIMBA SA
Andrew	Cook	SALMON GUMS WA
Matt	Cook	MINNIPA SA
Brent	Cronin	STREAKY BAY SA
Colin	Crossman	KYANCUTTA SA
Neil	Cummins	LOCK SA
Neil	Daniel	STREAKY BAY SA
Kevin	Dart	KIMBA SA
Leigh	Davis	WUDINNA SA
Martin	Deer	COWELL SA
Paul	Dolling	CLEVE SA
Ryan	DuBois	WUDINNA SA
Matthew	Dunn	RUDALL SA
Barry J	Durdin	PORT LINCOLN SA
Austen	Eatts	KIMBA SA
David	Elleway	KIELPA SA
Ray	Elleway	KIELPA SA
Michael	Evans	CLEVE SA
Andre	Eylward	STREAKY BAY SA
Tasman	Fitzgerald	KYANCUTTA SA
Scott	Forrest	MINNIPA SA
Jane	Forrest	MINNIPA SA
Matthew	Foster	WUDINNA SA
Rhianna	Foster	WUDINNA SA
David	Foxwell	CLEVE SA
Tony	Foxwell	CLEVE SA
Brett	Francis	KIMBA SA
Tim	Franklin	COWELL SA
John	Freeman	STREAKY BAY SA
John	Freeth	KIMBA SA
Thomas	Freeth	KIMBA SA

Jerel	Fromm	MINNIPA SA
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Kade	Gill	POOCHERA SA
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Terry	Guest	SALMON GUMS WA
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Ian	Gunn	PORT KENNY SA
John	Haagmans	ELLISTON SA
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Basil	Heath	PORT LINCOLN SA
Lachlan	Heath	PORT LINCOLN
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Nathan	Hebberman	POOCHERA SA
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Ian	Hood	PORT KENNY SA
Kaide	Hood	PORT KENNY SA
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Gregory	Inglis	KIMBA SA
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Jodie	Jones	WHARMINDA SA
Paul	Kaden	COWELL SA
Tony	Kaden	COWELL SA
Ty	Kaden	COWELL SA
Dylon	Kay	TOOLIGIE SA
Saxon	Kay	TOOLIGIE SA
Craig	Kelsh	TYRINGA SA
Zac	Kelsh	COLLEY SA
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Rex	Kobelt	CLEVE SA
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Craig	Lynch	POOCHERA SA
Christopher	Lynch	CHANDADA SA
Paul	Lynch	CHANDADA SA
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Troy	Maitland	KIMBA SA
Andrew	Major	KIMBA SA
Justine	Major	KIMBA SA
Shane	Malcolm	ARNO BAY SA
Beth	Malcolm	ARNO BAY SA
John	Masters	ARNO BAY SA
Linden	Masters	ARNO BAY SA
Todd	Matthews	KYANCUTTA SA
Wes	Matthews	KYANCUTTA SA
Nigel	May	ELLISTON SA
Ashley	May	KYANCUTTA SA
Paul	May	KYANCUTTA SA
Shannon	Mayfield	KIMBA SA
Clint	McEvoy	STREAKY BAY SA
Sarah	Meyer	CLEVE SA
Ashley	Michael	WUDINNA SA
John	Michael	WUDINNA SA
Darren	Millard	ARNO BAY SA
Leone	Mills	COWELL SA
Ian	Montgomerie	STREAKY BAY SA
John	Montgomerie	STREAKY BAY SA

Darren	Mudge	MILTABURRA SA
Damien	Mullan	WUDINNA SA
Blake	Murray	PENONG SA
Lynton	Murray	PENONG SA
Leonard	Newton	ELLISTON SA
Joy	Newton	ELLISTON SA
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Ian	Noble	WHARMINDA SA
Sarah	Nobel	CLEVE SA
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Bronwyn	O'Brian	KYANCUTTA SA
Darren	O'Brien	KYANCUTTA SA
Clinton	Olsen	WIRRULLA SA
Nigel	Oswald	WUDINNA SA
Lauren	Oswald	WUDINNA SA
John	Oswald	YANINEE SA
Clint	Oswald	YANINEE SA
Tim	Ottens	WHARMINDA SA
David	Peters	CHANDADA SA
Ashley	Phillips	MINNIPA SA
Darcy	Phillips	MINNIPA SA
Andrew	Polkinghorne	LOCK SA
Tim	Polkinghorne	LOCK SA
Ben	Pope	WARRAMBOO SA
Lindsay	Pope	WARRAMBOO SA
John	Post	MINNIPA SA
Clint	Powell	KIMBA SA
Kevin	Preiss	ARNO BAY SA
Rowan	Ramsey	KIMBA SA
Ben	Ranford	CLEVE SA
Dale	Rayson	KIMBA SA
Peter	Rayson	KIMBA SA
Reece	Rayson	KIMBA SA
Gavin	Rehn	ARNO BAY SA
Zachary	Richardson	CLEVE SA
Jason	Ridgway	PORT LINCOLN SA
Geoff	Rissmann	CLEVE SA
Bradley	Rowe	COWELL SA
Martin	Ryan	KIMBA SA
Kane	Sampson	WARRAMBOO SA
Paul	Schaefer	KIMBA SA
John	Schaefer	KIMBA SA
Wes	Schmidt	KIMBA SA
Terry	Schmucker	KYANCUTTA SA

Thomas	Schmucker	KYANCUTTA SA
Kelvin	Scholz	YANINEE SA
Lyle	Scholz	YANINEE SA
Mick	Scholz	YANINEE SA
Greg	Scholz	WUDINNA SA
Stuart	Scholz	WUDINNA SA
Yvonne	Scholz	WUDINNA SA
Gareth	Scholz	MINNIPA SA
Leigh	Scholz	MINNIPA SA
Nigel	Scholz	WUDINNA SA
Neville	Scholz	WUDINNA SA
Richard	Scott	KIMBA SA
Brook	Seal	KIMBA SA
Sam	Shipard	PENONG SA
John	Simpson	WUDINNA SA
Bryan	Smith	COORABIE SA
Dustin	Sparrow	WUDINNA SA
Mark	Stanley	PORT LINCOLN SA
Rodger	Story	COWELL SA
Suzanne	Story	COWELL SA
Aleks	Suljagic	CLEVE SA
Zac	Tiller	LOCK SA
Clint	Tomney	STREAKY BAY SA
Gareth	Tomney	CUNGENA SA
Jarad	Tomney	CHANDADA SA
Myles	Tomney	CUNGENA SA
Rhys	Tomney	CHANDADA SA
Peter	Treloar	EDILLILIE SA
Paul	Trevor	STREAKY BAY SA
Craig	Trowbridge	CEDUNA SA
John	Turnbull	CLEVE SA
Mark	Turnbull	CLEVE SA
Nigel	Turnbull	CLEVE SA
Quentin	Turner	ARNO BAY SA
Tim	van Loon	PORT ELLIOT SA
Leon	Veitch	WARRAMBOO SA
Simon	Veitch	WUDINNA SA
Sally	Veitch	WUDINNA SA
Henry	Voigt	UNLEY SA
Daniel	Vorstenbosch	WARRAMBOO SA
Dallas	Waters	WUDINNA SA
Graham	Waters	WUDINNA SA
Tristan	Waters	WUDINNA SA
Peter	Watson	WIRRULLA SA
Ryan	Watson	WIRRULLA SA
Paul	Webb	COWELL SA

David	Wendland	MINNIPA SA	Dean	Willmott	KIMBA SA
Melissa	Wendland	MINNIPA SA	Peta	Willmott	KIMBA SA
Craig	Wheare	LOCK SA	Craig	Wissell	ARDROSSAN SA
Philip	Wheaton	STREAKY BAY SA	Peter	Woolford	KIMBA SA
Evan	Whillas	WIRRULLA SA	James	Woolford	KIMBA SA
Brian	Wibberley	PORT LINCOLN SA	Brad	Woolford	KIMBA SA
Timothy	Wibberley	PORT LINCOLN SA	Graham	Woolford	KIMBA SA
Gregor	Wilkins	YANINEE SA	Dion	Woolford	KIMBA SA
Stefan	Wilkins	YANINEE SA	Simon	Woolford	KIMBA SA
Dion	Williams	STREAKY BAY SA	David	Woolford	KIMBA SA
Peter	Williams	WUDINNA SA	Amy	Wright	KIMBA SA
Josie	Williams	WUDINNA SA	Terry	Young	UNGARRA SA
Scott	Williams	WUDINNA SA	Michael	Zacher	LOCK SA
David	Williams	PORT NEILL SA	Allan	Zerna	COWELL SA
Jack	Williams	PORT NEILL SA	Lisa	Zibell	KIMBA SA

Photo: Left to Right. Michael Moodie, Andy Bates, Larn McMurray, Liz Farquharson, Jenny Davidson and Sam Holmes were speakers at the EPARF Member Day, February 2018.

Minnipa Agricultural Centre events in 2018

Naomi Scholz
SARDI, Minnipa Agricultural Centre

Event	Topics	Attendance
Soil Moisture Probe Network discussion group meetings Wudinna, Kimba and Cummins 8-9 February	The sessions covered included how the probes work, work being done behind the scenes to make sure the information is useful/accurate, how to access and read the graphs and how Yield Prophet works. Presenters were Andrew Ware (SARDI Port Lincoln), Shane Oster (Alpha Group Consulting), Tim McClelland (Model Agronomics).	60 farmers and advisors
EPARF member day MAC 14 February	Topic: Pulse management in low rainfall farming systems. This event brought in five high quality, experienced speakers who presented information and take home messages applicable to growing pulses and break crops in a low rainfall environment. Speakers: Larn McMurray, Pulse Research Scientist with Grains Innovation Australia; Dr Liz Farquharson, Senior Research Officer, SARDI; Dr Jenny Davidson, Leader Pulse Pathology laboratory, SARDI; Sam Holmes, a leading consultant from Yorke Peninsula; and Michael Moodie, a Mildura based agronomist. The program also included Andy Bates, a leading consultant on the Eyre Peninsula facilitating an interactive panel session and Naomi Scholz, Project leader Minnipa Agricultural Centre, SARDI, who concluded the day with an evaluation session, which showed growers had gained a better understanding on pulse production and the management of pulse crops by attending the event.	100 people, a mix of growers, industry and research scientists
GRDC Updates for Advisors Adelaide 20-21 February	Jessica Crettenden presented ongoing research about the 'Impact of Livestock on Paddock Health' from the Grain and Graze Project at the conference.	445 people, a mix of growers, industry and research scientists
Sheep pregnancy scanning workshops Minnipa, Cowell and Ungarra 27-28 February and 1 March	Jessica Crettenden organised and attended three workshops presented by Phillip and Sally Schoeffel of Advanced Farm Systems. The workshops were jointly funded by Eyre Peninsula Natural Resource Management, SheepConnect and Eyre Peninsula Agricultural Research Foundation.	30 farmers and advisors
Harvest report farmer meetings Minnipa, Port Kenny, Piednippie, Charra, Cowell, Rudall, Kimba and Warramboo 19-23 March	Presentation of 2017 research results and projects were made by SARDI staff, Amanda Cook, Jessica Crettenden, Fiona Tomney, Naomi Scholz and Nigel Wilhelm. The meetings were facilitated by Regional Landcare Facilitator, Linden Masters. Amanda Cook spoke about current topical issues for upper EP and the latest research from the GRDC Updates including Russian Wheat Aphid (Maarten Van Ryder, SARDI) and Brome grass research (Sam Kleemann and Gurjeet Gill, University of Adelaide). Amanda presented the outcomes from the GRDC EPARF Stubble Initiative, recently completed guidelines and current research, SAGIT weed seed burning results (Ben Fleet), SAGIT Fluid delivery systems and the SAGIT Barley grass monitoring project outcomes. Fiona Tomney spoke about her trial, 'Identifying the causes of unreliable N fixation in medic based pastures.'	140 farmers and advisors

Event	Topics	Attendance
	Jessica Crettenden spoke about three new mixed farming projects occurring at or involving the SARDI Minnipa Agricultural Centre. Nigel Wilhelm presented results on GRDC controlled traffic, trace element and sandy soils research. PIRSA Biosecurity Animal Health Officer Patric Lawler also informed farmers of welfare and biosecurity requirements, and livestock health issues and prevention strategies. Evaluation of the events and local farming practice surveys (soil probe network use, farm software program use, pasture issues and preferences and stubble management practice changes) was conducted by Naomi Scholz.	
EPARF Research & Review Committee annual trial planning meeting MAC 10 April	Current trials and potential new research opportunities were discussed and planned.	6 farmers and 7 staff
EPARF/SARDI RD&E on EP meeting MAC 27 June	The morning session involved an update from Craig Ruchs, GRDC Program Manager, South, on the new GRDC Strategic Plan and how grower groups can be involved in the submission of issues and ideas, discussed issues around RD&E capacity in regions and gaps in GRDC investment in recent years on Eyre Peninsula. Minister Tim Whetstone and Peter Treloar MP were present for part of the morning discussions, followed by a farm tour.	27 farmers, advisors, EPNRM, SARDI staff
'Farmers Catch Up in Hard Times' workshop Ceduna, Poochera, Wudinna and Cowell 30 July - 2 August	Jessica Crettenden presented information about livestock grazing systems, managing feed base options in dry seasons and livestock health and nutrition.	A total of 134 farmers and 30 advisors attended the four workshops
Minnipa Farmers Crop Walk Minnipa area 31 July	Amanda Cook presented results at the GRDC Herbicide Efficacy trial, and also at the SAGIT, UAV Grass Weed paddock at Bruce Heddle's.	14 local farmers
Buckleboo Farmers Group Crop Walk Buckleboo area 3 August	Amanda Cook presented results to the growers at the Balco Oats trial.	32 farmers and local industry reps
GRDC Business Updates Adelaide 17 August	Jessica Crettenden presented information about a 9-year Grain and Graze study.	Approximately 60 farmers and advisors
Upper North Farming Systems Expo Booleroo 30 August	Jessica Crettenden presented information on livestock feedbase options, animal nutrition and sheep health.	Approximately 40 farmers and advisors

Event	Topics	Attendance
Minnipa Agricultural Centre annual field day MAC 20 September	SARDI presenters and topics were: Naomi Scholz (welcome), Kathy Ophel-Keller (official opening), Jake Hull (farm report, broadacre demonstrations - wheat and barley varieties, mixed species for grazing/hay, ripping and spading), Kym Perry (snails and Russian Wheat Aphid), Kenton Porker (barley and wheat varieties), Penny Roberts (low rainfall break crop options), Andrew Ware (canola varieties), Amanda Cook (herbicide efficacy), Ross Ballard (overview of Dryland Legume Pasture Systems project), Jessica Crettenden (large scale pasture grazing trial), Fiona Tomney (pasture species selection trial). Other guest presenters were: James Hunt (LaTrobe University) spoke on early sown wheat varieties; Mary-Anne Young (RSSA) mitigation of wind erosion prone areas; Scott Gillett (Wisdom Data) using drone imagery for grass weed identification; Ben Fleet (University of Adelaide) management options for rye grass control. The EPARF AGM was held, with 2 new board members elected and Andy Bates (EPARF) farewelled Ken Webber, Nufarm and thanked him for his many years of service to agriculture on upper EP.	129 people: 80 farmers, 20 reps, 19 staff
Sticky Beak Days Upper Eyre Peninsula 3 September to 8 October	A series of 12 crop walks held by ag bureau groups across upper Eyre Peninsula. Approximately 42 people attended the Streaky Bay Sticky Beak Day held on 27 September, where Amanda Cook presented the trial results for the season at the GRDC Maximising dry matter production on alkaline soils trial at Piednippie.	A total of 470 people: 344 farmers, 17 SARDI staff, 3 Rural Solutions SA staff, 1 x RLF x 10 events, 6 EPNRM staff, and 90 agribusiness representatives

Eyre Peninsula seasonal summary 2018

Brett Masters
Rural Solutions SA, Pt Lincoln

Key messages

The 2018 season on Eyre Peninsula was a year of extremes with crop yields dependent not just on how much rain was received, but also on when the rain was received. Dry conditions across the region at sowing resulted in poor germination and early crop vigour in most districts. Although pastures germinated well in many districts, cold and dry conditions to August resulted in poor pasture growth, and producers in all districts needed to keep supplementary feeding livestock, which significantly reduced hay and feed grain reserves across the region.

Well above average rainfall in August turned the season around in much of the region, and with follow-up rainfall in October, average to slightly below average yields were achieved in Western and Central Eyre districts, with average to well above average yields on Lower Eyre Peninsula. However, continued dry conditions in Eastern Eyre districts around Franklin Harbour, Cleve, Arno Bay and Port Neill resulted in little crop and pasture growth, and low paddock surface cover and frequent strong winds resulted in significant erosion of sandy soils in these districts, negatively impacting crop establishment and growth.

Severe frosts during August and September damaged crops in all districts north of Cummins, with large areas of crops of types affected in the Kimba, Lock and Karkoo districts. Significant frost damage was also reported in districts where frost risk is traditionally lower such as the Far West, Streaky Bay, Port Kenny, Ungarra and Tumby Bay. High demand for hay because of drought conditions in eastern Australia, coupled with record prices made it profitable to cut frosted crops (and those suspected of being frosted) for hay.

Stored subsoil moisture from August rains combined with follow-up rain and an absence of heat stress events in October helped to fill grain and farmers in most districts (with the exception of the drought-affected districts in Eastern EP) were pleased with the yields achieved despite well below average growing season rainfall. Rain and humidity caused harvest delays across the region. Fortunately this did not result in significant grain quality downgrades until late December, and much of the grain had high protein and low screenings. High grain and hay prices resulted in good gross margins for crops in those districts where seasonal conditions delivered yields.

Summer/Early Autumn

Despite very dry conditions in early summer, thunderstorms in late January resulted in rainfall totals well above the average for the month. Summer weeds and volunteer crops emerged and grew rapidly during this period, and most growers sprayed at least once to control the green bridge and minimise the risk of pest and disease damage to 2018 crops. Given the high number of Russian wheat aphid in 2017, most growers applied a seed treatment insecticidal dressing to at least a portion of their seed to reduce the risk of crop damage.

Snail activity increased during this period and growers baited paddocks to be sown with vulnerable crops such as canola and pulses. A number of hot days during this period also gave growers an opportunity to control snails by rolling and chaining. However, in many cases these operations detached and exposed soils to erosion, with strong winds eroding sandy rises in many paddocks across the region.

Low paddock biomass levels in the previous spring resulted in very low surface cover levels over summer and livestock producers had to supplement paddock feed with hay and grain. Many prepared growers moved livestock into containment feeding areas at this time.

Late-Autumn/Winter

Dry conditions remained to early winter. Whilst several cold fronts passed over the region, most brought little rainfall, with strong winds drying out topsoils causing numerous stops and starts to seeding. Some canola and long season wheat varieties were dry sown in April, as well as cereal paddocks and vetch for feed. However, most growers held off sowing the majority of their crop until adequate rain was received, particularly those with non-wetting sands. Widespread rains totaling more than 15 mm in the first week of June allowed most growers to finish sowing by the end of June.

Crop and pasture germination was patchy and depended on location, sowing time and timing of rainfall. Considerable variation in crop maturity was seen, even within paddocks, depending on soil type variability. Numerous light frosts and moisture stress in late winter further checked the growth of crops and pastures, with livestock producers needing to continue supplementary feeding stock until at least the end of July.

This placed enormous pressure on farm feed reserves, and most growers had to buy in extra hay and grain at considerable expense. Most growers chose not to grass free pastures, preferring to maintain the little paddock biomass present, and instead spraytopped paddocks in spring to control grass weed seed set.

Cold fronts in August brought significant rainfall and most districts recorded well above the monthly average. This rain turned the season around in many districts, as it resulted in some stored soil moisture which helped crops and pastures continue to grow between irregular rainfall events. As a result of this rain most districts in Western and Central Eyre Peninsula and around Darke Peake, Rudall and Wharminda in the Eastern EP were finally able to grow adequate surface cover for erosion protection and crops in Lower Eyre grew rapidly with high yield potential.

However, in those districts east of Cleve, Arno Bay, Franklin Harbour and Cowell, continued dry conditions saw little to no growth of crops and pastures, with continuing erosion of exposed sandy soils. Growers tried a number of strategies to reduce erosion, including ripping paddocks to roughen the soil surface and reseeding areas of crop. Unfortunately these winds continued into spring and many of the resown crops were damaged by sandblasting just as they were emerging.

Spring

Although September rainfall was below average, stored soil moisture from August rains enabled crops and pastures to grow through this period until further rains were received in October. Crop disease levels were generally low, due to seasonal conditions and landholder's fungicide strategies. There were few reports of significant numbers of Russian wheat aphid. High numbers of cabbage and turnip aphids were reported in canola crops and most growers had to apply at least one spray to control them. There were also reports of native budworm above threshold levels in canola and pulse crops, and army worm cutting off the heads of cereal crops, but these were easily controlled. Cow pea aphids were reported in medic and vetch pastures in early spring and growers monitored livestock grazing in these paddocks to avoid animal health issues with photosensitization as seen in 2017.

There was heavy frost damage to crops in all districts north of Cummins in late September and early October. High demand for hay due to drought conditions in eastern Australia made hay a profitable option, and significant areas of frosted crop were cut in the Kimba, Buckleboo, Tooligie, Lock and Kapinnie districts. Strong winds in mid-October caused some damage to ripe canola and barley crops in Western and Eastern Eyre districts, however although the damage was significant in individual paddocks these were generally isolated and did not represent a high proportion of the total crop area.

Rain and humid days frustrated harvest efforts, and many growers did not finish harvest until early January. The conditions did not significantly impact grain quality until late in the harvest.

Yields were highly variable depending on rainfall, sowing time, rainfall timing and soil type. Further details of how these factors affected yield can be found below in the sub-regional reports. Most growers, with the exception of those in the drought affected Eastern EP districts, stated that crops yielded better than they expected given the very dry start to the season, patchy germination, early moisture stress, frost and well below average growing season rainfall. This is attributed to the generally well above average August rainfall combined with rain and a lack of heat stress events in October. Canola and peas which were not frosted yielded exceptionally well, but yields of other pulse crops varied dramatically. Grain quality was generally very high.

DISTRICT REPORTS

Western Eyre Peninsula

Summer

Most of January was dry, however thunderstorm activity late in the month resulted in above average rainfall. This germinated summer weeds and provided some 'green pick' for livestock.

However, well below average February rainfall stalled weed growth and paddock surface cover levels reduced during this period. Hot days during this period provided growers with the opportunity to chain and roll stubbles for snail control, these operations resulted in soils exposed to wind erosion in some areas, with strong wind events during this period resulting in erosion of some sandy rises between Poochera and Warramboo.

Autumn/Winter

Continued dry conditions to the end of July resulted in little weed growth and reduced the need for knockdown herbicide applications. Soil profiles contained little to no stored subsoil moisture and growers waited on good opening rains to complete their sowing programs. Although little rain was received, heavy overnight dews increased snail activity and growers baited paddocks which they intended to sow to vulnerable crops such as canola and pulses. As dry conditions continued growers decided to reduce the area intended to be sown to higher risk crops such as canola and replaced these with barley or a hay crop, with reports of up to a 20% reduction in the area sown to wheat in drier districts west of Wirrulla.

Regular cold fronts passed over the region in May and June, but these brought little rainfall. Scattered showers were accompanied by strong winds which dried out surface soils and caused paddocks with low surface cover levels to drift and crop and pasture establishment and growth was poor. By the end of June inland districts around Minnipa and Wudinna had only received 50 mm of rainfall since the start of February.

Rainfall in the middle of June enabled growers on better soil types to finish seeding by the end of June in most districts. On the non-wetting sands around Koongawa, Kyancutta and Warramboo growers waited until good rains were received before sowing crops. On heavier soils which received good early rainfall around Elliston, Streaky Bay and Mt Cooper, crops emerged well. However, in areas with continued dry conditions around Poochera, Mudamuckla and Nunjikompita, crop germination was delayed and patchy resulting in significant variability in crop maturity even within paddocks. Dry conditions continued into July and young crops suffered damage from light frosts and moisture stress. These crops struggled to regain crop vigour during the season. Strong winds eroded exposed sand dunes and sandblasted establishing crops.

Well above average August rainfall and warmer sunny days resulted in rapid growth of crops and pastures and most paddocks contained adequate surface cover levels for wind erosion protection by the end of the month. These favourable growing conditions reduced some of the early variability in crop growth.

Pastures had very low levels of feed until the end of August and most growers had to provide supplementary feed to livestock. Despite good conditions improving pasture growth in August, biomass levels were well below average and rather than grass-freeing pastures most growers chose to spraytop in spring to control grass-weed seed set whilst maintaining paddock biomass. Although biomass levels were low most livestock producers aimed to cut some hay to replenish supplies depleted during the preceding 9 months.

Spring

Cumulative April to October rainfall was well below the long term average. Good rains in early October resulted in average rainfall totals for the month, these rains had little impact on grain yields. Heavy frosts were reported in September, and whilst severe in some districts on average 10 to 30% yield losses were estimated. The worst affected paddocks were cut for hay.

Crop disease levels throughout the growing season were low. However, there were reports of large numbers of cabbage aphids in canola crops, particularly those stressed by low moisture conditions or frost. There were also reports of native budworm in pulses and canola and army worm damage to cereal crops on the grey calcareous soils around Streaky Bay and Elliston.

Although good growing conditions resulted in rapid growth of pastures, spring biomass levels were below normal levels and were not expected to provide long term feed value over summer. Most livestock producers in the region made arrangements to buy in hay and grain to replenish supplies.

Strong winds and hail accompanied intense storm activity in mid to late November. Although there were reports of significant crop damage in isolated paddocks, this did not represent a large proportion of the overall crop area. Further scattered showers in early to mid-December resulted above average rainfall being recorded for this period. These damp conditions caused delays to harvest with many growers not finishing until the end of December.

Crop yields were generally better than expected given the seasonal conditions. Early sown wheat on lighter soils in areas which had good early rainfall achieved well above average yields in the range 1.8 to 2.2 t/ha. The red flats around Nunjikompita, Wirrulla and Poochera yielded 1.0 to 1.2 t/ha on average and later sown crops on grey calcareous soils performed poorly with yields from 0.7 to 0.9 t/ha. Wheat quality was generally very good with high protein and low screenings.

Barley performed generally well with many crops yielding above 2.0 t/ha. Quality was also high with good grain weights, high protein and low screenings. Pea and canola yields were highly variable depending on soil type and frost damage.

Although November rainfall caused a decline in stubble feed quality a germination of summer weeds provided some high quality 'green pick' and many growers began summer weed spraying programs as soon as they had finished harvest.

Eastern Eyre Peninsula

Summer

Summer forage crops at harvest in 2017 grew well and provided valuable feed during a dry period in early summer. Although the first half of January was very dry, intense thunderstorms brought heavy rain to the region in the last week of the month resulting in above average January rainfall in many districts. Following these rains summer weeds and volunteer crops germinated and grew rapidly, with growers spraying these to control the 'green bridge' and manage pest and disease levels ahead of the 2018 cropping season.

Most growers also intended applying insecticidal seed treatments to reduce the risk of Russian wheat aphid impact on crop growth in 2018.

Low spring biomass production in 2017 provided few opportunities for growers to cut hay. Extended dry conditions into late January placed pressure on these limited on-farm hay reserves, with most growers intending to plant a paddock or two of hay in 2018 to replenish supplies. Low biomass levels also resulted in lower than usual surface cover levels in paddocks for protection against erosion.

Autumn/Winter

Dry conditions continued throughout autumn and early winter, with below average rainfall in March, April, May, June and July. Combined with hot, drying winds in autumn these conditions resulted in little to no pasture growth and put further pressure on on-farm feed reserves. Many growers removed livestock from paddocks into confinement feeding areas during April, and some began selling surplus livestock at this time. Dam water reserves were extremely low requiring growers in the Cleve Hills to cart water for livestock.

Whilst deep subsoil layers contained some stored moisture, surface soil remained very dry. Whilst this reduced the need for knockdown herbicide applications, it also reduced weed and pasture germination and extended the period of low paddock surface cover and erosion risk. Strong winds in the second week of April eroded exposed soils around Lock, Darke Peak, Kielpa, Wharminda, Arno Bay and Franklin Harbour and resulted in significant dust storms throughout the region.

Some vetch and cereal was sown in March for feed in the Kimba, Franklin Harbour and Mangalo districts. Clearfield barley varieties were used as an early sowing option as they provided an option for post-emergent weed control. Early indications were that the area of crop sown would not vary significantly from usual, however, growers did reduce the area sown to high risk crops such as canola and sowed barley instead.

Regular cold fronts passed across the region in May and June, however these brought little rain and the strong winds accompanying these resulted in further erosion of exposed dunes in the Darke Peak, Kielpa, Wharminda, Arno Bay and Franklin Harbour districts.

Poor soil moisture resulted in numerous stops and restarts to seeding. Widespread rainfall in mid-June enabled growers in the Kimba, Mitchellville and Cleve areas to finish seeding by the end of June. However, low rainfall to the end of June in the Wharminda, Arno Bay, Rudall, Darke Peak and Franklin Harbour districts caused growers to reduce the area they intended to sow (particularly of high risk crops), whilst they continued to wait for good opening rains.

Crop germination and development was highly variable depending on where rain had fell and sowing time. On heavier soil types around Cleve and Franklin Harbour, crops germinated well but soon suffered moisture stress when further rain was not received. Pasture paddocks in these areas contained little to no feed and growers needed to continue to supplementary feed livestock.

August rainfall was highly variable with western districts receiving well above average but falls in eastern districts were well below average. As a result the crop yield potential to the end of August varied significantly across the region from slightly below average at Kimba, Lock and Buckleboo to well below average at Darke Peak, Rudall, Wharminda, Arno Bay and Cleve. Franklin Harbour recorded its lowest April to August rainfall on record and crops there had little to no biomass.

Some growers near Cleve, Rudall, Arno Bay and Cowell, undertook emergency tillage operations to manage erosion risk, with many resowing exposed dunes multiple times to try and establish surface cover as drifting soils cut off emerging crops.

Whilst pests and diseases were generally low, high levels of cow-pea aphid were reported in some vetch and medic pastures with growers monitoring stock grazing on these paddocks to avoid potential photosensitisation issues as experienced in 2017. Low biomass in paddocks sown for hay at the end of winter meant that many growers reassessed whether they would cut hay, turn to stock into paddocks and graze or allow the crop to go through to harvest.

Spring

September rainfall was very much below average and Franklin Harbour recorded its lowest September rainfall on record. October rainfall was around the monthly average, however it was mostly too late to contribute significantly to yield.

Widespread heavy frosts in September and October damaged significant areas of crop in the Kimba, Lock, Tuckey and Wharminda districts. Demand for hay due to drought conditions in eastern Australia, and associated record high prices, made hay a profitable option and large areas of frosted crop were cut, including consecutive whole paddocks on a number of properties near Kimba and Tooligie. In other areas frost damage was estimated to have reduced yields between 10 and 30%.

Despite dry conditions in September good soil moisture reserves from the above average August rainfall resulted in good growth of crops and pastures near Darke Peak, Rudall, Wharminda and Mangalo and rainfall in October provided good conditions for grain fill. Canola crops in the Cleve Hills that weren't affected by frost maintained good yield potential, but pulse crops on heavier soil types around Cleve suffered significant moisture stress. Very high numbers of aphids and native budworm were reported in canola and pulse crops, with insecticide applications providing generally good control.

Strong winds during this period continued to erode exposed sandy rises in the Verran, Darke Peak, Rudall, Wharminda and Franklin Harbour areas. Growers employed a range of management strategies including sowing cereals or summer forage crops and roughening the soil surface by ripping with a tyned implement to reduce wind speed.

Harvest began in late November, but above average November rainfall caused significant harvest delays. Intense storm activity with strong winds and hail damaged isolated paddocks of canola and barley. However, whilst there were some paddocks with significant yield losses these represented a low proportion of the total crop area for the region.

Continued thunderstorms and cold fronts into December further frustrated harvest efforts with many only completing harvest in early January. Crop yields were highly variable depending on where rain fell, sowing time and frost damage. Kimba districts and the Cleve Hills fared generally better than other districts, and some exceptional yields above 2.5 t/ha were reported. Later sown districts near Kielpa, Rudall and Wharminda had generally low yields, with crops generally too poor to harvest at Franklin Harbour. Wheat and barley yields between 1.0 and 2.0 t/ha were generally below the long term average. Quality was generally good with good test weights, high protein and low screenings. Pulse yields were highly variable. Canola yields were generally good given the season and many paddocks yield over 1.0 t/ha with oil contents above 44%.

Warm days and good soil moisture from rain at harvest resulted in rapid germination and growth of summer weeds and volunteer crops and growers began to spray these immediately after finishing harvest. A number of growers also used the late rainfall as an opportunity to sow summer forage crops such as sorghum, canola and millet.

Lower Eyre Peninsula

Summer

January rainfall was well above the monthly average which resulted in high levels of summer weeds and volunteer crops in paddocks. Although this provided some quality feed during this period and surface cover for protection against erosion biomass levels were generally low and most growers needed to supplementary feed livestock with hay and grain, either in stubble paddocks or in containment areas. Weed growth was slowed during February due to dry conditions. These damp conditions also increased snail activity and growers baited paddocks intended to be sown with vulnerable crops such as peas and canola.

There were early indications that the crop area would be close to the long term average, with slight increases in the area of canola grown compared to 2017, and a corresponding decrease in the barley area. There was also some indication that growers were looking to increase the area of pulse break crops.

Autumn/Winter

Autumn rainfall was generally below average. Whilst multiple cold fronts passed across the region during this period, they brought little rain and hot north winds in the week of 9-13 April dried out surface soil layers. Small areas of vetch and cereals were sown for feed following April rainfall, and some growers with large cropping programs sowed small areas of canola, pulses and long season wheat. Intense cold fronts in May and June brought significant rainfall and, apart from in the Butler district where continued dry conditions delayed seeding further, enabled most growers finish sowing by mid-June.

Whilst most growers sowed all of their intended winter crop program, some livestock producers reduced the area of high risk crops (canola and pulses) and sowed an extra paddock or two of barley or vetch for feed, or an opportunity hay cut to replenish supplies depleted over summer.

Germination was staggered and crop maturity was variable even within the same paddock. Early sown crop with good moisture conditions at germination had good early growth and produced high levels of biomass by the end of spring. Later sown crops struggled with early vigour due to cold conditions during winter. Growers applied post-emergent herbicide sprays in early winter, however there were reports of reduced herbicide efficacy due to dry soil conditions. Livestock health was generally good, however pasture paddocks contained little to no feed throughout winter and whilst producers wanted to move stock into paddocks they were concerned that if they did so too early the pasture would not have the leaf area to recover quickly from grazing. This meant that producers kept feeding stock hay and grain throughout winter, putting considerable pressure on depleted feed reserves with many growers needing to buy in feed from outside of the region.

August rainfall was well above average and some areas near Cummins recorded their highest August rainfall on record. Whilst this rain and warmer days in late August resulted in excellent crop and pasture growth, waterlogging made paddock trafficability difficult toward the end of the month, reducing the opportunities for in-crop herbicide and fertiliser applications. Good growing conditions for crops and pastures resulted in high biomass levels toward the end of winter, which gave rise to opportunities for growers to cut hay to replenish on-farm feed reserves.

Spring

Several severe frosts in late September damaged crops (even in areas with a traditionally lower risk of frost such as Ungarra and Tumby Bay). High demand for hay due to drought conditions in eastern Australia made cutting hay a profitable option. Although it is estimated that only about 5% of the total crop area in Lower EP was affected overall, yield losses of above 30% were estimated on the worst affected areas, with significant areas of frosted crop cut and baled near Cummins, Kapinnie and Ungarra.

September rainfall was low, but widespread cold fronts brought rain in October helping to fill grain. Mild weather until mid-October provided good conditions for flowering and grain fill, with most Lower EP districts having average to above average yield potential. Canola was windrowed in mid-October with some early paddocks harvested toward the end of October.

Whilst pest levels were generally low, native budworm and aphids were reported to have caused damage in canola crops with armyworm damaging cereal crops on the calcareous soils around Mt Hope. These were easily controlled with pesticide applications.

Thunderstorms during November caused significant harvest delays, with only around 75% of harvest completed by the end of December. Crop yields were generally above average across most of Lower EP and some exceptionally high yields (more than 6 t/ha) were reported. The good yields were generally attributed to good stored soil moisture at the end of August and the widespread rainfall event as soil moisture reserves began to run out in late September. Canola and pulse yields were exceptional with many reports of canola yields in excess of 2 t/ha and pulses more than 3 t/ha. Grain quality was good with high protein and low screenings.

Stubbles provided a high levels of biomass and most livestock producers were able to replenish on-farm feed reserves.

Acknowledgements

The author wishes to acknowledge that much of the information contained within this summary has been compiled from PIRSA's 2018 Crop and Pasture Reports.

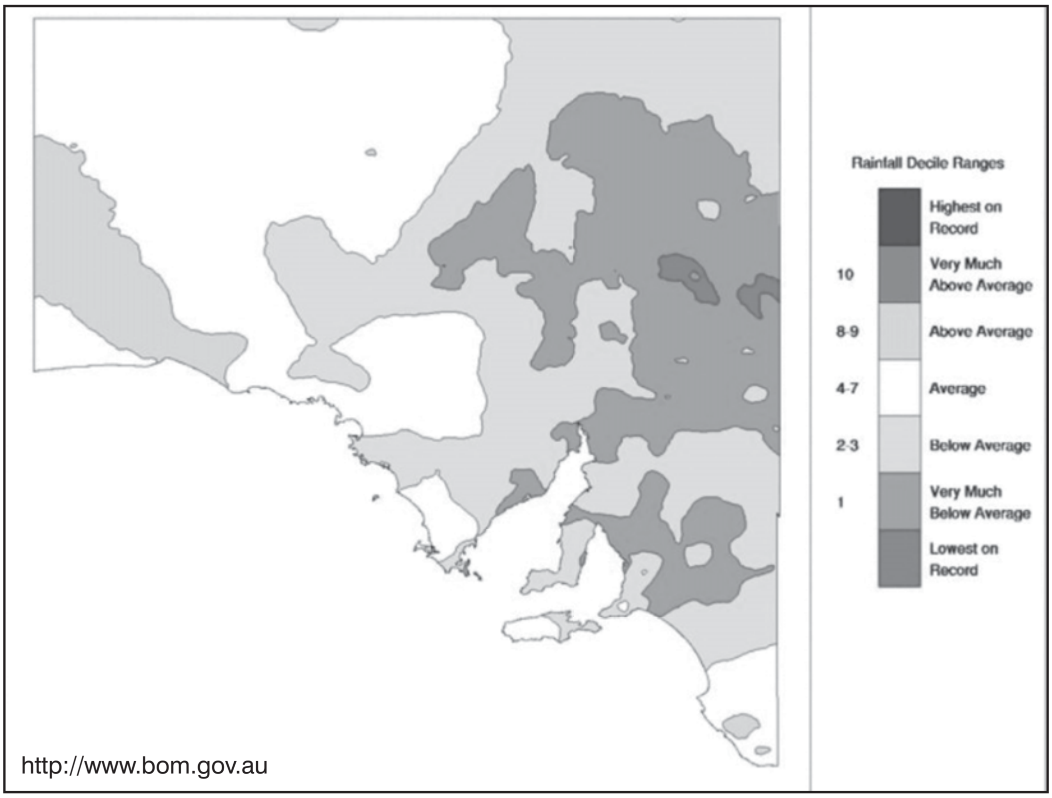


Figure 1. South Australian rainfall deciles, 1 April to 31 December 2018.

Government of South Australia
Primary Industries and Regions SA

MAC Farm Report 2018

INFORMATION

Jake Hull
Farm Manager
SARDI, Minnipa Agricultural Centre

Try this yourself now

Location
Minnipa Agricultural Centre
Rainfall
Av. Annual: 325 mm
Av. GSR: 241 mm
2018 Total: 269 mm
2018 GSR: 208 mm

Key outcomes

- **On average MAC wheat yielded 1.38 t/ha, barley 1.54 t/ha, canola 0.23 t/ha, peas 0.42 t/ha.**
- **80% of total farm area was sown to crops and pastures.**
- **335 breeding ewes mated to merino rams produced 290 lambs at marking with 39 scanned dry.**
- **55 tonnes of certified Razor CL and 18 tonnes of certified DS Bennett seed was made available for sale to growers.**

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 2018 season.

What happened?

Dry, dry, dry, then a wet August, then dry, dry, dry! The season was defined at MAC by a very wet August and yields attained were good considering; a mild finish also helped.

The seeding program began on 1 May and was completed on 7 June. All crops were sown dry with Granuloc Z fertilizer at 65 kg/ha.

- Wheat - 473 ha (Scepter, Trojan, Longsword, Chief CL, Razor CL, DS Bennett, Mace) sown at 75 kg/ha
- Barley - 222 ha (Spartacus, Compass, RGT Planet) sown at 70 kg/ha
- Canola - 25.5 ha (44Y90, 43Y92, Stingray) sown at 2 kg/ha
- Peas - 13 ha (PBA Butler) sown at 75 kg/ha
- Vetch - 115 ha (Volga, Cummins) sown at 40 kg/ha
- Pasture - 206 ha (regenerated medic)
- Trials - 45 ha (DLPS, NVT, etc.)

To try to prevent erosion, Super Sweet Sedan (forage sorghum-Sudan hybrid) was sown on 23 November after rain in paddock N5 with limited success.

Certified seed

- Razor CL
- DS Bennett winter wheat (yielded 1.13 t/ha, surprising for a true winter wheat in a dry and short year)

Harvest

Harvest commenced on 8 November (Volga and Cummins vetch) and finished on 5 December (DS Bennett). The program was completed with little interruption and efficiency of operations increased by using the new chaser bin. The average farm yields were; wheat 1.38 t/ha, barley 1.54 t/ha, canola 0.23 t/ha, peas 0.42 t/ha, and vetch yielded approximately 0.08 t/ha.

Issues encountered in 2018

- Poor establishment of canola due to lack of moisture
- Lack of early season rainfall
- Lack of paddock feed for livestock
- Lack of finishing rains

Farm improvements and equipment

- New Vennings 12 tonne chaser bin with scales purchased for harvest and sheep feeding duties
- New sheep yards and ramp installed
- Six kilometres of new fencing

Things of interest

- Variety comparisons in wheat, barley and canola
- Deep ripping demonstrations

Livestock

Stock currently on the farm: 342 merino ewes, 136 merino ewe lambs, 148 merino wether lambs and 7 merino rams.

Reproduction results overall for 2018: 334 ewes were mated and 39 ewes were scanned dry. 290 lambs were marked from 295 pregnant, with a combination of cold temperatures, low birth weights and high litter sizes, leading to starvation, mismothering and exposure as the main cause of lamb deaths. Giving an average lambing of 98% from ewes scanned in lamb.

The shearing of the flock was completed on 23 August, with the previous shearing in late January. For the August shearing, wool growth period was just under seven months. Ewes averaged 3.8 kilograms per animal and the ewe lambs/hoggets averaged 2.4 kilograms per animal, with average staple lengths measuring 52.5 cm and 56.6 cm respectively.

Ewe and wether lambs weighed in at an average of 33.1 kg per animal at weaning. Although this did include a third of the lambs that were on average two weeks older than the majority and weighed at 14 weeks compared to 12 weeks for the rest. This was due to a ram (AKA Romeo) getting in with the flock ewes around two weeks before joining.

Some issues carried forward in the animals from photosensitisation from the previous spring, with ewe dry weights approximately 5-10 kg lower than their average records, and some ewe and ewe hogget deaths were also attributed to the prolonged effect it had on some animals.

Two rams were purchased in 2018, from a stud on Eyre Peninsula presenting ASBVs.

Acknowledgements

MAC farm staff: Wade Shepperd and John Kelsh

MAC research staff: Jessica Crettenden

MAC administration staff: Leala Hoffmann, Dot Brace and Naomi Scholz.

Table 1 Harvest results, 2018 grain yields and protein aligned with paddock rotational histories

Paddock	Paddock History 2013-2017	Crop 2018	Sowing Date	Yield (t/ha)	Protein (%)	Screenings (%)
North 1	W W P W P	Medic (P)				
North 2	B P C W P	Medic (P)				
North 3	W V W B V	Scepter (W)	5 June	1.41	11.6	1.5
North 4	P W W P W	Compass (B)	16 May	2.10	14.5	1.8
North 5 N	W W B P W	Mace (W)/Compass (B)	17 May	1.56	11.2/14.5	2.4/1.8
North 5 S	W W P W P	Scepter (W)	6 June	1.34	12.2	2.0
North 6	Pe W W B P	Scepter (W)	7 June	1.23	11.13	2.5
North 7	W P W P C	Razor CL/Chief CL/Hatchet CL	31 May	1.61/1.45 /1.12	11.1/13.0 /12.8	6.0/2.8/4.5
North 8	W P W P C	Longsword/DS Bennett	31 May	1.44/1.14	13.6/13.9	1.4/5.5
North 9	B V W B/W O	Peas (P)	7 June	0.42		
North 10/11	W W P W P	Spartacus (B)	11 May	1.34	16.0	3.0
North 12	W S S W W	Canola (C)	2 May	0.02		
South 1	C W Pe W B	Vetch/Barley/Canola Hay Mix	1 May			
South 2	Pe W W P W	Spartacus (B)	14 May	1.31	16.0	3.0
South 3	P P W B V	Scepter (W)	25 May	1.36	11.4	2.4
South 4	W P O/V W B	Volga (V)	4 May	0.07		
South 5	B W P W B	Medic (P)				
South 6	W W B P W	Spartacus (B)	10 May	1.50	16.0	3.0
South 7	W W P W B	Medic (P)				
South 9	W B P P W	Spartacus/ RGT Planet/ Compass	15 May	1.50/1.25 /1.55	17.2/21.7 /18.3	11.2/20.9 /7.0
South 10	V B B V W	Longsword (W)	8 May	0.96	13.3	1.3
Barn	P P W O P	Scepter (W)	24 May	1.51	11.8	2.0
House	P P W O P	Scepter (W)	24 May	1.50	11.8	2.0

P = pasture, Pe = field pea, W = wheat, B = barley, O = oats, C = canola, V = vetch, S= sulla

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

LEADA's 2017 achievements and 2018 focus

LEADA wound up the delivery of the GRDC stubble management and NLP Soil Acidity projects and continued working on other smaller projects funded by a range of partners.

Through the stubble management project LEADA hosted two workshops and their annual crop walk through 2018. The workshops were based around work carried out through the stubble management project, one being the annual Expo "Harvest Weed Seed Management Expo" which included a site visit to Billy Pedler's property for a paddock and harvester (chaff decks) inspection. In June a post-seeding workshop was held in conjunction with GRDC, this included up to date information on Managing weeds in a retained stubble system, managing pests and resistance management and a revisit to Billy Pedler's property for a paddock and seeding inspection. In August LEADA held a Pulse workshop and Cropwalk which concentrated on Pulse breeding and marketing with visits to sites at Yeelanna and Marble Range with a look at different pasture options at Wanilla.

The conclusion of the NLP 'Managing Soil Acidity on Lower EP' was achieved with the completion of pH mapping of a total of 1,000 ha and production of best practice guidelines for management of low pH soils. Two case studies were produced from farmer experience and paddock data. This information provides farmers with locally relevant information to support their decision making around cost effectively improving soil condition and productive capacity by addressing soil acidity on their property.

LEADA reviewed the sites for the second year of the SAGIT grant looking at Copper Management for the Future. New sites were chosen and the results have been very positive. The project explores different management strategies to overcome copper deficiency in cereals, comparing the effectiveness of copper sulphate and copper chelate applied either as liquids banded at seeding or as a foliar spray.

LEADA will continue to deliver the GRDC funded project establishing and running nine 'pulse check' groups across the Southern Region of Australia and LEADA is facilitating the lower Eyre Peninsula group learning / discussion and practical field sessions that focus on 'back to basics' lentil and/or chickpea production. The delivery of the 'Pulse check' discussion group on lower Eyre Peninsula has been conducted by George Pedler with 4 being held in 2018 and a further 4 to be held in 2019.

In 2019 LEADA will be involved with the NLP Smart Farming Partnership initiative and the 'Warm and cool season mixed cover cropping for sustainable farming systems in south eastern Australia', with LEADA involved in two Cover Crop demonstration trials and one plant species screening trial. 'Increasing production on sandy soils in low and medium rainfall areas of the Southern Region' is another GRDC project that LEADA will be involved in for the next three years. LEADA has applied for NLP Smart Farms Small Grant for 'Increasing adoption of new techniques combining physical, chemical and plant based interventions to improve soil function on Eyre Peninsula'.

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

Contact:

Bruce Morgan,
Chair 0427 872 038

Megan Low,
Executive Officer 0427 393 065

Committee members:

Bruce Morgan (Chair), John Richardson (Vice Chair), Daniel Adams, George Pedler, Dustin Parker, Mark Habner, Derek Macdonald, Josh Telfer, Sam Ness, Mark Dennis, Billy Pedler, Mark Stanley (Ag Ex Alliance), Mary Crawford (EPNRMB), Andrew Ware, David Davenport (RSSA).

An initiative of the Australian Government Department of Agriculture.

Understanding trial results and statistics

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

The average (or mean)

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

The LSD test

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

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

Results from replicated trial

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

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

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

Types of work in this publication

The following table shows the major characteristics of the different types of work in this publication. The Editors would like to emphasise that because of their often un-replicated and broad scale nature, care should be taken when interpreting results from demonstrations.

Type of Work	Replication	Size	Work conducted by	How Analysed
DEMO	No	Normally large plots or paddock size	Farmers and Agronomists	Not statistical, trend comparisons
RESEARCH	Yes, usually 3	Generally small plot	Researchers	Statistics
SURVEY	Yes	Various	Various	Statistics or trend comparisons
EXTENSION	N/A	N/A	Agronomists and Researchers	Usually summary of research results
INFORMATION	N/A	N/A	N/A	N/A

Some useful conversions

Area

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

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

1 ha = 2.471 acres

Mass

1 t (metric tonne) = 1,000 kg

1 imperial tonne = 1,016 kg

1 kg = 2.205 lb

1 lb = 0.454 kg

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

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

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

1 bu (wheat) = 60 lb = 27.2 kg

1 bag = 3 bu = 81.6 kg (wheat)

Volume

1 L (litre) = 0.22 gallons

1 gallon = 4.55 L

1 L = 1,000 mL (millilitres)

Speed

1 km/hr = 0.62 miles/hr

10 km/hr = 6.2 miles/hr

15 km/hr = 9.3 miles/hr

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

Pressure

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

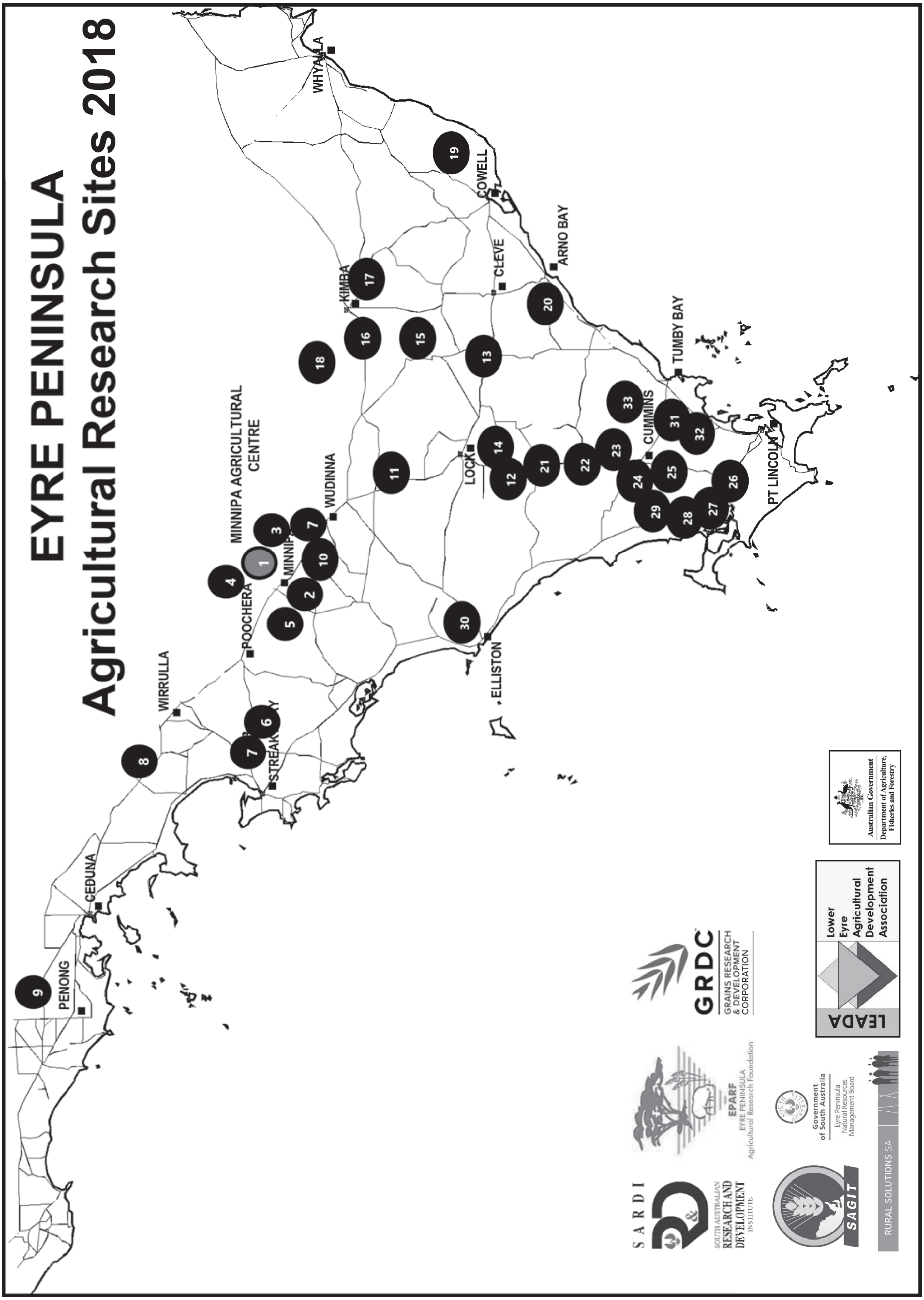
25 psi = 1.7 bar = 172 kPa

Yield

1 t/ha = 1000 kg/ha

Yield Approximations

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


EYRE PENINSULA
Agricultural Research Sites 2018
MINNIPA AGRICULTURAL CENTRE
WHYALLA
COWELL
ARNO BAY
CLEVE
KIMBA
TUMBY BAY
CUMMINS
PT LINCOLN
LOCK
WUDINNA
MINNIPA
POOCHERA
WIRRULLA
STREAKY BAY
ELLISTON
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SARDI
SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE
EPARF
EYRE PENINSULA Agricultural Research Foundation
GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION
LEADA
Lower Eyre Agricultural Development Association
Australian Government
Department of Agriculture, Fisheries and Forestry
Government of South Australia
Eyre Peninsula Natural Resources Management Board
SAGIT
RURAL SOLUTIONS SA

Eyre Peninsula agricultural research sites 2018 map references

Map reference	Location	Trials	Host farm business
1	Minnipa	NVT wheat, barley, canola. Blackspot peas. Time of sowing beans and lentils. Low rainfall zone pulses. Lentil herbicides. Carinata canola. Time of sowing wheat. Intergrain wheat and barley. Longreach wheat. Russian wheat aphid. Nitrogen and water co-limitation. Benchmarking. Canola risk management. Large scale annual pasture legume grazing trial. Annual pasture legume species evaluation. Hard seededness annual pasture legumes. Nitrogen fixation annual pasture legumes. Controlled traffic. UAV monitoring grass weeds. Microbes on seed.	SARDI Minnipa Agricultural Centre
2	Minnipa	Swathing crops for barley grass control. UAV monitoring grass weeds. Annual ryegrass management utilising crop competition and herbicides. Legume inoculants. Microbes on seed.	Bruce Heddle
3	Minnipa	Herbicide efficacy in retained stubbles. NVT canola.	John Oswald
4	Minnipa	Phosphorus response	Gareth Scholz
5	Minnipa	Chafflining weed seed decay	Jerel Fromm
6	Piednippie	Maximising DM production on grey soils	Brent Cronin
7	Piednippie	NVT wheat and barley. Water use efficiency.	John Montgomery
8	Nunjikompita	NVT wheat. Water use efficiency.	Tim Howard
9	Penong	NVT wheat	Butch Dunn
10	Yaninee	UAV monitoring grass weeds	Gregor Wilkins
11	Warramboo	NVT wheat	Murphy family
12	Murlong	Sandy soils	Mark Siviour
13	Rudall	NVT wheat	Jason Burton
14	Lock	Nitrogen and water co-limitation	Ian Burrows
15	Darke Peak	NVT barley	Mark Edwards
16	Kimba	NVT wheat	Shannon Mayfield
17	Kimba	Oat varieties	Trevor Cliff
17	Kimba	Pulse validation	Simon Allen
18	Pinkawillinie	Vetch and peas	Paul Schaefer
19	Cowell	NVT wheat	Kaden family
20	Wharminda	Water repellency	Chris Prime
20	Wharminda	District wheat trial. NVT barley.	Tim Ottens
20	Wharminda	Chafflining weed seed decay	Ed Hunt
20	Wharminda	Chafflining weed seed decay	Ian Noble
21	Murdinga	NVT field pea	Basil Heath
22	Tooligie	Pulse validation	Bill Long
23	Yeelanna	NVT canola	Peter & Steve Glover
23	Yeelanna	Eyespot in wheat	Ian Proctor
23	Yeelanna	Canola agronomy	Mark Modra
23	Yeelanna	Pulse and bean agronomy. NVT field pea and lentil.	Chad Glover
24	Cummins	Nitrogen and water co-limitation. NVT wheat and barley.	Douglas Green
25	Edillilie	Pulse validation	Simon Giddings

Map reference	Location	Trials	Host farm business
25	Edillilie	Copper management	Jed Siegert
26	Wanilla	NVT wheat, barley	Rob & Hayden McFarlane
27	Wangary	Nutrition disease management	Graeme Charlton
28	Mt Hope	Sclerotinia and blackleg in canola	Ashley & Sam Ness
29	Brimpton Lake	New Horizons (soil amelioration)	Luke Moroney
30	Elliston	District wheat trial. NVT barley.	Nigel & Debbie May
31	Yallunda Flat	Eyespot in wheat	Simon Pedlar
32	Koppio	Eyespot in wheat	Syd Lawrie
33	Stokes	Copper management. Nutrition disease management.	John Richardson

Photo: Fabio Arsego, SARDI Research Agronomist and Sue Budarick, SARDI Minnipa Agricultural Centre using the spectroradiometer

Section 1

Cereals

Section Editor:
Amanda Cook
SARDI, Minnipa Agricultural Centre

Wheat and barley variety update 2018

Rob Wheeler
GRDC NVT manager, Southern Region

EXTENSION

Key messages

- **Across a wide sowing date range and mostly very dry and frosty seasonal weather conditions, mid-season maturing wheat and barley varieties were generally most dominant in 2018.**
- **Vixen (AH), Scepter (AH), Beckom (AH), LRPB Arrow (AH) and the Clearfield varieties, Razor^{CLPLUS} (ASW) and Sheriff^{CLPLUS} (APW), led Mace, and were the highest yielding varieties across 2018 SA wheat NVT sites.**
- **Rosalind, Fathom, Buff and RGT Planet led Compass and were the highest yielding varieties across 2018 SA barley NVT sites.**
- **Long term results at a local level, found at NVTonline.com.au, will provide the most reliable yield information to guide choice of variety for a particular farming system.**

2018 seasonal overview for cereal NVT

Much like 2017, the 2018 cropping season began with an erratic opening break for most districts with limited opportunities to sow early into adequate moisture and very delayed germination in many dry sown situations. Extremely low rainfall in most districts except the South East continued through winter and into spring and was combined with severe frost (stem and head) events during late August and September and into early October, particularly within districts which rarely see these events. Strong winds in late September and early October further impacted crop growth through grain shattering and lodging. On a more positive note, incidence of cereal disease was very low with some Septoria noted within the high rainfall South East district. Despite the very challenging season in many SA districts and the confounding issues across districts, the majority of cereal national variety trials (NVT) produced good results and provided the opportunity to assess many of the newer varieties under diverse albeit mostly drier seasonal conditions.

Wheat NVT

The light and erratic opening rains impacted the NVT program, preventing the opportunity to sow "early break" wheat trials except for a long season trial in the South East. Otherwise for main season trials, sowing dates ranging from 8 May at Piednippie to 20 June at Penong, with most trials sown in the second half of May. Individual wheat NVT site yields ranged from 0.31 t/ha at Mitchellville to 7.3 t/ha at Conmurra in the South East with an average of 2.92 t/ha across the 19 successful main season trials, slightly above the 2.72 t/ha average in 2017 but below the 5-year (2013-2017) average of 3.30 t/ha.

Trial variability, severe drought conditions and frost, resulted in the failure of trials at Kimba, Pinnaroo, Nangari, Wanbi, Palmer, Spalding and Wokurna. The results from these sites were considered invalid for 'head to head' variety comparisons, but for transparency, are available in a 'Quarantined Trials Report' obtained at NVTonline.com.au. All other trials returned statistically acceptable results.

A total of 38 commercial wheat varieties and 19 breeding lines were evaluated in the South Australian main season NVT series. Overall, the 2018 seasonal conditions tended to favour early to mid-maturing varieties with Vixen, Scepter, Beckom, Cobalt, LRPB Arrow, Razor^{CLPLUS} and Sheriff^{CLPUS} respectively leading all other varieties, including Mace, tested at all sites.

Many of these leading varieties have only been released in the past 12 months or more and while it is useful to see their performance in a difficult year like 2018, longer term comparisons including their quality and disease resistance characteristics need to be considered by growers considering a change to them. Of particular interest will be the new Clearfield varieties, Razor^{CLPLUS} and Sheriff^{CLPLUS} which potentially offer much higher yields and a range of alternative agronomic characteristics, albeit lower market quality classification, relative to the older commercial varieties, Grenade^{CLPLUS} and Kord^{CLPLUS}.

Barley NVT

Within the main season 2018 barley NVT, sowing dates ranging from 8 May at Piednippie to 26 June at Darke Peak with most trials sown in the second half of May. Individual barley NVT site yields ranged from 0.84 t/ha at Lameroo to 7.07 t/ha at Maitland on the Yorke Peninsula with an average of 3.66 t/ha across the 15 successful main season trials, well below the 4.37 t/ha average in 2017 and below the 5-year (2013-2017) average of 4.04 t/ha.

Trial variability, severe drought conditions and frost, resulted in the failure of trials at Crystal Brook, Paruna and Wharminda. The results from these sites were considered invalid for 'head to head' variety comparisons, but for transparency, most results are available in a 'Quarantined Trials Report' obtained at NVTonline.com.au. All other trials returned statistically acceptable results.

A total of 35 commercial barley varieties and 15 breeding lines were evaluated in the South Australian main season NVT series. Overall, the 2018 seasonal conditions tended to favour early to mid-maturing varieties but across all sites, only six per cent difference in yield separated the top 12 varieties. Rosalind, Fathom, Buff, RGT Planet and Compass were the leading varieties respectively followed by Hindmarsh, LaTrobe and Spartacus CL. With, the exception of Buff, a recent release with acid soil tolerance, this group of varieties have generally been among the best performers in SA barley NVT across recent seasons.

Interpreting long term yield data and NVT new developments

The long-term yield data presented in annually published crop sowing guides, is an output of the new National Variety Trials (NVT) Long Term Multi Environment Trial (MET) analysis and use a minimum five-year rolling dataset in the MET analysis.

A factor analytic (FA) mixed model approach is used in the MET analysis drawing on expertise from the GRDC supported Statistics for the Australian Grains Industry (SAGI) program. This approach uses raw plot data to simultaneously model the individual trial variation and the variety by environment interactions (VEI) observed across years and geographical locations to develop the NVT long-term variety by environment predictions. In this way, NVT long-term predictions better exploit the true power that exists within the NVT database which now encompasses over 8,000 individual trials.

To gain the full benefit of these world leading statistical outputs, users should study variety rankings across locations and seasons relevant to their farming system. However, presenting this level of detail is difficult within hardcopy publications which are left needing to average across regions and/or yield groupings. Averaging does simplify the data and allows for broad sweeping generalisations but also actually masks variety performance comparisons that might otherwise be observed for specific environments, effectively undoing the sophistication of the new analysis.

To overcome this challenge the NVT team have continued to develop a simple web tool for viewing the vast datasets encountered in the NVT system and it is available at https://app.nvtonline.com.au.

When using the tool, the results are most accurate and reliable when viewed at the individual location (site) level, but the option is still provided for regional or multi-site selections for ease of use and/or more generic interpretations. In addition, users can still choose to view data on Year or Yield based groupings, both in chart or table format and they can also filter wheat varieties by delivery classification.

Future outlook for NVT

With the increased sophistication afforded by the latest analytical and reporting techniques, an opportunity now exists to help growers understand and interpret the Variety x Environment Interactions (VEI) observed in NVT. In particular, research to better explain the environmental drivers of variety performance will assist growers more easily relate NVT results to their growing environment.

Finally, the wide range of variety trait information made available through NVT, supports more considered variety selection decisions, but again adds complexity. To enable growers to more easily navigate the selection process, the NVT team are investigating options for growers to select their user preferences with regard to sites, varieties and traits of interest.

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GRDC™ GRAINS RESEARCH & DEVELOPMENT CORPORATION

Emerging management tips for early sown winter wheats

RESEARCH

Kenton Porker, Dylan Bruce, Brenton Spriggs and Sue Budarick[1], James Hunt[2], Felicity Harris and Greg Brooke[3], Sarah Noack[4], Michael Moodie, Mick Brady, and Todd McDonald[5], Michael Straight[6], Neil Fettell, Helen McMillan, and Barry Haskins[7], Genevieve Clarke, and Kelly Angel[8]

[1]SARDI, [2]La Trobe University, [3]NSW DPI, [4]Hart Field site, [5]Moodie Agronomy, [6]FAR, [7]CWFS, [8]BCG

Location
Minnipa Agricultural Centre, Paddock S2/8
Rainfall
Av. Annual: 325 mm
Av. GSR: 241 mm
2017 Total: 282 mm
2017 GSR: 155 mm
Yield
Potential: 1.7 t/ha (W)
Actual: Highest yielding treatment, 2.5 t/ha
Paddock History
2016: Grass free pasture
2015: Wheat
2014: Wheat
Soil Type
Sandy loam
Plot Size
5 m x 1.4 m x 4 reps
Yield Limiting Factors
Drought, mice

Key messages

- **Highest yields for winter wheats come from early – late April establishment.**
- **Highest yields of winter wheats sown early are similar to Scepter sown in its optimal window.**
- **Slower developing spring cultivars are not suited to pre 20 April sowing.**
- **Different winter wheats are required for different environments.**
- **Flowering time cannot be manipulated with sowing date in winter wheats like spring wheat.**
- **10 mm of rainfall was needed for establishment on sands, 25 mm on clays - more was not better.**

Why do the trials?

Winter wheat cultivars allow wheat growers in the southern region to sow much earlier than currently practiced, meaning a greater proportion of the farm can be sown on time. The previous GRDC Early Sowing Project (2013-2016) highlighted the yield penalty from delayed sowing. Wheat yield declined at 35 kg/ha for each day sowing was delayed beyond the end of the first week of May using a fast developing spring cultivar.

Sowing earlier requires varieties that are slower developing. For sowing prior to 20 April, winter cultivars are required, particularly in regions of high frost risk. Winter wheats will not progress to flower until their vernalisation requirement is met (cold accumulation) whereas spring cultivars will flower too early when sown early. The longer vegetative period of winter varieties also allows dual-purpose grazing.

The aim of this series of experiments is to determine which of the new generation of winter cultivars have the best yield and adaptation in different environments and what is their optimal sowing window. Prior to the start of the project in 2017 the low–medium rainfall environments of South Australia and Victoria had little exposure to winter cultivars, particularly at really early sowing dates (mid-March). Three different experiments have been conducted in the southern region in low–medium rainfall environments during 2017 and 2018, and one of these has been matched by collaborators in NSW for additional datasets presented in this paper.

How was it done?

Experiment 1

Which wheat cultivar performs best in which environment and when they should be sown?

- Target sowing dates: 15 March, 1 April, 15 April and 1 May (10 mm supplementary irrigation to ensure establishment).
- Locations: SA - Minnipa, Booleroo Centre, Loxton, Hart. Vic - Mildura, Horsham, Birchip and Yarrawonga. NSW - Condobolin, Wongarbon, Wallendbeen.
- Up to ten wheat cultivars - The new winter wheats differ in quality classification, development speed and disease rankings (Table 1).

Experiment 2

How much stored soil water and breaking rain is required for successful establishment of early sown wheat without yield penalty?

- Sowing dates: 15 March, 1 April, 15 April and 1 May.
- Cultivars: Longsword, Kittyhawk and DS Bennett.
- Irrigation: 10 mm, 25 mm and 50 mm applied at sowing.
- Locations: SA - Loxton. Vic - Horsham, Birchip.

Experiment 3
What management factors other than sowing time are required to maximise yields of winter wheats?

- Sowing date: 15 April.
- Cultivars: Longsword, Kittyhawk and DS Bennett.
- Management factors examined: Nitrogen at sowing vs. nitrogen at early stem elongation, defoliation to simulate grazing, plant density 50 plants/m^2 vs. plant density 150 plants/m^2.
- Locations: SA - Loxton. Vic - Yarrawonga.

What happened?

Experiment 1

Development speeds

Flowering time is a key determinant of wheat yield. Winter cultivars have stable flowering dates across a broad range of sowing dates. This has implications for variety choice as flowering time cannot be manipulated with sowing date in winter wheats like spring wheat. This means different winter varieties are required to target the different optimum flowering windows that exist in different environments. The flowering time difference between winter cultivars are characterised based on their relative development speed into four broad groups; fast, mid-fast, mid and mid-slow for medium-low rainfall environments (Table 1 and Figure 1).

Cereals

Table 1 Summary of winter cultivars, including Wheat Australia quality classification and disease rankings based on the 2019 SA Crop Sowing Guide

Cultivar	Release Year	Company	Development	Quality	Disease Rankings#			
					Stripe Rust	Leaf Rust	Stem Rust	YLS
Kittyhawk	2016	LRPB	Mid winter	AH	MR	MR	R	MRMS
Longsword	2017	AGT	Fast winter	Feed	RMR	MSS	MR	MRMS
Illabo	2018	AGT	Mid-fast winter	AH/APH*	RMR	S	MRMS	MRMS
DS Bennett	2018	Dow	Mid-slow winter	ASW	R	S	MRMS	MRMS
ADV08.0008	?	Dow	Mid winter	?	-	-	-	-
ADV15.9001	?	Dow	Fast winter	?	-	-	-	-
LPB14-0392	?	LRPB	Very slow spring	?	-	-	-	-
Cutlass	2015	AGT	Mid spring	APW/AH*	MS	RMR	R	MSS
Trojan	2013	LRPB	Mid-fast spring	APW	MR	MRMS	MRMS	MSS
Scepter	2015	AGT	Fast spring	AH	MSS	MSS	MR	MRMS

**SNSW only*

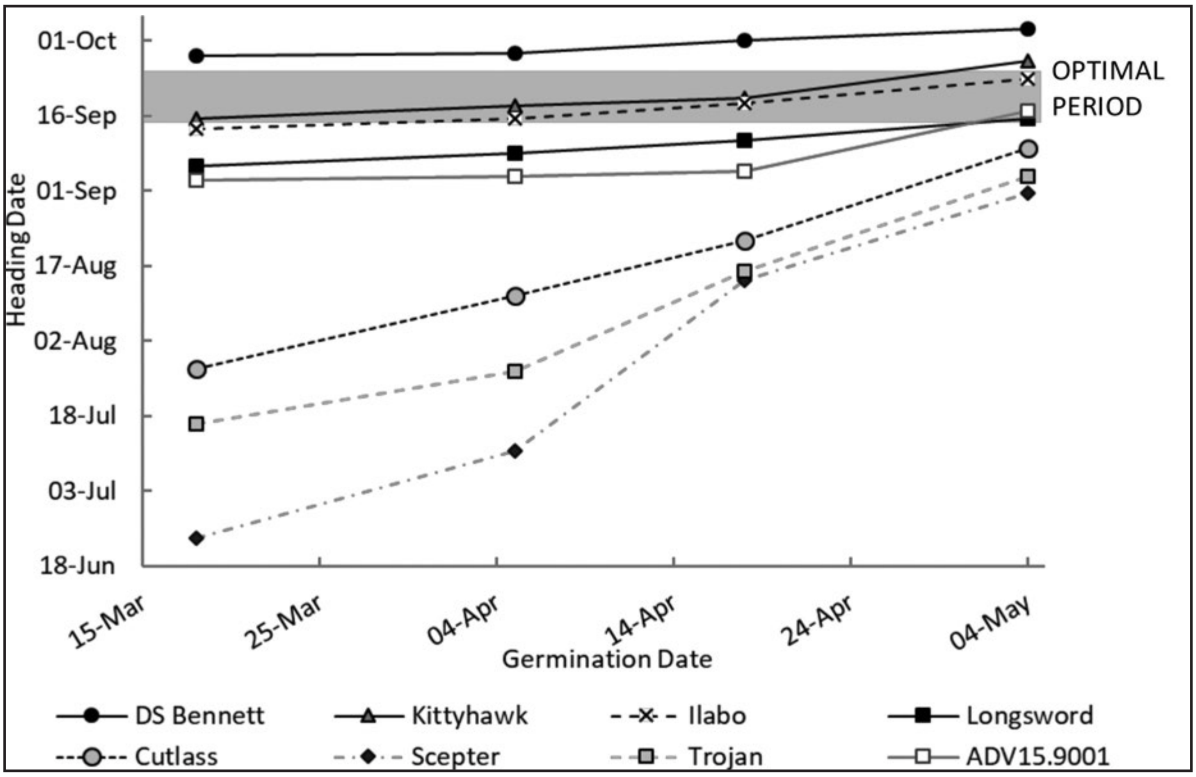

Figure 1 Mean heading date responses from winter and spring cultivars at Hart in 2017 and 2018 across all sowing times, grey box indicates the optimal period for heading at Hart.

For example at Hart in the Mid North of SA each winter variety flowered within a period of 7-10 days across all sowing dates, whereas spring cultivars were unstable and ranged in flowering dates over one month apart (Figure 1). In this Hart example the mid developing winter wheats such as Illabo and Kittyhawk were best suited to achieve the optimum flowering period of 15-25 September for Hart. In other lower yielding environments such as Loxton, Minnipa and Mildura the faster developing winter cultivar Longsword was better suited to achieve flowering times required for the first 10 days in September.

Winter versus spring wheat grain yield

Across all experiments the best performing winter wheat yielded similar to the fast developing spring variety Scepter sown at the optimal time (last few days of April or first few days of May, used as a best practice control) in 16 out of 20 sites, greater in 3 and less than in 1 environment (Figure 2). The best performing winter wheat yielded similar to the best performing slow developing spring variety (alternative development pattern) at 14 sites, greater at 4 and less than at 2 sites.

Sowing time responses

Across all environments the highest yields for winter wheats generally came from early – late April establishment. The results suggested that yields may decline from sowing earlier than April and these dates may be too early to maximise winter wheat performance (Table 2).

Slower developing spring wheats performed best from sowing dates after 20 April, and yielded less than the best performing winter cultivars when sown prior to 20 April. This reiterates slow developing spring varieties are not suited to pre 20 April sowing in low–medium frost prone environments.

Which winter cultivar performed best?

The best performing winter wheat cultivars depended on yield environment, development speed and the severity and timing of frost (Table 2). The rules generally held up that winter cultivars well-adjusted to a region yielded similar to Scepter sown in its optimal window, these results demonstrate that different winter wheats are required for different environments and there is genetic by yield environment interaction.

- In environments less than 2.5 t/ha the faster developing winter wheat Longsword was generally favoured (Table 2, Figure 3).
- In environments greater than 2.5 t/ha the mid–slow developing cultivars were favoured; Illabo in the Mid North of SA, and DS Bennett at the Vic and NSW sites (Table 2, Figure 4).
- The poor relative performance of Longsword in the higher yielding environments was explained by a combination of flowering too early and having inherently greater floret sterility than other cultivars irrespective of flowering date.

Sites defined by severe September frost and October rain included Yarrawonga, Mildura and Horsham in 2018, in these situations the slow developing cultivar DS Bennett was the highest yielding winter wheat and had the least amount of frost induced sterility. The October rains also favoured this cultivar in 2018 and mitigated some of the typical yield loss from terminal drought. Nonetheless the ability to yield well outside the optimal flowering period maybe a useful strategy for extremely high frost prone areas for growers wanting to sow early.

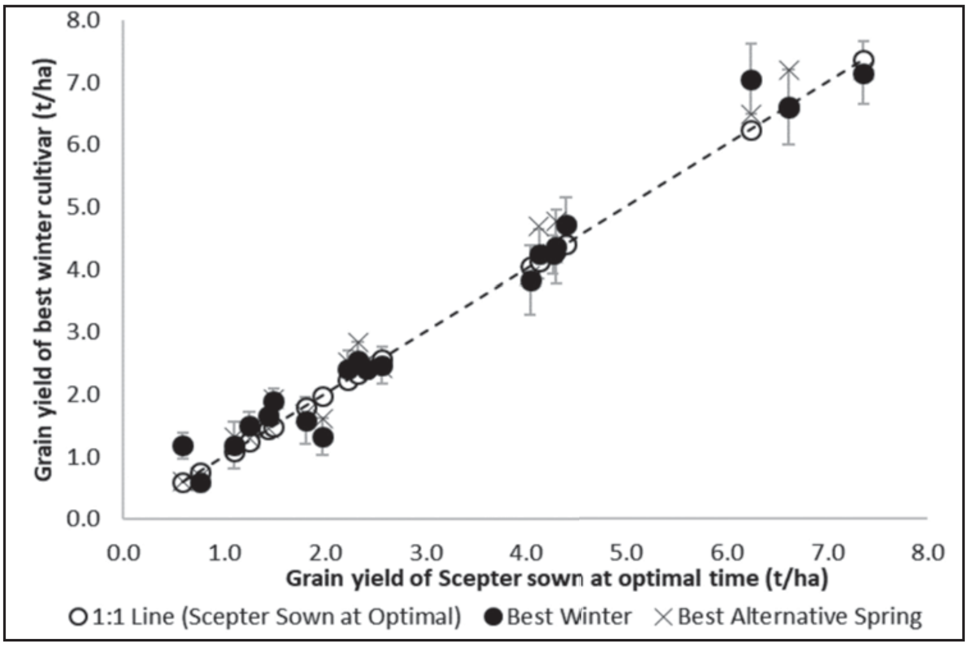

Figure 2 Grain yield performance of Scepter wheat sown at its optimal time (late April-early May) in 20 environments compared to the best performing winter wheat and best alternative spring. Error bars indicate LSD (P<0.05).

Table 2 Summary of grain yield performance of the best performing winter and alternate spring cultivar in comparison to Scepter sown at the optimum time (late April-early May). Different letters within a site indicate significant differences in grain yield.

Site	Year	Scepter sown at optimum grain yield (t/ha)	Best winter performance			Best alternate spring performance		
			Grain yield (t/ha)	Variety	Germ date	Grain yield (t/ha)	Variety	Germ date
Yarrawonga* - VIC	2018	0.59 a	1.18 b	DS Bennett	16-Apr	0.61 a	Cutlass	16-Apr
Booleroo - SA	2018	0.77 a	0.59 a	Longsword	4-Apr	0.69 a	Trojan	2-May
Loxton - SA	2018	1.10 a	1.19 a	Longsword	19-Mar	1.32 a	Cutlass	3-May
Minnipa - SA	2018	1.25 a	1.50 b	Longsword	3-May	1.29 a	Trojan	3-May
Mildura* - VIC	2018	1.44 a	1.66 b	DS Bennett	1-May	1.46 a	LPB14-0293	1-May
Mildura - VIC	2017	1.49 a	1.90 b	Longsword	13-Apr	1.93 b	Cutlass	28-Apr
Horsham* - VIC	2018	1.81 a	1.58 a	DS Bennett	6-Apr	1.70 a	Trojan	2-May
Booleroo - SA	2017	1.98 a	1.33 b	DS Bennett	4-May	1.61 b	Cutlass	4-May
Minnipa - SA	2017	2.23 a	2.42 a	Longsword	18-Apr	2.52 a	Cutlass	5-May
Loxton - SA	2017	2.33 a	2.55 a	Longsword	3-Apr	2.83 b	LPB14-0293	3-Apr
Hart - SA	2018	2.41 a	2.42 a	Illabo	17-Apr	2.52 a	LPB14-0293	17-Apr
Rankins Springs - NSW	2018	2.57 a	2.47 a	DS Bennett	19-Apr	2.42 a	Trojan	7-May
Birchip - VIC	2018	4.04 a	3.83 a	Longsword	30-Apr	3.90 a	Trojan	30-Apr
Hart - SA	2017	4.13 a	4.25 a	Illabo	18-Apr	4.70 b	LPB14-0293	18-Apr
Yarrawonga - VIC	2017	4.27 a	4.24 a	DS Bennett	3-Apr	4.26 a	Cutlass	26-Apr
Wongarbon - NSW	2017	4.30 a	4.37 a	DS Bennett	28-Apr	4.77 a	Trojan	13-Apr
Tarlee - SA	2018	4.40 a	4.71 a	Illabo	17-Apr	4.62 a	LPB14-0293	17-Apr
Wallendbeen - NSW	2017	6.24 a	7.05 b	DS Bennett	28-Mar	6.49 a	Cutlass	1-May
Birchip - VIC	2017	6.62 a	6.60 a	DS Bennett	15-Apr	7.20 a	Trojan	15-Apr
Horsham - VIC	2017	7.36 a	7.15 a	DS Bennett	16-Mar	7.19 a	Trojan	28-Apr

**repeated frost during September followed by October rain*

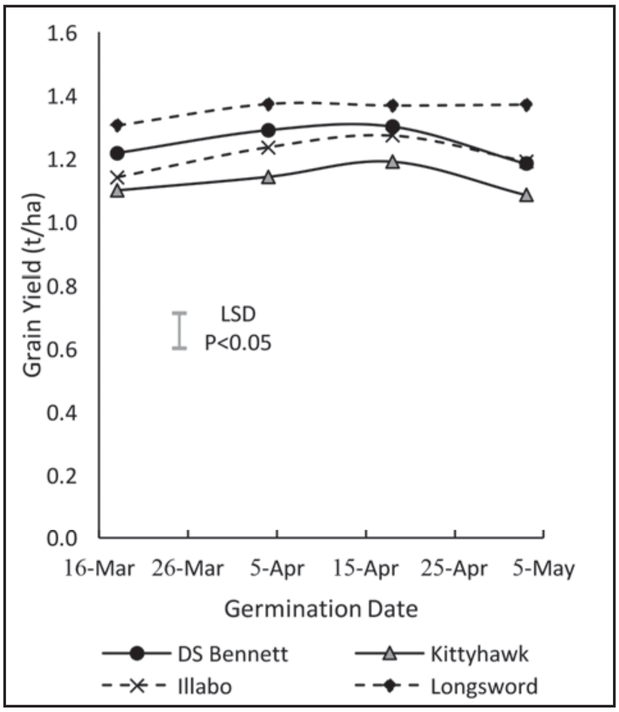

Figure 3. Mean yield performance of winter wheat in yield environments less than 2.5 t/ha (11 sites in SA/ Vic)

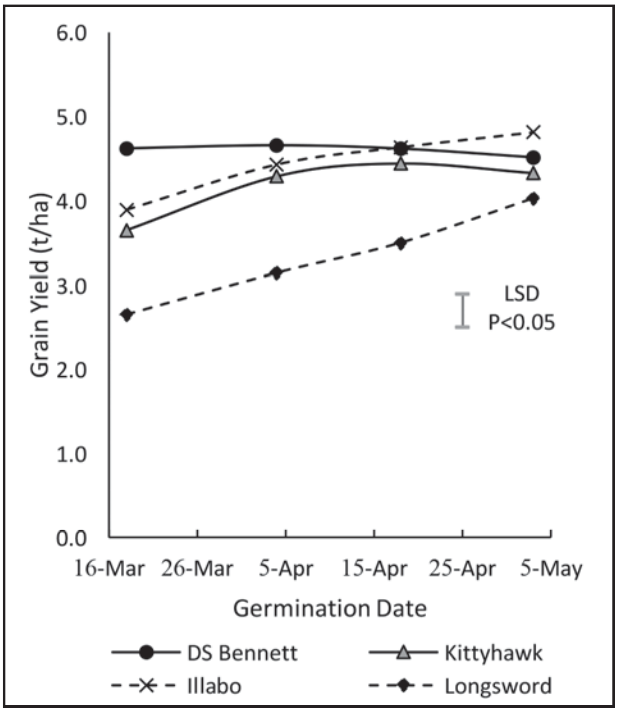

Figure 4. Mean yield performance of winter wheat in yield environments greater than 2.5 t/ha (5 sites in SA/ Vic)

Experiment 2

2018 had one of the hottest and driest autumns on record, and provided a good opportunity to test how much stored soil water and/or breaking rain is required to successfully establish winter wheats and carry them through until winter. The 10 mm of irrigation applied at sowing in the sowing furrow was sufficient to establish crops and keep them alive (albeit highly water stressed in most cases) until rains finally came in late May or early June at 7 of the 8 sites at which Experiment 1 was conducted in 2018. The one exception was Horsham, which had very little stored soil water and a heavy, dark clay soil. At this site, plants that emerged following the first time of sowing in mid-March died after establishment and prior to the arrival of winter rains. Plants at all other times of sowing were able to survive. Experiment 2 was also located at this site, and 25 mm of irrigation was sufficient to keep plants alive at the first time of sowing. A minimum value of 25 mm for sowing in March on heavier soil types is supported by results from Minnipa in 2017, which also experienced a very dry autumn. In this case, ~30 mm of combined irrigation, rainfall and stored soil water was sufficient to keep the first time of sowing alive. On lighter soil types, less water was needed and 10 mm irrigation at sowing with 8 mm of stored water plus an accumulated total of 13 mm of rain until June allowed crops to survive on a sandy soil type at Loxton in 2018.

Based on these observations, we conclude that when planting in March on clay soils, at least 25 mm of rainfall and/or accessible soil water are required for successful establishment. Once sowing moves to April, only 10 mm (or enough to germinate seed and allow plants to emerge) is sufficient.

Experiment 3

Yield responses to changes in plant density, N timing and defoliation have been small (Table 3). There have been limited interactions between management factors and cultivars. The results from experiment one and three confirm selecting the correct winter cultivar for the target environment and sowing winter wheats on time (before 20 April) increases the chances of high yields. The target density of 50 plants/m^2 is sufficient to allow maximum yields to be achieved, and there is no yield benefit from having higher densities in winter cultivars. Deferring N until stem elongation had a small positive benefit at Yarrawonga, and a negative effect at Loxton. Grazing typically has a small negative effect in all cultivars, however the mean percentage grain yield recovery from grazing has been higher in Longsword (95%) compared to DS Bennett (87%) and Kittyhawk (82%), respectively.

Table 3 Mean main effects on grain yield (t/ha) from management factors at Loxton and Yarrawonga (2017 & 2018 = 4 sites)

Management factor (Grain yield t/ha)						**Mean management effect (t/ha)**
Cultivar choice	DS Bennett (2.21) & Kittyhawk	(2.10)	Vs.	Longsword	(2.40)	+0.30***
Seeding rate (target density)	150 plants/m^2	(2.14)	Vs.	50 plants/m^2	(2.35)	+0.21***
Nitrogen timing	Seedbed applied N	(2.32)	Vs.	N Delayed to Stem Elongation	(2.21)	-0.11 ns
Grazing ^	Ungrazed	(2.38)	Vs.	Grazed	(2.11)	-0.27***
Sowing date#	Early May Germination	(1.70)	Vs.	Mid-April Germination	(2.19)	+0.49***

*^ grazing was simulated by using mechanical defoliation at Z15 and Z30, #Sowing date effect derived from experiment 1 at Loxton and Yarrawonga. Level of significance of main effect indicated by ns=not significant, *** = P<0.001.*

What does this mean?

Growers in the low-medium rainfall zones of the southern region now have winter wheat cultivars that can be sown over the entire month of April and are capable of achieving similar yields to Scepter sown at its optimum time. However, grain quality of the best performing cultivars leaves something to be desired (Longsword=feed, DS Bennett=ASW). Sowing some wheat area early allows a greater proportion of farm area to be sown on time. Growers will need to select winter wheats suited to their flowering environment (fast winter in low rainfall, mid and mid-slow winter in medium rainfall) and maximum yields are likely to come from early–mid April planting dates. If planting in April, enough rainfall to allow germination and emergence will also be enough to keep plants alive until winter. If planting in March, at least 25 mm is required on heavy soils. Reducing plant density from 150 to 50 plants/m^2 gives a small yield increase, grazing tends to reduce yield slightly.

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Eyre Peninsula 2018 NVT wheat trial yields in t/ha and expressed as percentage of site mean

Region	Lower EP						Upper EP											
Nearest Town	Cummins		Rudall		Wanilla		Minnipa		Mitchellville		Nunjikompita		Penong		Piednippie		Warramboo	
Variety Name	t/ha	%	t/ha	%	t/ha	%	t/ha	%	t/ha	%	t/ha	%	t/ha	%	t/ha	%	t/ha	%
Axe	-	-	2.19	96	-	-	1.14	99	0.47	150	1.16	90	0.93	91	1.61	89	2.16	95
Beckom	5.31	101	2.34	102	3.69	108	1.19	103	0.31	99	1.32	102	1.09	107	1.85	102	2.41	106
Chief CL Plus	5.42	103	2.23	97	3.61	106	1.21	105	0.27	87	1.40	108	1.11	109	1.97	109	2.31	101
Cobalt	5.36	102	2.23	98	4.09	120	1.21	105	0.26	83	1.39	108	1.03	101	1.88	104	2.36	104
Corack	5.30	101	2.45	107	3.63	106	1.19	103	0.38	122	1.31	101	1.08	105	1.81	100	2.32	102
Cosmick	5.46	104	2.36	103	3.45	101	1.17	101	0.27	85	1.29	100	1.07	105	1.78	99	2.27	100
Cutlass	5.21	99	2.25	99	3.86	113	1.13	98	0.19	62	1.35	104	1.03	101	1.87	103	2.24	98
DS Darwin	4.90	93	2.06	90	3.20	94	-	-	-	-	-	-	-	-	-	-	-	-
DS Pascal	5.11	97	1.75	76	2.78	81	-	-	-	-	-	-	-	-	-	-	-	-
Emu Rock	5.02	95	2.35	103	3.54	103	1.07	93	0.43	139	1.10	86	0.94	92	1.80	100	2.14	94
Estoc	4.96	94	2.05	90	3.34	98	1.11	97	0.24	78	1.27	98	0.91	89	1.76	97	2.18	96
Gladius	5.02	96	2.34	103	2.98	87	1.13	98	0.35	113	1.20	93	1.05	103	1.91	106	2.18	96
Grenade CL Plus	4.94	94	2.07	91	3.08	90	1.12	97	0.33	106	1.15	89	0.94	92	1.69	93	2.28	100
Kord CL Plus	4.93	94	2.18	95	3.15	92	1.16	100	0.29	92	1.23	96	1.00	98	1.86	103	2.25	99
LRPB Arrow	5.21	99	2.26	99	3.70	108	1.14	99	0.31	100	1.33	103	1.05	103	1.83	102	2.39	105
LRPB Cobra	5.38	102	2.25	99	3.29	96	1.07	93	0.18	56	1.20	93	0.98	96	1.79	99	2.24	98
LRPB Havoc	5.03	96	2.44	107	3.77	110	1.20	104	0.41	130	1.36	105	1.02	99	1.94	107	2.59	114
LRPB Scout	5.15	98	2.31	101	3.07	90	1.12	97	0.24	77	1.20	93	0.96	94	1.64	91	1.87	82
LRPB Trojan	5.54	105	2.10	92	3.36	98	1.26	109	0.19	60	1.46	113	1.05	103	1.93	107	2.22	97
Mace	5.33	101	2.44	107	3.21	94	1.27	110	0.38	120	1.41	109	1.09	106	1.93	107	2.34	103
Razor CL Plus	4.98	95	2.69	118	3.12	91	1.16	101	0.46	148	1.24	96	1.02	99	1.76	97	2.32	102
Scepter	5.73	109	2.63	115	4.02	118	1.28	111	0.38	122	1.39	108	1.20	118	2.14	118	2.43	107
Sheriff CL Plus	5.58	106	2.26	99	3.76	110	1.15	100	0.21	68	1.41	109	1.12	110	1.95	108	2.19	96
Shield	4.89	93	2.44	107	3.07	90	1.05	91	0.32	103	1.21	94	0.99	97	1.67	93	2.07	91
Vixen	5.83	111	2.66	116	4.00	117	1.17	101	0.52	168	1.30	101	1.05	103	1.78	99	2.61	115
Wallup	5.01	95	2.00	88	2.85	83	1.05	91	0.30	95	1.19	93	0.91	89	1.64	91	2.13	94
Wyalkatchem	5.14	98	2.24	98	3.68	107	1.13	98	0.30	96	1.25	97	0.94	92	1.88	104	2.25	99
Yitpi	5.01	95	1.85	81	3.32	97	1.10	95	0.19	62	1.32	103	0.99	96	1.77	98	2.31	102
Zen	5.35	102	2.13	93	4.24	124	-	-	-	-	-	-	-	-	-	-	-	-
Site Mean (t/ha)	5.26		2.28		3.42		1.15		0.31		1.29		1.02		1.81		2.28	
CV (%)	4.3		5.09		7.3		3.24		10.3		4.72		4.54		3.23		4.55	
Probability	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001	
LSD (t/ha)	*0.4*	*8*	*0.2*	*9*	*0.44*	*13*	*0.06*	*6*	*0.06*	*18*	*0.11*	*8*	*0.08*	*8*	*0.1*	*6*	*0.18*	*8*
Sowing Date	15-May		6-Jun		17-May		15-Jun		21-May		18-Jun		20-Jun		8-May		30-May	
Trial Comments							caution results - late sown		caution results affected by severe droughting		caution results - late sown		caution results - late sown					

Source: www.nvtonline.com.au

Eyre Peninsula 2018 NVT barley trial yields in t/ha and expressed as percentage of site mean

Region	Lower EP				Upper EP							
Nearest Town	Cummins		Wanilla		Darke Peake		Elliston		Minnipa		Piednippie	
Variety Name	t/ha	%	t/ha	%	t/ha	%	t/ha	%	t/ha	%	t/ha	%
Alestar	6.17	93	5.10	97	2.00	81	1.81	80	1.11	80	2.25	87
Banks	6.69	101	5.37	102	2.30	93	2.02	90	1.34	96	2.56	99
Bass	6.09	92	5.20	99	1.88	76	2.11	94	1.12	81	2.29	89
Buff	6.84	103	5.37	102	2.58	104	2.38	106	1.56	112	2.79	108
Commander	6.89	104	4.97	95	2.51	101	1.99	89	1.38	99	2.68	104
Compass	6.50	98	5.11	97	2.57	103	2.52	112	1.53	110	2.68	104
Fathom	6.57	99	5.37	102	2.92	118	2.42	108	1.68	120	2.80	108
Fleet	6.27	95	5.09	97	2.55	103	2.28	101	1.55	111	2.74	106
Flinders	6.38	96	5.43	103	-	-	-	-	-	-	-	-
Gairdner	5.89	89	4.51	86	-	-	-	-	-	-	-	-
Granger	6.67	101	5.08	97	-	-	-	-	-	-	-	-
Hindmarsh	6.70	101	5.54	105	2.73	110	2.26	100	1.60	115	2.46	95
Keel	6.32	95	4.97	95	2.55	103	2.52	112	1.59	114	2.70	104
La Trobe	6.73	102	5.38	102	2.85	115	2.19	97	1.60	115	2.62	101
Maltstar	6.80	103	4.81	92	1.99	80	1.82	81	1.04	75	2.49	96
Oxford	6.05	91	5.48	104	-	-	-	-	-	-	-	-
RGT Planet	7.54	114	5.30	101	2.03	82	2.11	94	1.01	72	2.58	100
Rosalind	7.31	110	5.71	109	2.72	110	2.24	100	1.44	104	2.72	105
Scope	6.18	93	4.67	89	2.08	84	2.11	94	1.34	96	2.56	99
Spartacus CL	6.64	100	5.49	105	2.70	109	2.16	96	1.57	113	2.62	101
Topstart	6.58	99	5.40	103	1.53	62	1.63	73	0.67	48	2.04	79
Site Mean (t/ha)	6.63		5.25		2.48		2.25		1.39		2.59	
CV (%)	3.93		5.01		9.14		9.42		4.23		4.40	
Probability	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001	
LSD (t/ha)	*0.43*	*7*	*0.45*	*9*	*0.36*	*15*	*0.35*	*16*	*0.09*	*7*	*0.20*	*8*
Sowing Date	15-May		17-May		26-Jun		9-May		15-Jun		8-May	
Trial Comments					caution results - late sown, delayed and variable establishment				caution results - late sown			

Source: www.nvtonline.com.au

Cereals

***NVT long term wheat performance** expressed as a % of mean yield averaged across upper EP sites (Penong, Minnipa, Kimba, Mitchellville, Nunjikompita, Piednippie, Poochera, Warramboo) from 2013-2018*

Variety	Classification	All Trials	2013	2014	2015	2016	2017	2018
Vixen	AH	6	-	-	-	-	111	107
Scepter	AH	20	-	-	111	106	112	112
Cobalt	APW	23	-	108	110	107	109	109
Beckom	AH	29	109	107	106	109	106	106
Cosmick	AH	29	106	107	101	108	104	101
Mace	AH	29	107	106	108	99	105	107
Corack	APW	29	107	107	110	96	105	106
Razor CL Plus	ASW	13	-	-	-	104	105	101
Emu Rock	AH	29	104	117	101	102	103	96
Sheriff CL Plus	*	13	-	-	-	104	103	107
Shield	AH	29	102	112	99	106	103	99
Wyalkatchem	APW	29	104	100	106	102	102	103
LRPB Trojan	APW	29	104	93	101	103	102	106
Cutlass	APW	20	-	-	98	103	102	104
LRPB Havoc	AH	13	-	-	-	99	104	104
LRPB Cobra	AH	29	102	94	100	104	97	96
LRPB Scout	AH	29	100	104	94	105	98	95
Chief CL Plus	APW	16	-	94	-	101	104	109
Estoc	APW	29	97	97	97	98	99	100
Grenade CL Plus	AH	29	96	108	94	97	99	95
Gladius	AH	29	96	104	95	98	98	97
Axe	AH	29	95	112	95	92	99	95
Kord CL Plus	AH	29	95	104	95	94	99	98
Yitpi	AH	29	93	93	93	98	97	99
Mean yield (t/ha)			**2.36**	**2.43**	**1.86**	**2.36**	**1.21**	**1.52**
Number of trials			*6*	*3*	*7*	*7*	*6*	*5*

* no classification yet

NVT long term barley performance *expressed as a % of mean yield averaged across upper EP sites (Darke Peak, Elliston, Minnipa, Piednippie, Poochera) from 2013-2018*

Variety	All Trials	2013	2014	2015	2016	2017	2018
Compass	18	112	119	131	102	132	103
Spartacus CL	14	-	115	125	101	128	104
Rosalind	14	-	120	127	108	110	110
La Trobe	18	109	113	121	100	123	103
Hindmarsh	18	108	113	122	97	127	103
Fathom	18	110	109	116	112	112	102
Keel	18	105	107	117	102	126	99
Banks	10	-	-	115	107	99	105
Fleet	18	105	104	107	107	107	98
Commander	18	102	101	100	104	99	99
Scope	18	98	97	98	96	108	97
Bass	18	100	94	95	103	102	-
Granger	12	98	96	93	-	-	100
Maltstar	18	97	97	91	105	74	101
Alestar	18	96	96	92	98	84	101
RGT Planet	6	-	-	-	111	73	111
Topstart	14	95	90	80	-	67	101
Mean yield (t/ha)		**2.88**	**3.17**	**2.49**	**3.98**	**2.16**	**2.18**
Number of trials		*4*	*4*	*4*	*4*	*2*	*4*

Section Editor:
Fabio Arsego
SARDI, Minnipa Agricultural Centre/
Port Lincoln

Section 2

Break Crops

NVT field pea - adjusted 2018 trial in t/ha and expressed as percentage of site mean

	Lower Eyre Peninsula			
Variety	**Rudall**		**Yeelanna**	
	t/ha	**%**	**t/ha**	**%**
Kaspa	1.43	95	2.93	97
Parafield	1.37	91	2.43	80
PBA Butler	1.55	103	3.40	112
PBA Gunyah	1.48	98	2.65	88
PBA Oura	1.44	95	2.82	93
PBA Pearl	1.59	105	3.40	113
PBA Percy	1.53	101	3.13	104
PBA Wharton	1.41	94	3.06	101
Site mean (t/ha)	**1.51**		**3.03**	
CV (%)	5.23		6.34	
Probability	0.0094		<0.001	
LSD (t/ha)	*0.13*	*9*	*0.31*	*10*
Sowing Date	30-May		14-May	
	Minnipa trial not reported - high variability			

NVT canola - adjusted 2018 trial yields in t/ha and expressed as percentage of site mean

	Upper Eyre Peninsula			
Variety	**Lock**		**Minnipa**	
	t/ha	**%**	**t/ha**	**%**
ATR Bonito	1.10	84	0.90	94
ATR Stingray	0.97	74	0.80	84
DG 560TT	1.30	99	0.96	100
Hyola 350TT	1.50	115	1.11	116
Hyola 559TT	1.48	113	1.07	111
HyTTec Trophy	1.32	101	1.01	105
InVigor T 3510	1.32	101	0.96	100
InVigor T 4510	1.43	109	0.94	98
Pioneer 44T02 TT	1.39	106	1.09	114
Site mean (t/ha)	**1.31**		**0.96**	
CV (%)	7.18		5.28	
Probability	<0.001		<0.001	
LSD (t/ha)	*0.15*	*11*	*0.08*	*9*
Sowing Date	30-May		29-May	
Trial comments			furrow irrigated to assist initial establishment	

Break crop production in southern low rainfall environments

Sarah Day
SARDI, Clare

RESEARCH

Location:
Minnipa Agricultural Centre, paddock N9
Rainfall
Av. Annual: 325 mm
Av. GSR: 241 mm
2018 Total: 269 mm
2018 GSR: 208 mm
Paddock History
2018: Field pea
2017: Oat
2016: Barley
Soil Type
Loam
Plot Size
1.75 m x 10 m x 3 reps
Trial Design
Experimental: Split plot
Yield Limiting Factors
Moisture stress

Key messages

- **Field pea, vetch, faba bean and lentil had 3-125% higher biomass yield and 51-110% higher grain yield than chickpea and canola at Minnipa, 2018.**
- **Current high demand and grain prices for faba bean meant they were the most profitable break crop species.**
- **Low grain yield of canola (0.43 t/ha) and chickpea (0.39 t/ha) resulted in these crop species not being profitable as grain crops.**
- **Field pea and vetch, in particular, have multiple alternative end-use options in dry seasonal conditions that can be utilised to recover crop input costs.**

Why do the trial?

Current farming systems in the low rainfall zone of southern Australia are dominated by cereal production. There is increasing concern about grass weed and soil-borne disease pressure, as well as diminishing soil fertility (particularly nitrogen), and water use efficiency, as a result of continuously cropping cereals. Break crops have a key role to play in addressing these issues, as well as diversifying crop production and economic risk, and maintaining long-term sustainability of the system. However, there remains a lack of information available to growers about choosing the break crop best suited to their situation, as break crop development to date has largely occurred in medium and high rainfall zones. The aim of this research is to identify the best break crop options for different climate, soil type and biotic stress situations within major cropping regions of the southern low rainfall zone. This project builds on previous GRDC and SAGIT funded projects, including DAS00119 (profitable crop sequencing in the low rainfall areas of South Eastern Australia) and MS115 (adopting profitable crop sequences in the SA Mallee).

How was it done?

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

The trial was sown at Minnipa on 21 June 2018 using an experimental plot seeder with 27 cm row spacing. Biomass measurements were taken in early October at late flowering to early podding growth stage to identify potential use as a hay, forage or manure crop. Harvesting of the trial was conducted on 16 November 2018.

The data was analysed using Genstat 19th Edition, with gross margins calculated using the Rural Solutions 'Farm Gross Margin and Enterprise Planning Guide'. The costs were calculated using actual inputs in the trial and values provided in the gross margin guide.

What happened?

Many cropping regions across South Australia experienced dry seasonal conditions combined with low levels (2-12%) of stored soil moisture in 2018. Minnipa experienced below average rainfall from February to July. For this reason, sowing was delayed until late June, following 28 mm of rainfall in the two weeks prior.

Field pea (2.25 t/ha) had the highest biomass yield compared to other break crop species at Minnipa in 2018 (Figure 1). High biomass potential of field pea, combined with relatively early maturity, opens up potential alternative end-use options other than grain production such as hay, silage, or utilised as green manure in seasons where grain production may not be profitable. Chickpea had the lowest biomass yield compared to other break crop species, 56% lower than field pea. Canola, faba bean, lentil and vetch had similar biomass yields, and were 24-56% lower than field pea, but 36-71% higher than chickpea. Vetch, like field pea, is a versatile crop and has potential to be used for hay, forage, green manure or grain production.

The highest grain yields were from vetch, field pea, faba bean and lentil compared to canola and chickpea at Minnipa, in 2018 (Figure 2). Field pea demonstrates reliability and grain yield stability over variable seasonal conditions in low rainfall environments, compared to alternative break crop species. Canola and chickpea yields were similar, and 42% and 47% lower yielding than field pea, respectively. Canola emergence was poor in 2018 due to dry seasonal conditions. Successful canola establishment is generally achieved following at least 15 mm of rainfall over a three-day period at time of sowing.

With a gross margin of $300/ha, faba bean was the most profitable species at Minnipa in 2018 (Figure 3). This high return is in concurrence with current high demand and high grain prices for faba bean, and is unlikely to be sustained. If faba bean grain price is averaged over five years (2014-2018), faba bean remain profitable, with a gross margin of $85.26/ha. Field pea, lentil and vetch all had similar gross margins as grain crops, although relatively low at $24-$65/ha. Chickpea and canola were not profitable at Minnipa in 2018.

What does this mean?

Biomass and grain yield for field pea and vetch was higher than for other break crop species at Minnipa in 2018. Although faba bean grain yield was similar to field pea and vetch, current high demand and grain prices resulted in faba bean being the more profitable species. These high prices are unlikely to be sustained. However, faba bean remain profitable if grain price is averaged over five years.

Field pea continues to express its yield and biomass stability at Minnipa when compared to alternative break crop species. High biomass potential of field pea, as well as vetch, can provide potential end-use options and, in particular, have potential to salvage a financial return if a crop is frost or drought affected. Replicated trials will be sown in 2019 at multiple locations in order to further validate this research across the southern low rainfall zone.

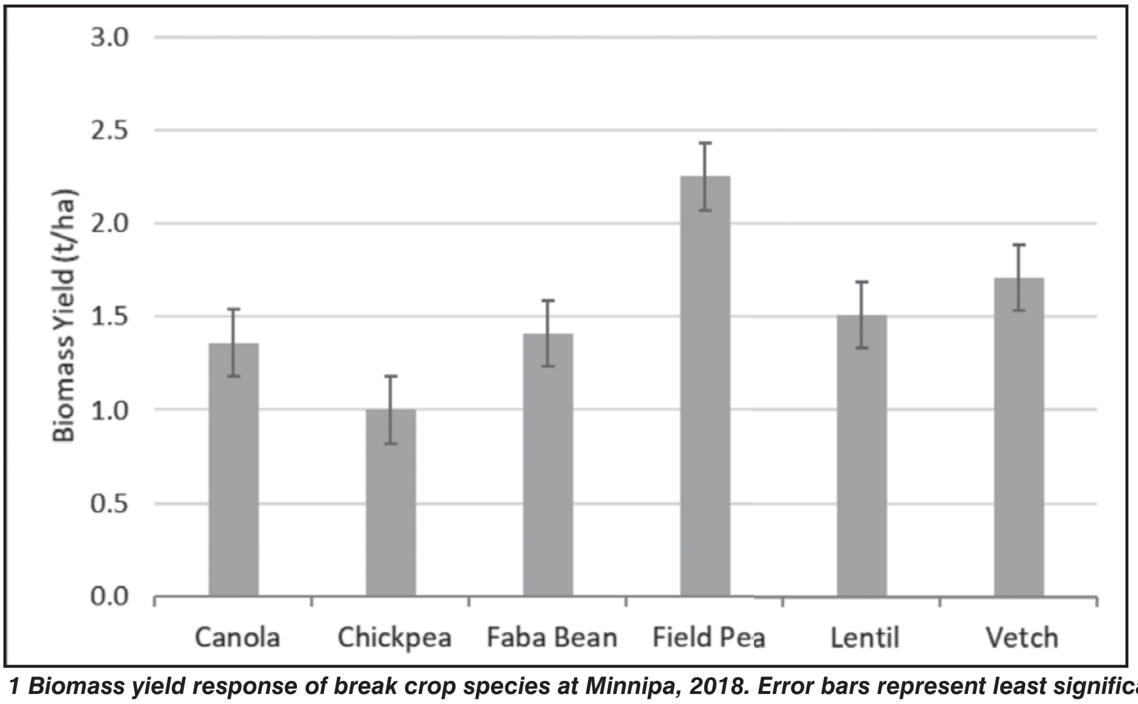

Figure 1 Biomass yield response of break crop species at Minnipa, 2018. Error bars represent least significant difference (0.238 t/ha).

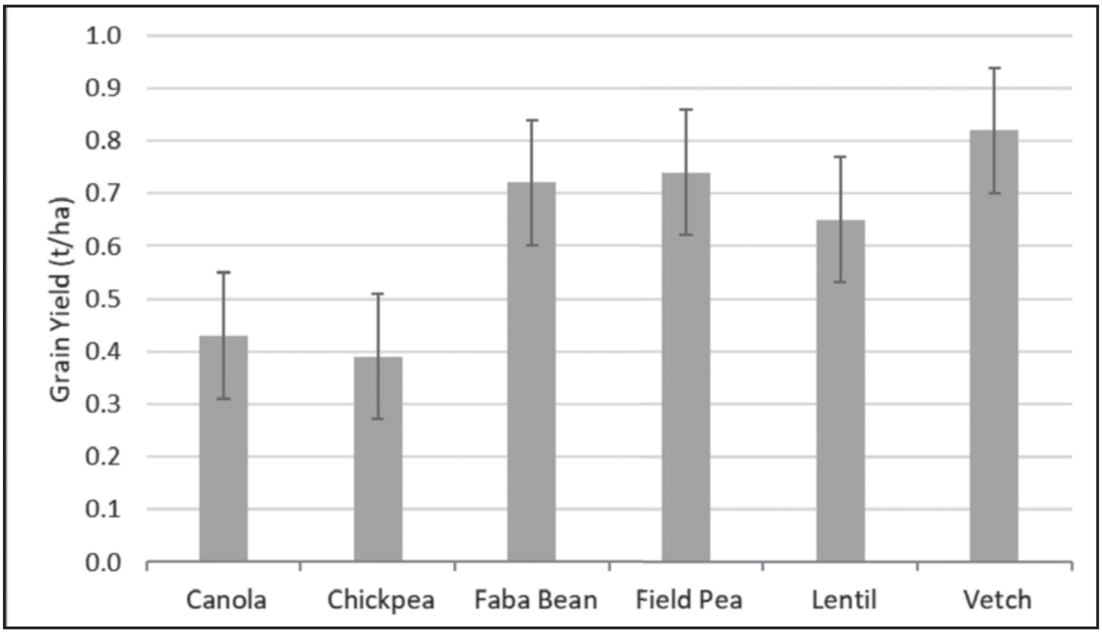

Figure 2 Grain yield response of break crop species at Minnipa, 2018. Error bars represent least significant difference (0.356 t/ha).

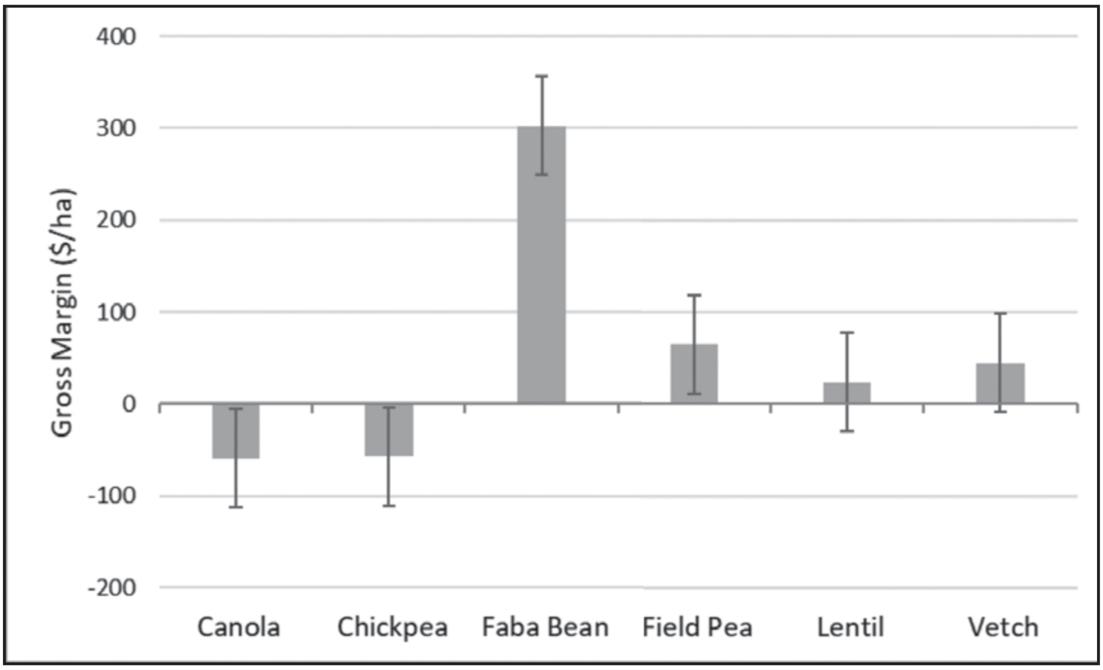

Figure 3 Gross margin response of break crop species at Minnipa, 2018. Error bars represent least significant difference ($107.50/ha).

**Note that gross margins represent average case scenarios and should be used as a guide only.*

Acknowledgements

Funding for this project is provided by GRDC (DAS00162-A) and their continued support is gratefully acknowledged. The continued assistance from SARDI New Variety Agronomy groups at Clare and Minnipa, in particular Brenton Spriggs and Sue Budarick, is gratefully acknowledged and appreciated. We would also like to acknowledge support from property owners and low rainfall farming system groups involved in this project.

SARDI

SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE

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GRAINS RESEARCH & DEVELOPMENT CORPORATION

Break Crops

Lentil herbicide management in southern low rainfall environments

Sarah Day
SARDI New Variety Agronomy, Clare

Location:
Minnipa Agricultural Centre, paddock N9
Rainfall
Av. Annual: 325 mm
Av. GSR: 241 mm
2018 Total: 269 mm
2018 GSR: 208 mm
Paddock History
2018: Field pea
2017: Oat
2016: Barley
Soil Type
Loam
Soil Test
pH at 10 to 30 cm: 7.9
Plot Size
1.75 m x 10 m x 3 reps
Trial Design
Experimental: Randomised complete block
Yield Limiting Factors
Moisture stress

Key messages

- **Interactions between herbicide and application rate did not have differing responses for grain yield, biomass yield, or gross margin at Minnipa, 2018.**
- **Combined herbicide and application timing treatments did show differences in grain yield, biomass yield and gross margin.**
- **Metribuzin and Diuron treatments indicated increased safety levels (58-466% higher biomass and 6-161% higher grain yield) and lower economic risk compared to Terbuthylazine treatments.**
- **For herbicide applications incorporated by sowing, Metribuzin was of lower economic risk (45% higher gross margin) than Diuron.**

Why do the trial?

Break crops continue to occupy a small percentage of arable land across the southern low rainfall zone, despite extensive research demonstrating their role and value in farming systems. This is generally thought to be due to a perception that break crops have an increased risk and production cost, compared to cereals. There is also a lack of confidence about correct break crop management required to reduce production risk and minimise inputs in a low rainfall system. There is little information in this area, as break crop development has largely occurred in medium and high rainfall zones, and often these strategies are inappropriate for low rainfall environments. The aim of this work is to identify low-risk break crop management strategies for the low rainfall zone.

Herbicide damage in lentil commonly occurs in low rainfall environments. This trial aims to identify crop safety levels and economic risk of pre- and post-emergent herbicide use on lentil across different soil types and environments in the southern low rainfall zone. This project builds on previous GRDC-funded projects, including DAV00113 (southern region pulse agronomy).

How was it done?

To address the knowledge gap, a lentil herbicide management trial was established at Minnipa Agricultural Centre in 2018. The trial was arranged in a randomised complete block design with one lentil variety, PBA Hurricane XT. There were 24 treatments in the trial, with each treatment replicated three times. Treatments included a combination of six herbicides (Group B and C), each applied at two timings and a high and low rate for each timing (Table 1). An untreated control was not included in the trial, as Metribuzin applied at a low rate incorporated by sowing (IBS) is considered to be a control or standard treatment for the purpose of this experiment.

Measurements taken include grain yield, biomass yield, gross margin, normalised difference vegetation index (NDVI), and site soil characteristics. The Rural Solutions 'Farm Gross Margin and Enterprise Planning Guide' was used to calculate gross margin, using actual inputs in the trial and values provided in the gross margin guide. Crop safety level is determined by crop response to herbicide application.

In addition to herbicide treatments, Sprayseed was applied to the trial site prior to sowing. Sowing was conducted on 22 June 2018 using an experimental plot seeder with 27 cm row spacings. Incorporated by sowing (IBS) and post-sowing pre-emergent (PSPE) herbicide treatments were applied on 22 June 2018. Post-emergent herbicide treatments were applied on 1 August 2018. Biomass cuts were taken on 21 September 2018 at early flowering. Harvest was conducted on 16 November 2018. Data was analysed using Genstat 19th Edition.

Table 1 Lentil herbicide treatments compared in the trial. IBS = incorporated by sowing, PSPE = post-sowing pre-emergent.

Chemical	Application Timing	Application Rate	
		Low	High
Metribuzin 750 g/kg	IBS	150 g	280 g
Metribuzin 750 g/kg	PSPE	150 g	180 g
Diuron 900 g/kg	IBS	500 g	1000 g
Diuron 900 g/kg	PSPE	550 g	800 g
Terbuthylazine 750 g/kg	IBS	500 g	1000 g
Terbuthylazine 750 g/kg	PSPE	500 g	860 g
Chemical A*	IBS	1.0x	1.5x
Chemical A*	PSPE	0.7x	1.0x
Chemical B*	PSPE	1.0x	1.6x
Chemical B*	Post-emergent	1.0x	1.6x
Chemical C*	PSPE	1.0x	1.5x
Chemical C*	Post-emergent	1.0x	1.5x

** Note that some herbicides are currently unregistered for use in lentil and these treatments were included for experimental purposes only. The results within this document do not constitute a recommendation by the author or author's organisation for that particular use.*
A reminder that any off-label herbicide use can result in crop damage, and product label rates, permits, plant-back periods and directions for use must be adhered to.

Break Crops

What happened?

Dry seasonal conditions, combined with low levels of stored soil moisture (2-12%), were experienced across many cropping regions of South Australia in 2018. Minnipa experienced below average rainfall from February to July. For this reason, sowing was delayed until late June following 28 mm of rainfall in the two weeks prior. Minimal rainfall (0.04 mm) was recorded following sowing and the first two herbicide application timings. Lentil emergence occurred on 9 July 2018. In the week following post-emergent herbicide treatments (August 1-7), 43 mm of rainfall was recorded.

Application rate, regardless of herbicide used, affected biomass yield response of PBA Hurricane XT at Minnipa in 2018. Higher herbicide rates resulted in lower biomass yield (0.62 t/ha) compared to low herbicide rates (0.82 t/ha), as could be expected. However, interactions between application rate and herbicide had similar biomass yield responses (P=0.705). Combinations of herbicide and application timing did affect biomass yield at Minnipa, 2018 (Figure 1). Terbuthylazine applied post-sowing pre-emergent (PSPE) had the lowest biomass yield compared to all other herbicide treatments, including Terbuthylazine incorporated by sowing (IBS). This result supports the recommended IBS use of Terbuthylazine reported on the label. Metribuzin and Diuron, applied both PSPE and IBS, had 37-82% higher biomass yield than Terbuthylazine. This indicates that Metribuzin and Diuron have increased safety levels for use in lentil (58-466% higher biomass yield), compared to Terbuthylazine.

The mean site grain yield for PBA Hurricane XT was 0.71 t/ha. The interactions between herbicide and application rate did not have observable differences for grain yield at Minnipa, 2018 (P=0.94). However, combinations of herbicide and application timing did affect grain yield response (Figure 2), as previously observed for biomass yield. Terbuthylazine applied PSPE had lower grain yield than all other herbicide treatments, including Terbuthylazine IBS. Terbuthylazine IBS had similar grain yield response to Diuron IBS, but 13-18% lower than Diuron applied PSPE and both Metribuzin application timings. Comparable grain yield responses were observed for Metribuzin applied PSPE and IBS, and Diuron applied PSPE. Diuron IBS had similar grain yield to Metribuzin IBS and Diuron applied PSPE, but 14% lower than Metribuzin applied PSPE.

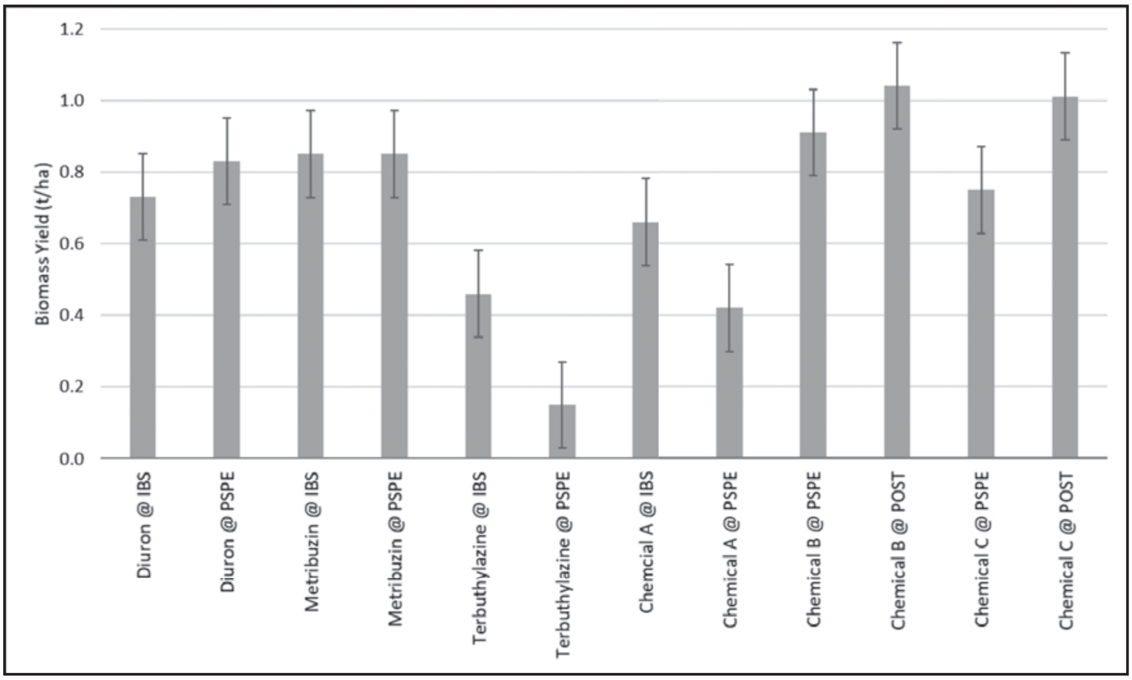

Figure 1 Biomass yield response of PBA Hurricane XT lentil to combined herbicide and application timing at Minnipa, 2018. Error bars represent least significant difference (0.24 t/ha).

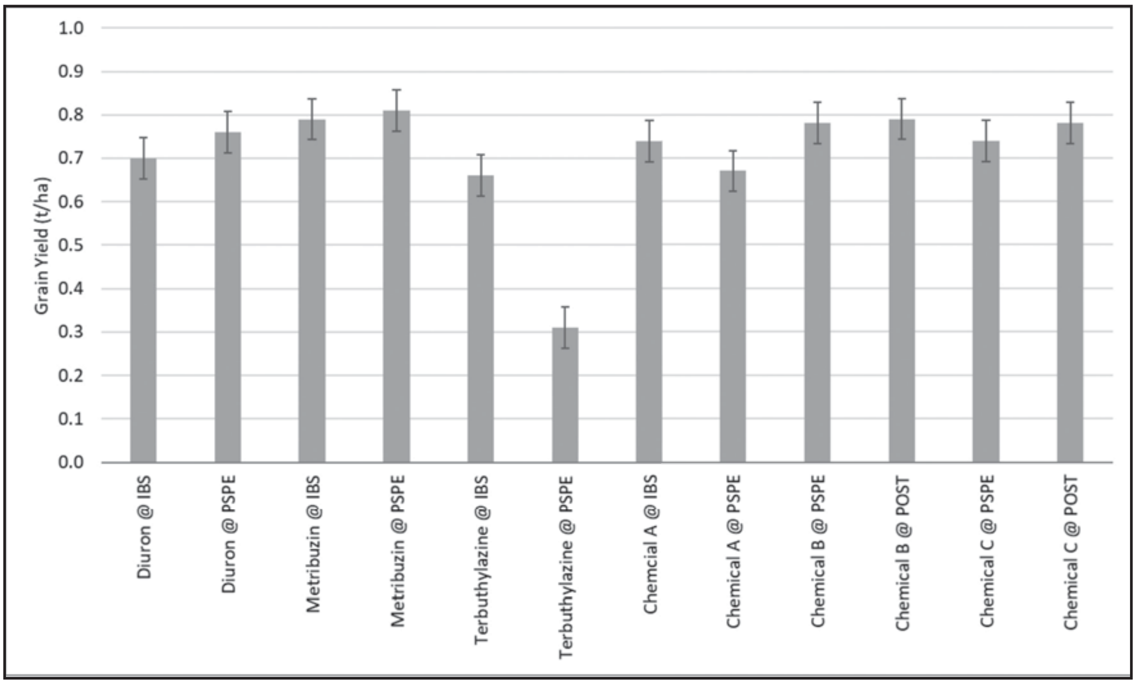

Figure 2 Grain yield response of PBA Hurricane XT lentil to combined herbicide and application timing at Minnipa, 2018. Error bars represent least significant difference (0.095 t/ha).

Interactions between herbicide and application rate had similar gross margin responses at Minnipa in 2018 (P=0.892). However, the combination of herbicide and application timing did influence gross margin response (Figure 3). Metribuzin applied PSPE ($138/ha) and IBS ($132/ha) resulted in equal highest gross margins. However, there was no reduction in profit from applying Chemical B, Chemical C or Diuron applied PSPE at Minnipa in 2018. There was also no difference in gross margin response between Diuron applied PSPE and IBS. However, the application of Diuron IBS ($91/ha) resulted in a lower gross margin than Metribuzin IBS ($132/ha). In summary, although application of Diuron IBS had similar grain yield and biomass yield responses compared to Metribuzin IBS, it was less profitable. Therefore, if IBS timing is preferred over PSPE, the use of Diuron is of higher economic risk than Metribuzin. Terbuthylazine applied to lentil was the least profitable herbicide, particularly when applied PSPE (-$78.10/ha). Terbuthylazine IBS had a similar gross margin to Diuron IBS and therefore has higher economic risk than the use of Metribuzin.

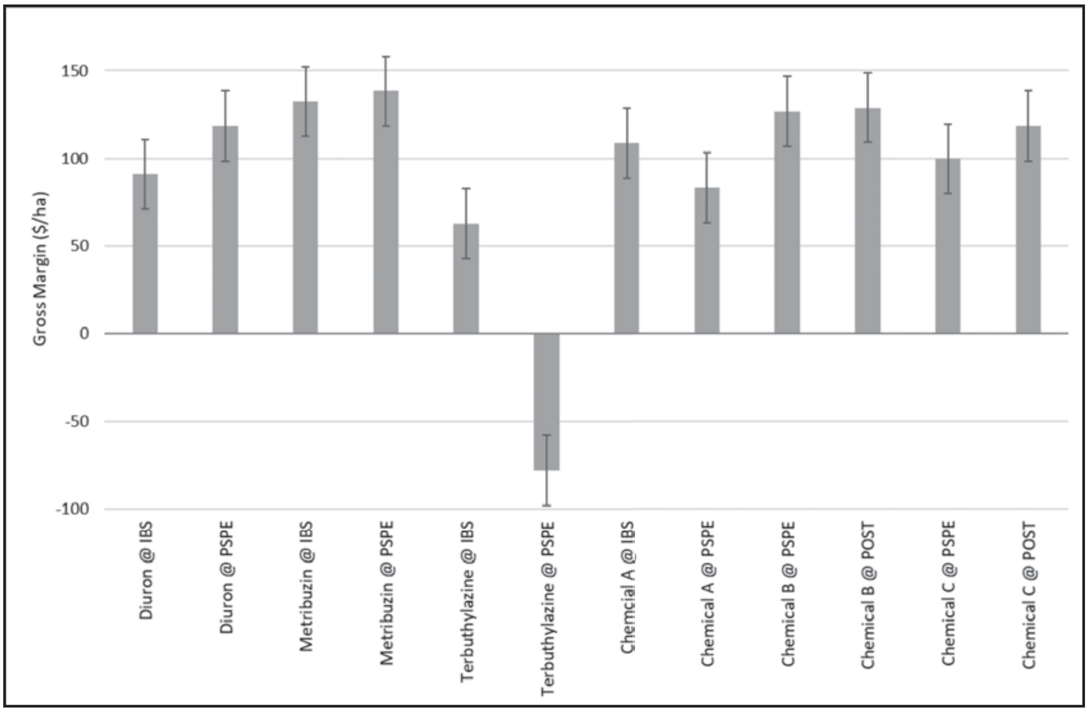

Figure 3 Gross margin response of PBA Hurricane XT lentil to combined herbicide and application timing at Minnipa, 2018. Error bars represent least significant difference ($39.81/ha).
Note: Gross margins represent average case scenarios and should be used as a guide only.

What does this mean?

Herbicide choice and application timing is important to reduce risk associated with lentil production in low rainfall environments, particularly as lentil is sensitive to herbicide use in dry conditions. Terbuthylazine expressed a lower safety level and higher economic risk than Diuron and Metribuzin in lentil at Minnipa in 2018, with lentil generally more sensitive to Terbuthylazine than other pulse crops. The use of Diuron or Metribuzin was lower risk in this environment, with biomass yield 58-466% and grain yield 6-161% higher than Terbuthylazine treatments. If IBS application is preferable to PSPE application, Metribuzin was a lower risk option than Diuron in this environment. However, if applying herbicide PSPE, economic and production risk was similar for Diuron and Metribuzin and either option would be suitable. The experimental herbicides used in this trial show potential safe use in lentil and a lower risk than use of Terbuthylazine. If registration occurs for the use of these experimental herbicides in lentil, they have potential for safe control of weeds when applied in-crop to herbicide-tolerant (XT) lentil varieties.

This report only contains results from one season at Minnipa, and any conclusions drawn do not apply to other low rainfall environments and seasons at this stage. For this reason, replicated trials were established at multiple locations across the southern low rainfall zone in 2018 and will be continued in 2019. Collated data obtained from multiple low rainfall environments will validate this research.

Acknowledgements

Funding for this project is provided by GRDC (DAS00162-A) and their continued support is gratefully acknowledged. The continued assistance from SARDI New Variety Agronomy groups at Clare and Minnipa, in particular Brenton Spriggs and Sue Budarick, is gratefully acknowledged and appreciated. We would also like to acknowledge support from property owners and low rainfall farming system groups involved in this project.

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Optimising legume inoculation for dry sowing

Liz Farquharson[1], Amanda Cook[2], Ian Richter[2], Fiona Tomney[2], Lynette Schubert[1] and Ross Ballard[1]
[1]SARDI, Waite; [2]SARDI, Minnipa Agricultural Centre

RESEARCH

Location:
Minnipa - Bruce Heddle
Rainfall
Av. Annual: 325 mm
Av. GSR: 241 mm
2018 Total: 244 mm
2018 GSR: 178 mm
Soil Type
Red sandy loam, pH($CaCl_2$): 7.8
Plot Size
12 m x 1.7 m x 4 reps

Key messages

- **Standard inoculation practices are unlikely to deliver satisfactory nodulation where pulses are sown into dry soils.**
- **Pea and chickpea sown late (26 June) had the higher nodulation and crop production than those sown dry. Where the soil remained dry for 20 days after sowing nodulation was poor, regardless of the inoculation strategy used.**
- **Nodulation of pea was low regardless of sowing time at Minnipa in 2018. Both peat applied to seed and granule formulations resulted in similar nodule numbers per plant.**
- **Nodulation can be improved when dry sowing if inoculation rate of peat is increased. Doubling the rate of inoculation significantly improved pea nodulation.**
- **The performance the rhizobial granules was inconsistent. A granule produced at SARDI was more effective in one experiment, but not the other. Two commercial granules provided no advantage compared to peat applied to seed.**

Why do the trial?

In the past 15 years the area sown to pulses in South Australia has increased by 50% (ABARES 2015) and continues to expand as new pulse varieties become available with improved herbicide, disease and soil constraints tolerance. Dry sowing legumes allows growers to better manage time demands around sowing, ensure successful early establishment of crops and reduce yield losses in dry springs.

The trials at Minnipa were part of a larger program to assess a range of commercial rhizobia inoculant products, application strategies and sowing times to provide growers with recommendations that ensures adequate nodulation and nitrogen fixation in dry sown crops.

Inoculation provides one of the most cost effective ways to improve legume performance where the legume (or another from the same inoculation group) has not previously been grown and/or where conditions are detrimental to the survival of rhizobia in the soil.

There is less risk of poor crop nodulation when a background of soil rhizobia is present. On Eyre Peninsula chickpea is nearly always responsive to inoculation.

How was it done?

Two replicated trials were sown on a sandy soil of pH$CaCl_2$ 7.8 on the property of Bruce Heddle's at Minnipa on Eyre Peninsula. Previous soil tests had indicated the site was likely to be responsive to inoculation for field pea and chickpea, due to the absence of suitable rhizobia in the soil.

Trial 1: Peat v granule at different sowing times

One of the difficulties of comparing commercial granule products is that they are manufactured using various substrates (often not peat based), which can make the comparison and interpretation of their performance difficult. To enable a valid comparison of the delivery platform (rhizobia in a granule vs. rhizobia in a peat applied to seed) we made moist peat and peat granule inoculants at SARDI for both chickpea and field pea in 2018. Both contained high numbers of their corresponding rhizobia.

The first trial had three times of sowing (13 April, 26 April and 6 June, Figure 1), two crops (Genesis090 chickpea and PBA Oura pea) and three inoculation treatments (no rhizobia applied, moist peat inoculant applied as a slurry to seed, and peat based granule).

All inoculants were applied at the recommended commercial rates. Peat slurry treatments were applied on seed and sown within 24 hours and granules were sown in furrow with seed.

Nodulation (number and weight per plant) was measured 10 weeks after crop emergence, peak biomass production was measured at mid pod fill for time of sowing (TOS) 3 and end pod fill for TOS 2. Where possible plots were harvested with a plot harvester and grain yield measured. Nitrogen fixation is still being determined.

Trial 2: Commercial products and inoculation rate

Two trials were sown, one for field pea (PBA Oura) and one for chickpea (Genesis 090) on 26 April to compare the performance of commercial inoculant formulations when sown dry. Due to the exceptionally dry season the chickpea trial was unsuccessful and only results from the field pea trial are presented.

There were eight treatments in the pea trial, including an un-inoculated (nil) control. All further treatments contained the commercial rhizobia strain for field pea (WSM1455−Group F) provided in SARDI made peat applied at two different rates, in a SARDI made granule, or in peats or granules supplied by two of the commercial inoculant companies (Table 1). All inoculants were applied at the recommended commercial rates (RR), except for SARDI peat which was also applied at double the RR. Peat slurry treatments were applied on seed within 24 hours of sowing and granular products were sown in furrow with seed. It should be noted commercial peat applied as slurry is currently not recommended for dry sowing.

Measurements made as for Trial 1.

What happened?

Trial 1

The soil at the trial site had no known pulse cropping history and therefore no pea or chickpea rhizobia were present in the soil at sowing. As a result, plants in the un-inoculated (nil) treatments for both crops did not form nodules.

Overall, the conditions for nodulation and crop growth in 2018 were challenging. Treatments sown on 13 April (TOS 1) and 26 April (TOS 2) germinated in early May, however were affected by an extended dry period until mid-June. As a result, the total number of nodules measured 10 weeks after the crop emerged (14/8 for TOS1, TOS2 and 19/9 for TOS3) was low (averaging just 10 nodules per plant for field pea, which is well below the level of 50 that is often measured). Despite the low levels of nodulation, significant treatment effects were measured (Figure 2).

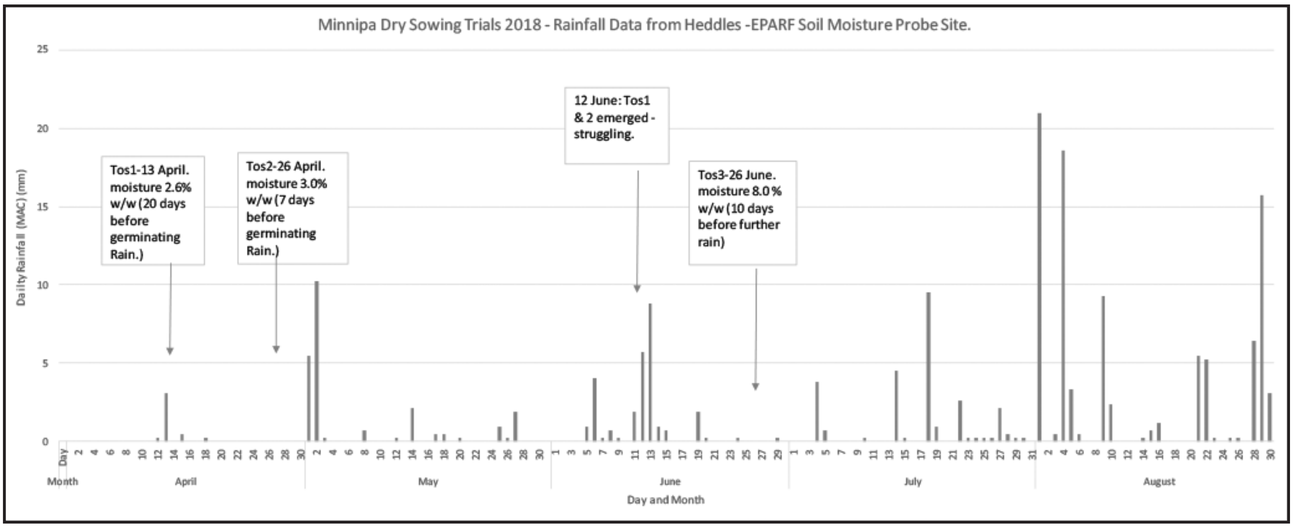

Figure 1 Rainfall and sowing times for trials at Minnipa in 2018

Table 1 Inoculation treatments and application rate for Trial 2

Treatment	Formulation	Application Rate
Nil	Un-inoculated	0
SP	SARDI peat	*RR
SP2.0	SARDI peat	2 x RR
SG	SARDI granule	4.8 kg/ha
NP	#Novozymes Tag-Team Peat	RR
NG	Novozymes Tag-Team Granule	4.5 kg/ha
BP	BASF Nodulaid Peat	RR
BG	BASF Nodulator Granule	5.0 kg/ha

** Recommended Rate*
 # Novozymes has been acquired by Monsanto

For chickpea, nodulation of plants in the dry sown treatments (TOS 1 and TOS 2) was negligible for all inoculation treatments. However, for TOS 3 (break of season) when some soil moisture was present, the SARDI granule treatment resulted in the most nodulation, with the majority of nodules on lateral roots. For field pea, both peat and granule treatments significantly increased nodulation above the Nil treatments at TOS 2 and TOS 3. The granule treatment performed as well or better than peat on seed at both of the later sowing times.

Due to the restricted growth of the crop due to below average rainfall, peak biomass estimates were only made for TOS 2 and TOS 3 sown treatments and only TOS 3 treatments were harvested. There were no significant treatment effects (Table 2).

Trial 2

The nodulation of field pea sown into dry soil on 26 April (TOS 2) was improved by inoculation. The SARDI made moist peat applied to seed at double RR was the most effective treatment. However as for Trial 1, nodule number per plant was below the benchmark of 50 per plant commonly measured under optimal sowing conditions. When applied to seed at RR, the performance of the SARDI and commercial formulations of moist peat was similar (Figure 3). Although not significant, moist peat treatments had slightly better nodulation than granule treatments.

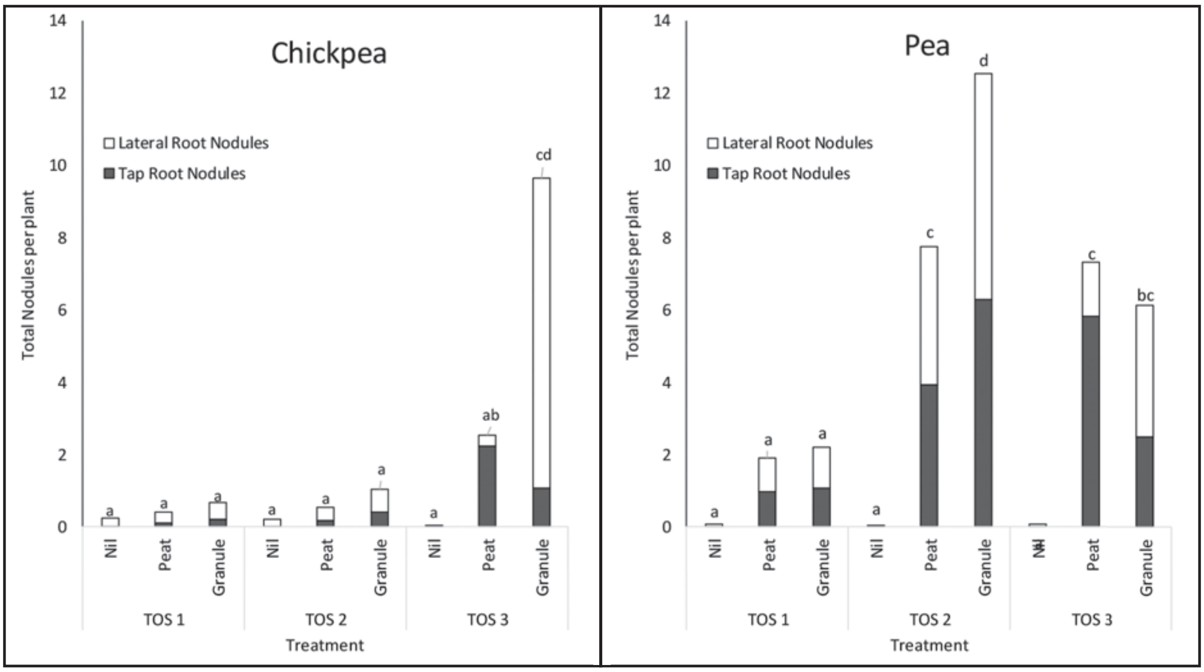

Figure 2 The number of nodules on the tap roots and lateral roots was measured 10 weeks after emergence
Letters above columns indicate significance for Total Nodule Number per plant at P<0.05, where by columns with the same letters are not significantly different.

Table 2 Impact of sowing time and inoculant formulation on biomass production (mid pod fill) and yield for chickpea and field pea at Minnipa. No significant differences at P<0.05.

Sown	Crop	Formulation	Peak Biomass (t/ha)	Yield (t/ha)
TOS 2 Dry	Chickpea	Nil	0.21	not harvested
		Peat	0.17	
		Granule	0.17	
	Pea	Nil	0.40	
		Peat	0.42	
		Granule	0.51	
TOS 3 Break	Chickpea	Nil	0.49	0.17
		Peat	0.47	0.17
		Granule	0.59	0.18
	Pea	Nil	0.41	0.14
		Peat	0.68	0.24
		Granule	0.60	0.23

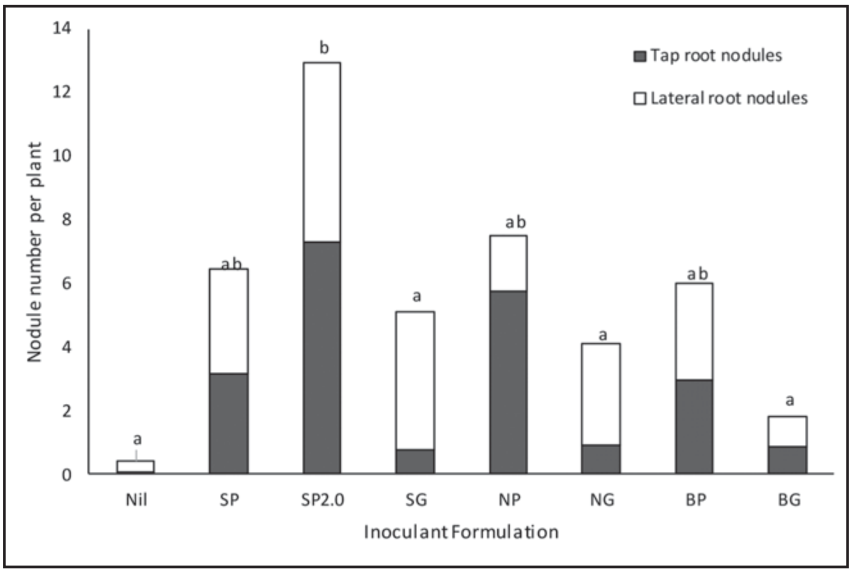

Figure 3 Impact of inoculant formulation on nodulation of dry sown field pea (PBA Oura). The number of nodules on the tap roots and lateral roots was measured 10 weeks after emergence. *Letters above columns indicate significance for total nodule number per plant at P<0.05, where by columns with the same letters are not significantly different.*

Table 3 Impact of inoculant formulation non biomass production (mid pod fill) and grain yield of dry sown field pea at Minnipa. P<0.05, where by values with the same letters are not significantly different.

Treatment	Formulation	Peak biomass (t/ha)	Yield (t/ha)
Nil	Un-inoculated	0.35 a	0.11 a
SP	SARDI peat	0.75 d	0.25 c
SP2.0	SARDI peat (2 x rate)	0.69 cd	0.24 c
SG	SARDI granule	0.61 bcd	0.18 abc
NP	#Novozymes Tag-Team Peat	0.59 bcd	0.21 bc
NG	#Novozymes Tag-Team Granule	0.60 bcd	0.20 bc
BP	BASF Nodulaid Peat	0.51 abc	0.14 ab
BG	BASF Nodulator Granule	0.45 ab	0.15 ab

** Recommended Rate*
 # Novozymes has been acquired by Monsanto

As in Trial 1, maximum biomass production and yield were limited by the below average growing season rainfall. Despite this, most inoculated treatments produced significantly more biomass and yield than the un-inoculated controls, with the SARDI peat applied at both rates performing best (Table 3).

How does this compare to elsewhere in SA?

Several other field trials (Wanilla - bean 2017, Farrell Flat - lupin 2017, Lameroo - chickpea 2018) have demonstrated that there is a significant correlation between the number or rhizobia applied (either in peat applied to seed or in granules applied in furrow) and the subsequent nodulation of the crop when dry sown.

- When peat is applied to seed at twice the recommended rate there have been significant and consistent improvements in nodule number per plant.
- When the number of rhizobia in granules is high (i.e. quality granule) the outcome for nodulation and biomass production has generally been good.

What does it mean?

Where inoculation of a pulse crop is necessary (due to an absence of suitable soil rhizobia) using standard rates of peat slurry on seed when dry sowing has rarely been the most effective inoculation strategy and often resulted in sub-optimal nodulation, especially if extended dry conditions are combined with other stresses such as low pH.

The duration of the dry period between sowing and germination is significant to the outcome. In Trial 1, where this was 20 days (TOS 1), nodulation was poor, regardless of the legume type or inoculation strategy used. At TOS 2 the chickpea symbiosis was most sensitive, forming few nodules even though it was only 7 days before significant rain. Very early sowing should be restricted to paddocks that already contain suitable rhizobia, since the nodulation in inoculation responsive paddocks will almost certainly be compromised.

Improved nodulation was consistently achieved by doubling the rate of inoculation when dry sowing. This result was observed in the trials at Minnipa as well as several other trials across the duration of the project.

The performance of granules has been inconsistent, both here and in other trials. The promising performance of the SARDI granule in Trial 1 (TOS 2 for pea), was not repeated in Trial 2. The reasons for this are not clear, since the exact same granule was used. The commercial granules provided no advantage in Trial 2, although at other trial sites they have. Variation in granule quality (the number of rhizobia they contain) has been measured and is one factor that has affected their performance (data not shown). Their quality standard is the responsibility of the manufacturer and therefore carries more risk than peat inoculants which have to comply with minimum standards which are independently tested. The influence of soil type on granule performance is still not well understood.

Nodulation in the two trials for field pea was at best 12 per plant, which is well below that of 50 nodules per plant (10 weeks after sowing) that we often observe. While this may indicate below potential nodulation, it could also simply be what can be realistically achieved at Minnipa in a dry year on small plants.

In general, anything that affects the survival of applied rhizobia will in turn decrease nodulation. For example; application of pesticides (see article by Rathjen *et al*. in this book), delayed sowing of inoculated seed and conditions in the soil prior to germination. Further to this correct storage (as per manufacture recommendations) of inoculant prior to use is essential for maintaining high numbers of rhizobia.

References

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Acknowledgements

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Impact of fungicide seed coating on rhizobia survival and nodulation of pea plants

RESEARCH

Judith Rathjen, Maarten Ryder, Thang Viet Lai and Matthew Denton
University of Adelaide, Waite Campus

Location
Minnipa - Bruce Heddle
Rainfall
Av. Annual: 325 mm
Av. GSR: 241 mm
2018 Total: 244 mm
2018 GSR: 178 mm
Soil Type
Red sandy loam, pH_{CaCl_2}: 7.8
Plot Size
12 m x 1.8 m with 25 cm row spacing (6 rows)
Trial Design
Experimental, complete randomised

Key messages

- **Nodulation was reduced when pea seeds were coated with P-Pickel T fungicide before inoculation.**
- **Reductions in rhizobia numbers on fungicide-coated seeds occurred very quickly, within two hours, but the toxic effect of the fungicide continued after sowing.**
- **Dry soil conditions are likely to have exacerbated fungicide toxicity to the rhizobia.**

Why do the trial?

Legumes are frequently inoculated with rhizobia at sowing, to improve nodulation and nitrogen fixation. Rhizobia can be supplied as peat, freeze-dried (liquid) or granular inoculant formulations. At sowing time, farmers often wish to apply different treatments together, to increase the efficiency of the sowing operation. In some cases, rhizobial inoculant is combined with the application of commonly used seed pesticides, but this may result in toxic effects on the rhizobia. Given the importance of rhizobial survival to crop production, there is a need for independent data and guidelines to inform farmers about the potential reduction in legume nodulation and nitrogen fixation arising from the combination of various treatments with inoculants.

Laboratory data has shown that under sterile conditions, P-Pickel T is toxic to *Rhizobium leguminosarum* which nodulates pea, bean, lentil and vetch. This work also showed that peat may offer protection to the rhizobia compared with freeze-dried inoculant. The objective of this work was to determine the potential toxicity of the fungicide P-Pickel T (PPT) to rhizobia applied as a commercial inoculant (peat and freeze-dried) on field pea (*R. leguminosarum*, group F) in field conditions in a soil with a low rhizobial background.

How was it done?

A field site with low background of field pea rhizobia was selected on Bruce Heddle's property, near Minnipa Agricultural Centre. The trial was a completely randomised design with three replications. Pea *cv*. Oura seeds were coated with the label recommendations for PPT, and then inoculated with either a commercial freeze-dried or peat formulation, again at commercial rates. Seed was sown immediately (0 h) or stored at room temperature in the dark for 24 h before sowing. Plots with no inoculation (Nil) were also sown as controls. The plot sizes were 12 m x 1.8 m with 25 cm row spacing (6 rows), and an estimated plant density of 54 plants per m^2.

Before sowing, rhizobial counts from the inoculated and PPT treated/untreated seeds were performed to determine if there were adequate numbers of rhizobia on seed. Seed samples (10 seeds) from all treatments (excluding Nil) were washed and diluted 10^{-1} to 10^{-5} in sterile water, and each dilution was plated drop-wise on sterile agar. After incubation, colonies were counted and rhizobia numbers per seed were calculated.

The trial was sown on 30 June and a nodulation assessment was conducted on 20 September (12 weeks after sowing). Plants and roots with soil were dug up in groups of three across the central four rows of the plot approximately 1 m apart, with a total of 12 plants collected from each plot. Soil was gently shaken from the roots which were then washed clean for nodule counts. Nodule fresh weight from each plot was also collected. On 19 October (16 weeks after sowing) shoot dry weight measurements were taken at peak biomass, and yield data was recorded after harvest. Nitrogen fixation measurements are currently being analysed using the N^{15} natural abundance method.

What happened?

Conditions were very dry (gravimetric water content 8% w/w) and sowing delayed (30 June) due to low soil moisture. After sowing there was about 5 mm of rainfall over the following week. At nodule sampling, it was visually easy to differentiate the well-nodulated plants from those with low nodulation, as the latter were stunted and yellow. Rainfall throughout the growing season was below average (2018 GSR 178 mm), which reduced yield and biomass production.

Table 1 shows that rhizobial counts taken from the inoculated seeds before sowing verified that there were no detectable rhizobia on the seeds with freeze-dried inoculant that was stored for 24 h before sowing, even in the absence of fungicide. However, there were adequate (4.8 x 10^5 cfu/seed) populations of bacteria associated with seed treated with the peat and freeze-dried inoculant at 0 h (Table 1). The peat and freeze-dried inoculant treatment that had been coated with PPT 24 h before sowing, showed a significant decline in rhizobia numbers.

Figure 1 shows that there was a much lower number of nodules per plant grown from seed inoculated with freeze-dried rhizobia compared to peat formulation. Figure 1 shows that there was a negative effect of PPT on plant nodulation. Although plants treated with the peat inoculant treatments without fungicide had 72% greater nodules/plant compared to the Nil treatment, the nodule number was still relatively low. There was very low nodulation in the freeze-dried inoculant treatments both with and without the fungicide seed dressing, but a larger decrease in nodule number can be seen in the seed treated with fungicide and stored for 24 h before sowing, compared with seed that was sown immediately after inoculation.

Nodule fresh weight per plant (Figure 2) was correlated with the average nodule number per plant (r=0.91, data not shown). Figure 2 shows a similar pattern to plant nodule number, with a decrease in nodule fresh weight in seed coated with PPT before inoculation. In particular, the plants had lower nodule fresh weight in the PPT treatments compared to the no fungicide treatments.

Table 1 Rhizobial counts from seeds (10 seeds) prior to sowing

Treatment	Fungicide	Time (0 h)	Log_{10} cfu/seed
Peat	-	0	5.5
Peat	+	0	5.0
Peat	-	24	4.9
Peat	+	24	4.1
FD	-	0	4.7
FD	+	0	below detection
FD	-	24	below detection
FD	+	24	below detection

Peat = peat slurry inoculum, FD = freeze-dried inoculum, +/- fungicide coating and inoculated before sowing (0 h) or stored for 24 h before sowing.

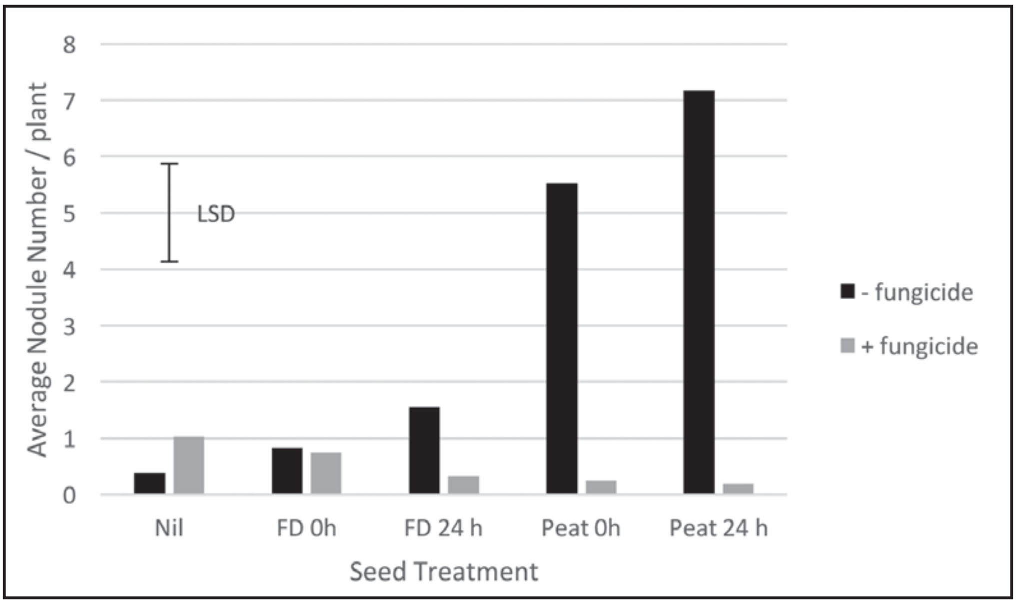

Figure 1 Effect of seed fungicide treatment PPT on average nodule number of plants from seed inoculated with freeze-dried or peat slurry at 0 h or 24 h before sowing

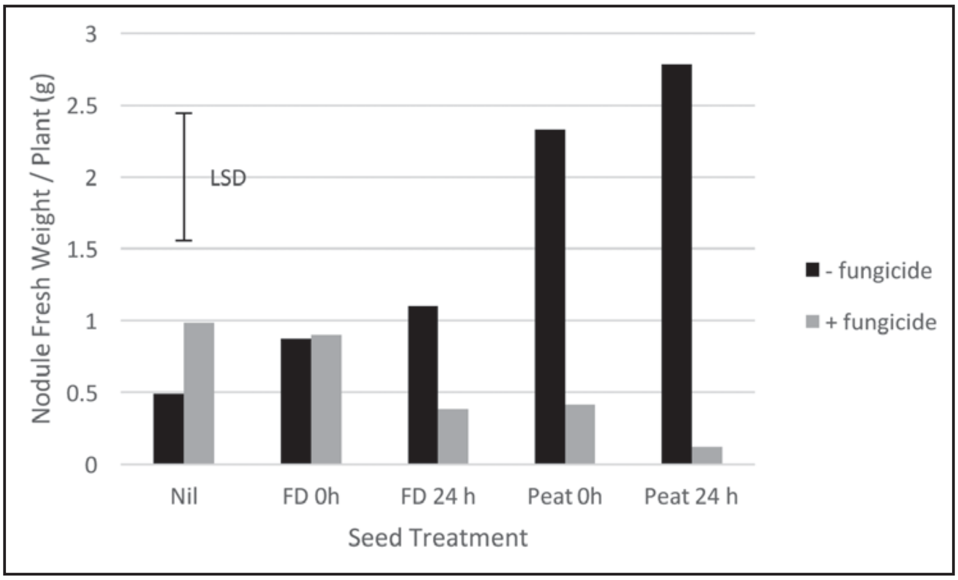

Figure 2 Effect of seed fungicide treatment PPT on nodule fresh weight of plants from seed inoculated with freeze-dried or peat slurry at 0 h or 24 h before sowing

The fresh nodule weight was lower in the freeze-dried treatments than the peat inoculant, so there was not such a dramatic decrease when combined with the PPT seed dressing. The Nil treatment had only a few nodules, but these nodules had a high fresh weight.

What does this mean?

In vitro studies in the laboratory and nodulation experiments conducted under sterile conditions have shown that the fungicide PPT is toxic to some commercial strains of rhizobia. In this experiment, we investigated if this effect was observed in a field situation. The low number of nodules detected in the Nil treatment confirms that the field site had very low nodulation resulting from background soil rhizobial populations (Figure 1). However, adequate nodulation for field pea on light soils is considered to be 20 nodules per plant, which was not achieved in this field trial (Drew *et al*. 2012).

For seed coated with the fungicide PPT and inoculated with a peat slurry, there was a decrease (91% 0 h and 84% 24 h) in rhizobial survival on the seed and subsequent nodulation. It has previously been recommended to sow coated and inoculated seed within 6 hours to avoid toxicity to the rhizobia (Drew *et al*. 2012, Table 5.4), however our results show that rhizobial survival on the seed decreased rapidly before sowing (less than 2 hours). With freeze-dried inoculant, nodulation was much reduced (78 to 85% less) compared with the peat formulation. Rhizobial survival on the seed was reduced, which resulted in fewer nodules without the presence of PPT.

Some of the plants with a low nodule number appeared to have much bigger nodules than the plants with more nodules, but this did not completely compensate for the loss of nodulation, as nodule fresh weight also declined in the presence of PPT. In general there was a decrease in plant nodulation and nodule weight, despite adequate rhizobial numbers on PPT treated seeds at sowing.

The dry conditions at this site may have contributed to the observed toxic effect of PPT, as the low soil moisture and rainfall means that the rhizobia are in contact with the fungicide longer than in a year of increased rainfall. Moisture stress during growth and development would also have contributed to inconsistent shoot weight and yield data, which was not correlated with nodulation measurements.

The data suggest that in a season where conditions are likely to be stressful (e.g. under moisture stress), then the added stress of exposure to toxic fungicide can be quite detrimental to nodulation and N fixation. The best results were obtained with peat formulation which appears to have a protective effect on rhizobial survival. Separating the fungicide and rhizobia, e.g. by applying inoculant as liquid in furrow or as a granular formulation, may lead to avoidance of toxic interactions and adequate nodulation. It would be useful to test these options in the field.

Acknowledgements

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Yield and phenology of lentil and faba bean in response to variety and management

RESEARCH

Lachlan Lake, Mariano Cossani and Victor Sadras
SARDI, Waite

Location
Minnipa Agricultural Centre, Paddock N9
Rainfall
Av. Annual: 325 mm
Av. GSR: 241 mm
2018 Total: 269 mm
2018 GSR: 208 mm
Yield
Potential: Pulses - 2 t/ha
Actual: 1 to 1.2 t/ha
Paddock History
2017: Wheat
2016: Pasture
2015: Wheat
Soil Type
Loam
Soil Test
Nitrate 16, ammonium 2, sulphur 9.3 (mg/kg)
Plot Size
1 m x 1 m x 3 reps
Trial Design
The trial was a factorial split plot design with sowing date allocated to main plots and variety to subplots
Yield Limiting Factors
Limited rainfall throughout the growing season

Location
Roseworthy
Rainfall
Av. Annual: 400 mm
Av. GSR: 315 mm
2018 Total: 275 mm
2018 GSR: 201 mm
Yield
Potential: Pulses - 5 t/ha
Actual: 1.5 to 2 t/ha
Paddock History
2017: Barley
2016: Canola
2015: Faba bean
Soil Type
Sandy clay loam
Soil Test
Ammonium 15, nitrate 10 (mg/kg)
Plot Size
1 m x 1 m x 3 reps

Key messages

- **Pulses are more vulnerable to stress related yield loss just after flowering at the early podding stage.**
- **In the trials on the upper Eyre Peninsula, Mid North and South East, the risks posed by late sowing, (heat and water stress), outweighed the risks posed by early sowing (frost).**
- **Trends for sowings from mid-April to early July, show that for each days delay in sowing, lentil flowered on average 0.5 days earlier, and yielded 0.5 kg/ha less; faba bean flowered 0.3 days earlier and yielded 0.7 kg/ha less.**
- **Results should be considered in conjunction with grower specific conditions and the trade-off between early sowing, weed and disease management and frost risk.**

Why do the trial?

Lentil and faba bean are moving further into low rainfall areas of South Australia. Pulses are growing in popularity as a result of good prices and rotational benefits such as decreased N input and enhanced grass weed control options. However, frost and combinations of water and heat stress at critical growth stages can compromise crop yield. Previous work in pulses has established that the most important time to maintain growth and limit stress is the period around pod set. Sowing date and variety choice are the two main tools to manipulate time of flowering and pod-set, and thus manage the risk of extreme temperatures, water stress and the trade-off between frost and heat risk.

The aim of this work is to determine the best management practices to avoid stress and maximise yield of lentil and faba bean. We analysed the impact of sowing date and variety on the phenology and grain yield of lentil and faba bean across different South Australian cropping environments, including the upper Eyre Peninsula.

This is the third year of trials previously reported in EPFS Summary 2017, p 146 and 2016, p 62.

How was it done?

Field trials have been conducted at Minnipa Agricultural Centre (2016, 2017 and 2018), Hart (2016), Roseworthy (2017 and 2018), Bool Lagoon (2016 and 2017) and Conmurra (2018) to test the effect of sowing date on phenology and yield of lentil and faba bean varieties. The trials combined six sowing dates ranging from 20 April to 11 July, with ten varieties of each crop chosen in consultation with breeders and industry experts. Faba bean varieties included Icarus, AF03001-1, PBA Rana, PBA Samira, Farah, PBA Zahra, Aquadulce, 91-69, Fiord, and Nura. Lentil varieties were PBA Blitz, Northfield, CIPAL901, CIPAL1301, PBA HurricaneXT, PBA Hallmark XT, PBA Giant, PBA Jumbo2, Nugget and Matilda.

Trial Design
As above
Yield Limiting Factors
Limited rainfall throughout the growing season

Location
Conmurra - SARDI Straun
Rainfall
Av. Annual: 650 mm
Av. GSR: 490 mm
2018 Total: 709 mm
2018 GSR: 570 mm
Yield
Potential: Pulses - 5 t/ha
Actual: 3 t/ha
Paddock History
2017: Faba bean
2016: Cereal
2015: Cereal
Soil Type
Black clay loam
Soil Test
Ammonium 5, nitrate 35, sulphur 9 (mg/kg)
Plot Size
1 m x 1 m x 3 reps
Trial Design
As above
Yield Limiting Factors
Some accidental herbicide damage limited yield

For each species at each location, three replications were sown for each genotype and sowing date. Crops were sown by hand in a split-plot design with sowing dates allocated to the main plot and varieties randomized within each subplot. Plot size was 1 m by 1 m and consisted of 3 rows, 0.27 m apart. Density was 60 (faba bean) and 120 (lentil) plants per square metre. Prior to sowing, P was supplied by applying 80 kg/ha of MAP. During the growing season, we measured phenology twice weekly within the central rows of the plots. We recorded the date when 50% of plants within the central row had reached: flowering, pod emergence, end of flowering and maturity.

At Minnipa (2016, 2017, 2018) and Roseworthy (2017, 2018), yield was measured from a subsample of 0.5 m length from the central rows of all plots. Samples were dried at 70°C until constant weight was achieved and then grains were separated from the pods, cleaned, counted and weighed. Data was analysed using Sigmaplot 14.0 and R.

What happened?

The general trends in phenology have been consistent across environments with time to flowering and podding decreasing with delayed sowing (Figure 2); temperature and day length are the primary influences on phenology with later sown crops experiencing longer warmer days. The differences for time from sowing to flowering and pod emergence across environments is presented in Table 1. Faba bean tended to flower earlier than lentil, however took longer from flowering to pod set (Table 2). For every ten days delay in sowing, there was an associated loss of five days vegetative growth for lentil and three for faba bean.

As with time to flowering and pod emergence, yield showed a decline with delayed sowing when considering all locations (Figure 1), however we found that the relationship differed between species, years and locations (Figure 2).

Table 1 Variation in time (days) from sowing to flowering in lentil and faba bean varieties

Beans	Mean	Minimum	Maximum	Lentils	Mean	Minimum	Maximum
AF03001-1	76	51	117	PBABlitz	93	71	138
Fiord	78	55	93	CIPAL901	95	71	138
AF009169	80	57	146	PBAGiant	97	72	142
Farah	81	57	125	PBAJumbo2	98	71	146
PBAZahra	84	59	113	CIPAL1301	99	76	149
PBARana	85	60	110	PBAHallmarkXT	100	71	150
Nura	85	61	115	PBAHurricaneXT	101	77	150
PBASamira	86	60	116	Matilda	103	73	149
Aquadulce	88	59	122	Nugget	104	76	150
Icarus	98	66	133	Northfield	109	82	170

Table 2 Variation in time (days) from sowing to pod emergence in lentil and faba bean varieties

Beans	Mean	Minimum	Maximum	Lentils	Mean	Minimum	Maximum
Fiord	90	63	108	PBABlitz	98	78	123
AF03001-1	90	59	129	CIPAL901	100	81	134
AF009169	92	66	111	PBAGiant	101	80	126
Farah	94	64	114	PBAJumbo2	102	81	127
Nura	96	67	116	PBAHallmarkXT	103	80	135
PBARana	96	70	115	CIPAL1301	104	83	134
PBAZahra	96	70	120	PBAHurricaneXT	105	84	135
PBASamira	97	69	121	Matilda	108	84	132
Aquadulce	103	74	131	Nugget	109	84	137
Icarus	104	74	127	Northfield	112	88	143

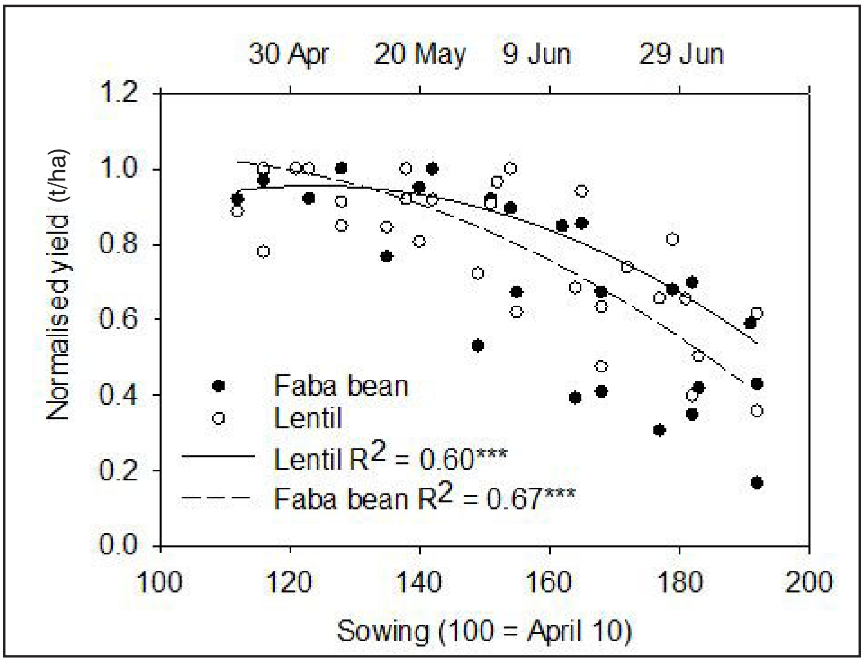

Figure 1 Yield penalty as a function of sowing delay from April 22. Yield is presented as a proportion of maximum attainable yield for each location x season combination. There were five location x season combinations each with six times of sowing. Lines are polynomial regressions.

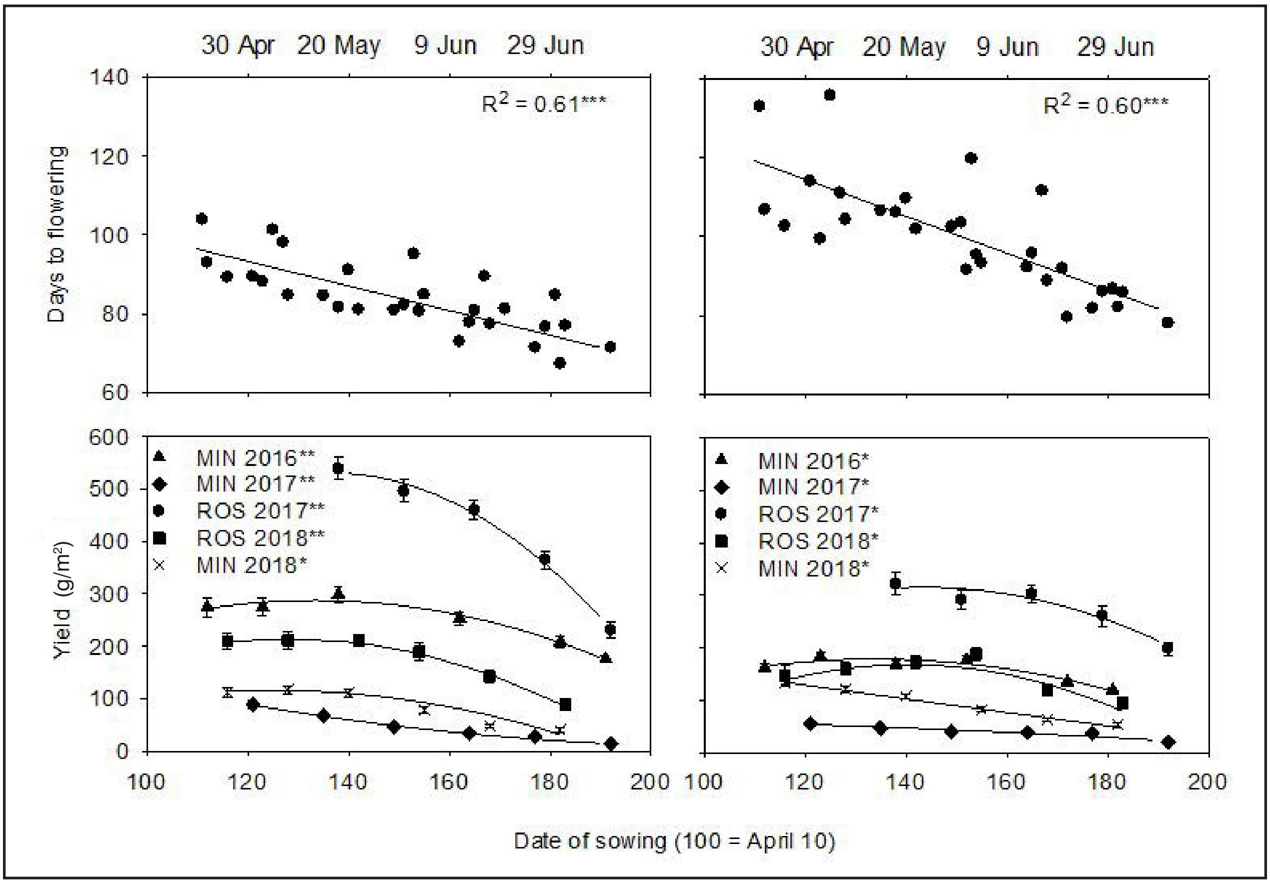

Figure 2 Phenology (top panels) and grain yield (bottom panels) of faba bean (left panels) and lentil (right panels) as a function of sowing date. Yield has been separated by environment while phenology is pooled across environments. Significance is denoted as P<0.05*, P<0.01** and P<0.001.***

When considering specific locations, yield losses could be incurred from any delay in sowing such as faba bean at Minnipa in 2017 and lentil at Minnipa in 2017 and 2018. However it was also common to see losses only after mid May (Figure 1 & 2). Across all environments, and for every ten days delay in sowing of faba bean from 20 April there was an associated loss of 7% of maximum yield while for lentil that value was 5% (Figure 1). Using 2018 data for Minnipa, this represents a loss in terms of gross margins of $20/ha or 10% for lentil and $19/ha or 14% for faba bean.

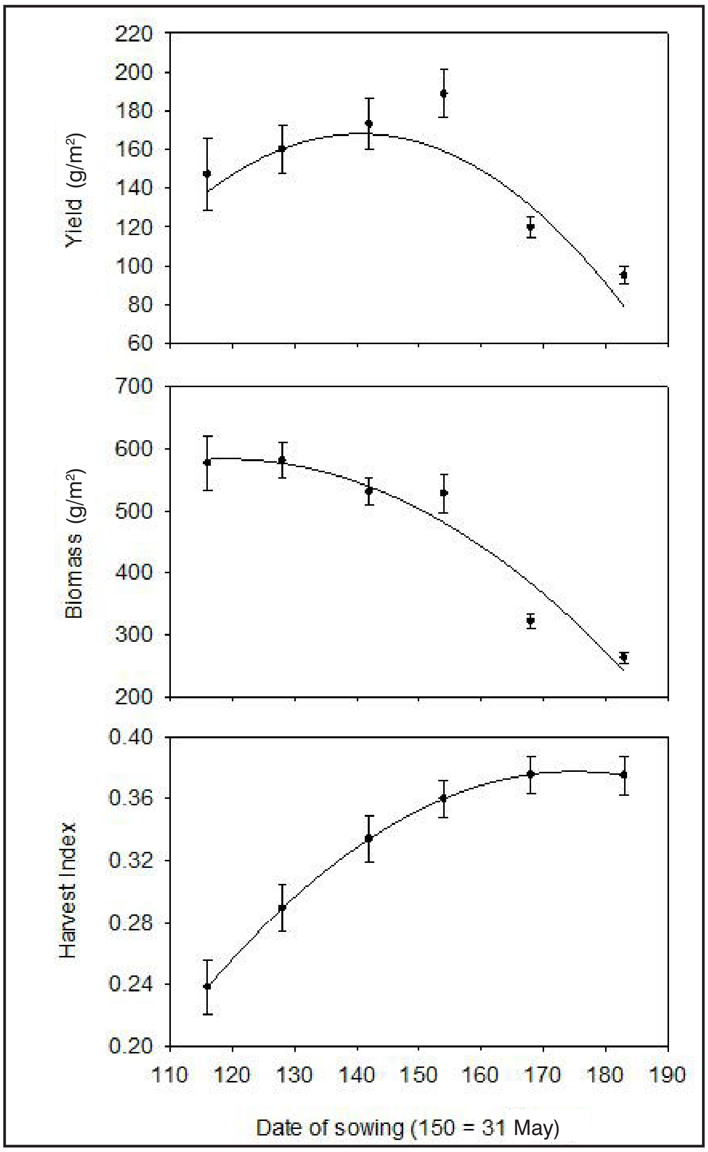

Figure 3 Effect of sowing date on lentil yield and components at Roseworthy 2018

Yield losses were higher in higher yielding environments but proportionally higher in lower yielding environments. The largest faba bean yield reductions were over 2.5 t/ha at Roseworthy in 2017 with a delay in sowing from 18 May to 11 July, while in the lowest yielding environment (Minnipa 2017) the yield loss was lower at 0.74 t/ha with a delay from 1 March to 11 July; this represents a loss of almost 85%. For lentil, the yield penalty associated with delayed sowing was smaller with more variation between locations; the largest loss was at Roseworthy in 2017 with 1.3 t/ha lost with a delay from 18 May to 11 July, while in the lowest yielding environment of Minnipa in 2018 the loss was 0.5 t/ha or nearly 65% when sowing was delayed from 27 April to 3 July.

Figure 3 demonstrates that in some instances for lentil, early sowing may lead to a yield penalty. In this instance the first and second times of sowing yielding significantly less than the fourth time of sowing ($P<0.05$). This yield loss was incurred at Roseworthy 2018 and was most likely due to excessive canopy growth with low harvest index. The relatively dry season may have resulted in the higher biomass canopies from early sowing to suffer from moisture stress later in the season, failing to convert potential yield into actual yield.

What does this mean?

The yield of both lentil and faba bean are significantly reduced when sowing is delayed past the optimal sowing date which varies for location and rainfall. In low rainfall environments such as Minnipa, optimal sowing tended to be as early as possible, while in the medium to higher rainfall areas, the middle of May was better. The yield penalty associated with delayed sowing is a result of a shorter time to flowering and podset, caused by accelerated development. This has a negative effect on potential yield resulting in reduced seed set, particularly in good years and environments. The other factor reducing yield was delayed sowing pushing the reproductive window further toward hot dry conditions that also hasten phenological development and limit yield. On average, the penalty for faba beans was 7% of their maximum yield per 10 days that sowing was delayed after 20 April, and 5% for lentil.

The genetic variability in phenology of both lentil and faba bean can be used by growers who wish to target a specific growth window to avoid both frost and heat stress, whilst maximising yield. However, in the absence of severe frost, sowing before the middle of May will be more likely to provide the maximum yield for the location whilst allowing some flexibility in the system for other factors such as soil moisture, weed and disease control.

Acknowledgements

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Herbicide tolerance and weed control in lentil on sandy soils

Sam Trengove and Stuart Sherriff
Trengove Consulting

RESEARCH

Location
Alford, Yorke Peninsula
Soil Type
Red/grey alkaline sand with low organic carbon (0-10 cm) 0.94% and surface pH of 7.7 ($CaCl_2$)
Plot Size
The plots were 9.5 m x 1.5 m sown with knife points and press wheels on 250 mm spacing
Trial Design
Randomised complete block design consisting of 22 treatments x 3 replicates.

Key messages

- **Sandy soils can have narrow safety margins for commonly used broadleaved herbicides used in lentils. Herbicide damage from some group C and B herbicides reduced lentil growth and grain yield on a sandy soil at Alford on Yorke Peninsula.**
- **Herbicide efficacy on four weed species was variable between products. Herbicide combinations were required to provide high levels of control of all four weed species.**
- **Treatments that provided the highest levels of weed control also tended to have the largest negative effect on the crop.**
- **Optimising the herbicide strategy in lentils on sandy soils requires a balance between minimising crop effect and achieving acceptable weed control. This requires knowledge of the target weeds and their resistance status to determine which herbicides to use and in what combination. The benefit of high level weed control then needs to be weighed against the risk of herbicide damage to the crop.**

Why do the trial?

Herbicide damage in lentils can occur readily on sandy soils from both pre and post emergent applications. Low clay content, low organic carbon and low cation exchange capacity of sand hills predispose these areas to increased risk from herbicide damage. It is possible that even without visible plant injury symptoms there is an underlying level of herbicide damage restricting biomass production and yield of lentils on these soil types. Previous work conducted on a similar soil type in 2015 and 2017 showed that when more than one herbicide is applied the level of damage can be greater than the sum of the damage of the single herbicides on their own.

This trial aimed to test the safety level of several commonly used herbicide options and combinations on PBA Hurricane XT lentils.

How was it done?

The trial was sown with PBA Hurricane XT lentils on 21 May 2018 with 60 kg/ha MAP. The treatments included two rates of Group C herbicides Simazine900 (500 and 750 g/ha), Diuron900 (550 and 825 g/ha), Terbyne (500 and 750 g/ha) and Metribuzin (150 and 225 g/ha) applied 4 days pre-sowing (IBS), Group B herbicide chlorsulfuron (5 g/ha) applied IBS and Intervix (500 ml/ha) applied post emergent (9 July) and Group F herbicide diflufenican (150 ml) applied post emergent (14 June) and combinations of Simazine + Diuron and the Group B and F herbicides as per the treatment list (Table 1 and 2). Herbicide treatments were applied using a 2 m hand boom in 100 L water per ha.

Seven mm of rain fell between the IBS herbicide application and seeding. Plots were rolled prior to crop emergence.

Measurements throughout the season included visual herbicide damage scores, weed counts, GreenSeeker NDVI on 16 July, 4 August, 16 August and 5 September, pod drop prior to harvest, grain yield and general plant growth observations throughout the season.

Weed control of Wild turnip (*Brassica tournefortii*), Sow thistle (*Sonchus asper*), Medic (*Medicago spp.*) and Indian hedge mustard (*Sisymbrium orietale*) was assessed by plant counts when plots were hand weeded.

Results were analysed with the statistical package R.

What happened?

Herbicide damage

Significant levels of group C herbicide damage occurred at the site in 2018, even though all group C herbicides were applied IBS to improve crop safety (Table 1).

Herbicide damage scores show that there were significant differences between treatments at early growth stages with diuron being the safest of the group C herbicides evaluated in 2018.

The highest level of damage from any single group C herbicide occurred with Simazine900 at the high rate (750 g/ha) where there was a 23% reduction in NDVI compared with the untreated control on 16 July. This level of damage increased to 44% by early August and then remained at that level until the end of the season, where a 32% reduction in grain yield compared with the untreated control was observed (Table 1). High rates of metribuzin resulted in low levels of plant damage early, as measured by NDVI, but the plots recovered towards the end of the season. This was in contrast to the Terbyne treatment where damage started low but increased towards the end of the season. Diuron plots were not significantly affected at either rate, producing grain yields of 1.3 t/ha and similar to the untreated control. The crop safety of the simazine and diuron mixture (250/275 g/ha) was improved over the simazine applied as a standalone treatment.

The NDVI and grain yield data shows that Terbyne provided good levels of crop safety in 2018. However, observation of necrosis around the leaf margins in September suggests that had it been a wetter and longer growing season higher levels of plant damage may have occurred.

The group F herbicide treatment, diflufenican (Brodal) applied at 150 ml/ha early post emergent had a transient visual effect on the lentils in 2018. A reduction in NDVI of 9% on 4 August and 14% on 16 August compared with untreated control was observed, however no yield loss was observed. When diflufenican was applied in combination with group B or C herbicides, there was no increase in the level of damage to either of these herbicides when compared with their respective standalone treatments.

Of the group B herbicides, chlorsulfuron applied at 5 g/ha prior to sowing had higher levels of plant damage and yield loss than Intervix at 500 ml/ha, however, both resulted in significant reductions in NDVI, of 20% and 9% respectively by 4 August. The NDVI results on 5 September suggest that Intervix applied as a standalone treatment had recovered completely.

When the group B products were applied in combination with the group C mixture of simazine + diuron, the level of damage was cumulative. For example, the yield loss from simazine + diuron was 11% and the yield loss from Intervix was 8% and the yield loss of them combined was 19%. A similar result was observed with the chlorsulfuron and simazine+diuron combination. In contrast, when the group B herbicides Intervix and chlorsulfuron were applied in combination the effect was greater than the sum of each on their own, producing a 28% reduction in NDVI on 5 September and 55% reduction in grain yield.

Weed control

Turnip control ranged from 52% with the low rate of diuron to greater than 97% for Intervix or any combination with simazine + diuron mixtures (Table 2). There was no difference between any of the other group C products at either the high or low rate. Diflufenican also provided good control (97%).

Sow thistle control was poor with the use of chlorsulfuron alone with only 11% of weeds controlled. In comparison 88% control was achieved with Intervix. Of the group C herbicides metribuzin only controlled 35 and 69% of sow thistle weeds at 150 and 225 g/ha respectively, however higher levels of control were achieved with the other group C herbicides and diflufenican (83% control).

The sulphonyl urea (SU) product chlorsulfuron was the only individual treatment to provide high levels of medic control (98%), with Intervix next best at 74%. Most group C products struggled and provided suppression at best, but the combination of simazine + diuron followed by Intervix improved control to 94%.

The population of Indian hedge mustard (IHM) was sporadic across the trial site so there was poor statistical separation between treatments. However, chlorsulfuron alone and the low rate of metribuzin provided limited control.

What does this mean?

Herbicide damage from some Group C herbicide products caused significant biomass reductions and yield loss. The herbicide mixture of simazine + diuron at the lower rate provided a reasonable level of safety to the lentil crop and was still able to maintain good weed control for most species. Given the results recorded it may be possible to adjust the ratios of these two herbicides to reduce the amount of simazine to further improve crop safety and maintain weed control, however these results need to be considered with respect to the seasonal conditions too, where different rainfall patterns may produce a different result.

It was necessary to include some group B chemistry to get good control of the full spectrum of weeds, particularly medic, however it is important to note the impact this has on crop NDVI and the resulting grain yield. Intervix applied post emergent was the safest group B product in this trial.

Diflufenican in combination with the Group C mixture provided excellent control of the brassica weeds and had very good crop safety but provided poor control of medic.

The variation in efficacy between herbicide products and groups means it is important to know what weeds are present in the paddock and plan the herbicide strategy accordingly. Further to this, it is also important to know the herbicide resistance status of the target weeds. For example, Intervix has provided reasonable control of milk thistle and Indian hedge mustard at this site, however resistance to this herbicide is known to be increasing in these species and weed control failures will occur where this is the case unless alternative options can be used.

Figure 1 shows that for a given level of herbicide damage visible at flowering, as measured by a reduction in NDVI, there can be a variety of grain yield responses. The NDVI or biomass reduction from the combination of group B + C herbicides in 2018 had a much greater impact on grain yield compared to the same symptoms from the group C herbicides.

It is important to note that grain yields achieved were in the absence of weed competition, with plots hand weeded in mid-August, before the weeds imposed significant competition. The aim being to measure the effect of herbicide on crop performance, rather than the effect of weeds on crop yield. However, in a real paddock scenario where yields will reflect both crop effect from herbicide damage and remaining levels of weed competition, treatments that balance both crop damage and weed control are expected to perform better than the untreated control. The compromise between optimising weed control and minimising crop effect is highlighted in Figure 2, where group C herbicides that provided the best weed control also had the largest negative effect on crop yield. Weed competition in lentils can reduce yields close to zero where weeds are left uncontrolled and in high numbers. Previous research by the University of Adelaide at Minlaton, SA using triazine canola as a surrogate brassica weed showed that 10 canola plants per square metre reduced lentil yields by 15 to 26%.

Seasonal conditions have a large impact on weed emergence, herbicide efficacy and herbicide damage. Group C and B herbicides applied to sandy soils and incorporated by sowing (IBS) or post sowing and pre emergence (PSPE) are particularly sensitive to rainfall frequency and amounts. Therefore results should be interpreted with this in mind. Growing season rainfall was well below average, with the six week period post sowing being particularly dry. Results may differ in seasons with different seasonal conditions.

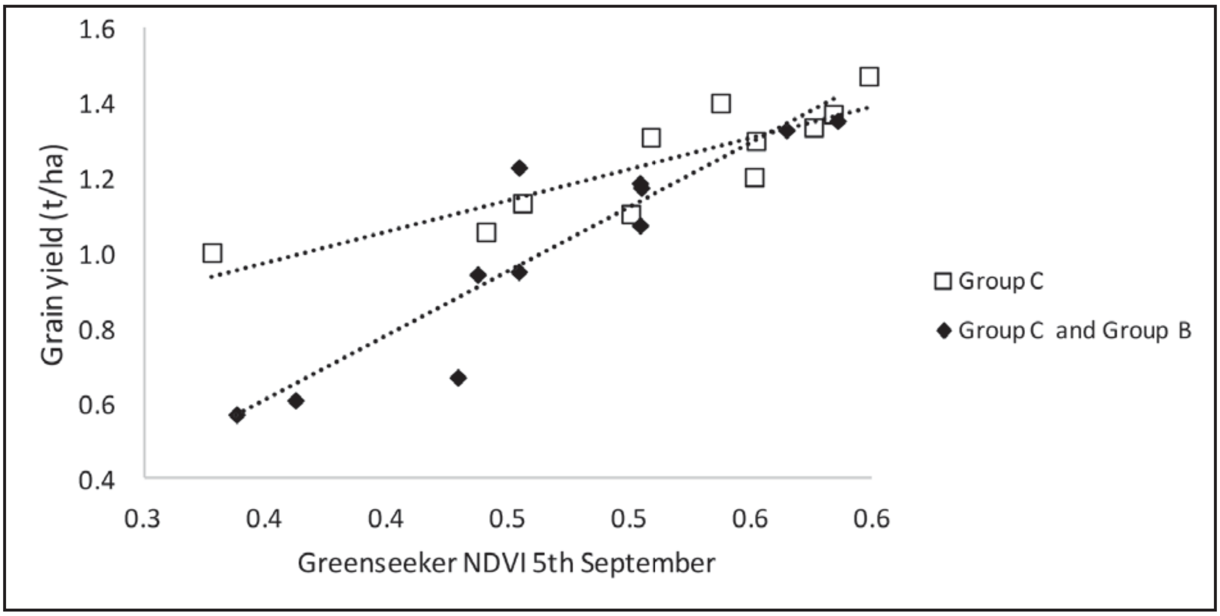

Figure 1 Lentil grain yield (t/ha) and Greenseeker NDVI 5 September (early flowering) for group C treatments only (y=1.668x + 0.3912 , R^2=0.7434) and Group B / Group C combinations (y=3.4308x – 0.5941, R^2=0.8418) at Alford in 2018

Table 1 Herbicide damage score (0=no symptoms, 6=plot death), Green seeker NDVI 16 July, 4 August and 5 September and grain yield (t/ha) for 2018 lentil herbicide tolerance trial at Alford, 2018

Treatment	Group C	Group C Rate (g/ha)	Diflufenican (ml/ha)	Chlorsulfuron (g/ha)	Intervix (ml/ha)	Damage score 14 June	Damage Score 2 July	NDVI 16 July	NDVI 4 Aug	NDVI 16 Aug	NDVI 5 Sept	Grain yield (t/ha)
1	Control					1.0	1.0	0.20	0.32	0.44	0.60	1.47
2	Simazine900	500				1.7	3.3	0.18	0.23	0.33	0.46	1.14
3	Simazine900	750				1.7	4.2	0.15	0.18	0.24	0.33	1.00
4	Diuron900	550				1.3	1.3	0.19	0.30	0.43	0.55	1.30
5	Diuron900	825				1.0	1.5	0.19	0.31	0.45	0.58	1.34
6	Terbyne	500				1.7	1.3	0.19	0.28	0.39	0.55	1.20
7	Terbyne	750				2.3	1.8	0.19	0.28	0.36	0.50	1.11
8	Metribuzin720	150				1.7	1.2	0.19	0.29	0.39	0.58	1.37
9	Metribuzin720	225				1.7	1.5	0.18	0.27	0.39	0.54	1.40
10	Sim/Diu	250/275				1.3	2.5	0.19	0.25	0.33	0.51	1.31
11	Sim/Diu	375/412.5				1.7	2.7	0.17	0.23	0.32	0.44	1.06
12				5		1.0	1.8	0.18	0.26	0.36	0.50	1.08
13					500	1.0	1.8	0.20	0.29	0.39	0.59	1.35
14	Sim/Diu	250/275		5		1.7	2.2	0.17	0.22	0.30	0.45	0.95
15	Sim/Diu	250/275			500	1.7	2.5	0.18	0.24	0.34	0.50	1.19
16				5	500	1.0	2.2	0.17	0.23	0.31	0.43	0.67
17	Sim/Diu	250/275		5	500	2.0	2.7	0.16	0.19	0.26	0.36	0.61
18			150			1.0	1.0	0.20	0.30	0.38	0.56	1.33
19	Sim/Diu	250/275	150			1.0	2.8	0.18	0.24	0.31	0.45	1.23
20	Sim/Diu	250/275	150	5		1.7	2.3	0.17	0.22	0.30	0.44	0.94
21	Sim/Diu	250/275	150		500	1.3	2.7	0.18	0.23	0.30	0.51	1.18
22	Sim/Diu	250/275	150	5	500	1.3	2.5	0.17	0.19	0.24	0.34	0.57
LSD (P=0.05)						*0.72*	*0.77*	*0.01*	*0.03*	*0.05*	*0.06*	*0.18*

***Table 2** Weed control of Wild turnip (Brassica tournefortii), Sow thistle (Sonchus asper), Medic (Medicago spp.) and Indian hedge mustard (Sisymbrium orientale) presented as percent control, the same letters denote statistically similar results as analysed as log(weeds per plot +1) at the 5% level.*

Treatment	Group C	Group C Rate (g/ha)	Diflufenican (ml/ha)	Chlorsulfuron (g/ha)	Intervix (ml/ha)	Wild turnip (% control)		Sow thistle (% control)		Medic (% control)		IHM (% control)	
1	Control					0.0	a	0.0	a	0.0	ab	0.0	a
2	Simazine900	500				76	bc	89	de	71	bcde	86	bc
3	Simazine900	750				79	bcd	99	gh	74	cde	99	c
4	Diuron900	550				52	ab	74	bc	26	abc	93	bc
5	Diuron900	825				72	bc	94	ef	54	abcde	97	bc
6	Terbyne	500				86	cd	84	cd	62	abcde	100	c
7	Terbyne	750				79	cd	96	fg	68	abcde	100	c
8	Metribuzin720	150				72	bc	35	a	23	a	29	ab
9	Metribuzin720	225				83	bc	69	b	45	abcd	82	bc
10	Sim/Diu	250/275				93	cd	90	de	59	cde	99	c
11	Sim/Diu	375/412.5				86	cd	93	ef	69	cde	91	bc
12				5		83	bcd	11	a	98	fgh	72	ab
13					500	97	cd	88	de	74	e	91	bc
14	Sim/Diu	250/275		5		97	cd	98	gh	98	fg	99	c
15	Sim/Diu	250/275			500	100	d	96	fg	94	f	97	bc
16				5	500	97	cd	96	fg	100	h	97	bc
17	Sim/Diu	250/275		5	500	100	d	100	h	100	h	97	bc
18			150			97	cd	83	bcd	34	abc	95	bc
19	Sim/Diu	250/275	150			100	d	100	h	74	de	100	c
20	Sim/Diu	250/275	150	5		100	d	99	gh	99	gh	100	c
21	Sim/Diu	250/275	150		500	100	d	100	h	96	fgh	100	c
22	Sim/Diu	250/275	150	5	500	100	d	100	h	100	h	100	c

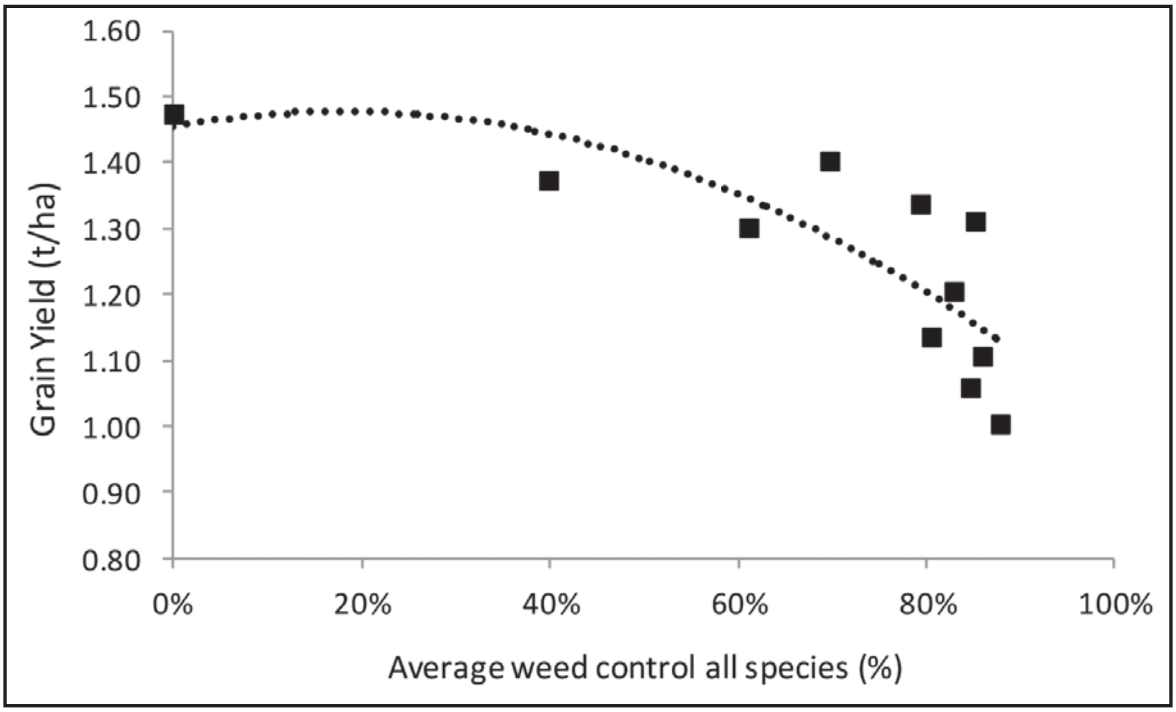

Figure 2 Effect of weed control of all species from Group C herbicides on grain yield (t/ha) of lentil at Alford, 2018. Y = -0.72x2 + 0.26x + 1.45, R2 = 0.60.

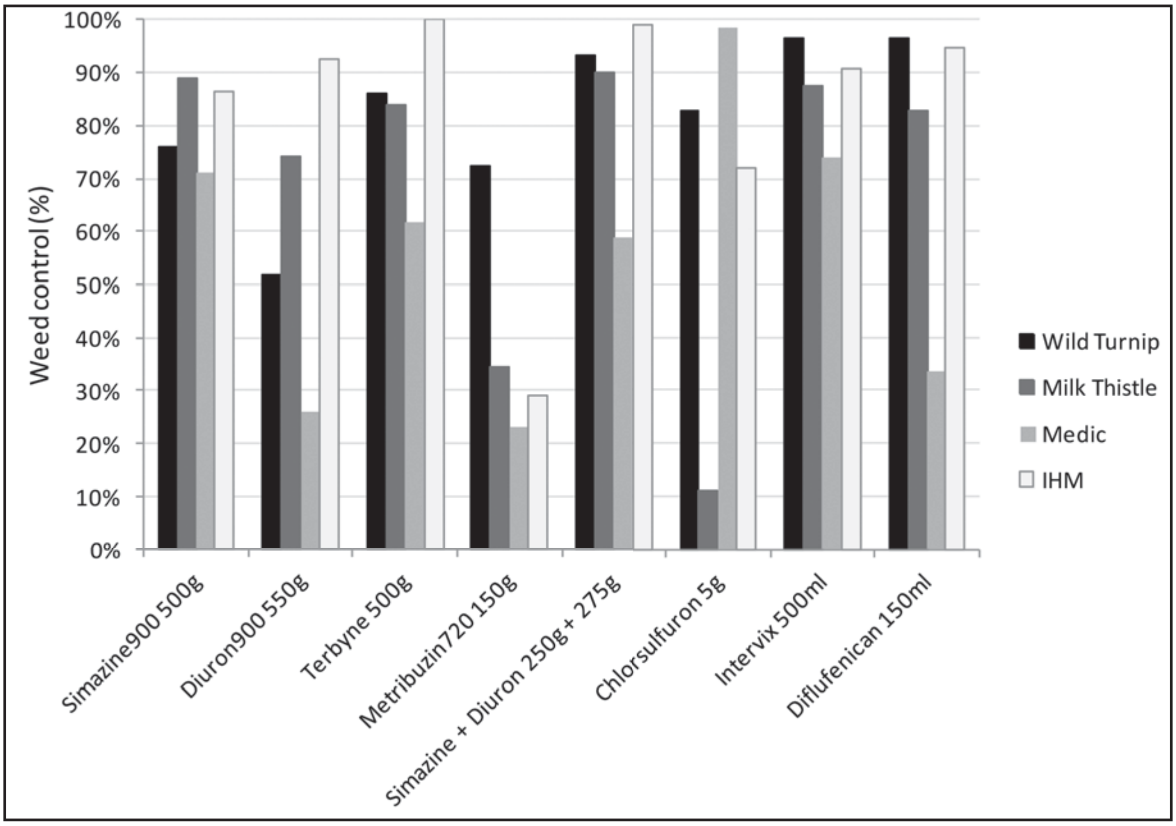

Figure 3 Weed control of four weed species with individual herbicides at Alford, 2018

Acknowledgements

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NOTE: Not all rates and herbicides used in this trial are registered for use in lentil and the results and findings reported in this article do not constitute a recommendation of their use by the authors.

SAGIT

Section Editor:
Fiona Tomney
SARDI, Minnipa Agricultural Centre

Section 3

Disease

Cereal variety disease guide 2019

Hugh Wallwork and Tara Garrard
Cereal pathologists, SARDI

EXTENSION

Summary of 2018 season and implications for 2019

2018 was a second quiet year in succession for foliar diseases in the cereals. Low inoculum levels of most diseases from 2017 certainly helped but also dry conditions in autumn and winter would have slowed any disease development. Good rainfall in the South-East meant that diseases were more prevalent in that region.

Septoria tritici blotch continued to be the main disease of interest and the fungus was certainly widespread across the medium and high rainfall areas. Most varieties are susceptible to varying degrees and fungicide sprays were likely to have been beneficial in many situations.

Net form net blotch and spot form net blotch were at low levels in both 2017 and 2018 and this will mean low levels going in to 2019. With early sowing and favourable conditions both diseases can develop rapidly. Growers sowing susceptible varieties should be ready to apply early sprays as these are the most effective way to manage these diseases. NFNB is particularly damaging and very variable so the disease ratings are provided as a range.

Leaf rust and stripe rust were absent from wheat crops in SA in 2018. Very low levels of rust in 2017 and use of fungicides either for rust, septoria or eyespot will have contributed to this success.

Barley leaf rust was also present at lower levels than previous years. We recorded it on the lower Yorke Peninsula including at severe levels in one crop of Compass, which also had the rust on the weed Star of Bethlehem. This weed allows the rust to transfer from old barley stubbles to new crops by hosting a key stage of the rust's life cycle. Hence growers with this weed should be very careful about sowing barley where infected barley stubbles are also present.

Stem rust

Stem rust was not observed in wheat in 2018. It remains a concern however that some new varieties are highly susceptible to stem rust. This is particularly the case with some long season wheats not included in this table. Some of them are bred overseas where stem rust is not such a concern. Factsheets on these varieties do not always reveal this deficiency, so if considering these varieties it is important to ask the agent about stem rust. Whilst stem rust has not been a problem in recent years this has perhaps led to some complacency that growers should be aware of because an epidemic could be hard to control and very damaging.

Powdery mildew in wheat has become a higher concern in the past two years. Thicker crops with increased canopy humidity, closer rotations and increased use of applied N have favoured the disease. The variety Scepter is particularly susceptible and worse than Mace. In 2018 it also became evident that Chief CL Plus is also very susceptible to a strain identified from the Yorke Peninsula. Collections of mildew from a severely infected crop of Chief near Bute in early September was used to test adult plants grown on the Waite Campus under controlled conditions and this confirmed that Chief CL Plus was very susceptible along with several other varieties including the new varieties Arrow and Havoc.

Because powdery mildew grows on leaf sheathes around the lower stem, controlling this disease requires fungicide sprays before canopy closure similar to eyespot. Sprays after this time will only be partially effective and unable to control infection in the head, which can be a problem in wetter seasons.

Barley powdery mildew is also variable and so the ratings provided in this guide may not reflect all situations. The data comes mostly from nurseries in Queensland and Western Australia. Some barleys from Europe carry the mlo resistance gene which has proven durable over a long period of time. Where known this will be indicated in the table so that growers are notified that mildew control is not required in seed treatments for these varieties. All other varieties should be treated for mildew control to keep inoculum levels low thereby reducing the risk of resistance loss in other varieties and also reducing the risk of loss of fungicide efficacy.

Crown rot was not obviously a problem in 2018. Conditions for infection were not ideal. However there would have been a reduced breakdown of infected stubbles from 2017 so growers may need to use PredictaB samples to check on paddocks where crown rot has been a problem in previous years, especially if planning to sow a durum crop.

Eyespot

Whilst there is not a lot of variation amongst the varieties, those that are rated MS or MSS should provide a useful level of resistance over varieties rated S. Note however that taller varieties or varieties with weaker straw will be more prone to lodging due to eyespot than varieties with similar resistance ratings but which have stronger stems. Mace for example is more prone to eyespot lodging than Wyalkatchem, although both are equally susceptible to infection and yield loss other than through lodging.

Black point is not a disease but a genetic response to particular environmental conditions, mainly damp weather post flowering. It is however included in this sheet for historical reasons.

Explanation for resistance classification

R The disease will not multiply or cause any damage on this variety. This rating is only used where the variety also has seedling resistance.

MR The disease may be visible and multiply but no significant economic losses will occur. This rating signifies strong adult plant resistance.

MS The disease may cause damage but this is unlikely to be more than around 15% except in very severe situations.

S The disease can be severe on this variety and losses of up to 50% can occur.

VS Where a disease is a problem, this variety should not be grown. Losses greater than 50% are possible and the variety may create significant problems to other growers.

Where '-' is used then the rating is given as a range of scores that may be observed depending on which strain of the pathogen is present. This is currently only used for some barley and oat diseases where the pathogens are particularly variable and unpredictable.

This classification based on yield loss is only a general guide and is less applicable for the minor diseases such as common root rot, or for the leaf diseases in lower rainfall areas, where yield losses are rarely as severe.

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. Samples should be sent, not just before a weekend, to the following address:

SARDI Diagnostics
Plant Research Centre,
Hartley Grove
Urrbrae SA 5064

Further information contact: hugh.wallwork@sa.gov.au or tara.garrard@sa.gov.au

SARDI

SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE

Wheat	Rust			*Septoria tritici* blotch	CCN Resistance	Yellow leaf spot	Eyespot	Powdery mildew	Root lesion nematodes		Crown rot	Common root rot	Flag smut	Black point ‡	Quality in SA
	Stem	Stripe	Leaf						*P. neglectus*	*P. thornei*					
Arrow	S	S	SVS	S	MS	MRMS	–	SVS	MRMS	MRMS	S	MS	MS	MRMS	AH
Beckom	MRMS	MRMS	MSS	S	R	MSS	S	MSS	S	MSS	S	MSS	MR	MRMS	AH
Chief CL Plus	RMR	S	R	MS	MS	MRMS	–	SVS	MR	MS	S	MS	SVS	MS	APW
Cobra	RMR	MSS	MR	MS	MS	MRMS	S	MSS	MSS	MSS	S	MSS	S	MSS	AH
Corack	MR	MS	SVS	S	RMR	MR	S	SVS	MSS	MSS	S	MS	S	S	APW
Cutlass	R	MS	R	MSS	MR	MSS	S	MSS	MSS	MSS	S	MS	MS	MS	APW
DS Bennett	MRMS	RMR	S	MSS	MSS	MRMS	–	R	MSS	MSS	SVS	–	SVS	S	ASW
DS Darwin	MRMS	MR	S	S	MS	S	MSS	MS	S	S	S	MSS	MR	MS	AH
DS Pascal	MSS	RMR	MS	MS	S	MRMS	MSS	R	S	S	S	MS	S	MS	APW
Emu Rock	MS	MRMS	S	SVS	S	MRMS	MSS	MSS	MSS	MSS	MS	MSS	MS	MS	AH
Forrest	RMR	RMR	MSS	MS	S	MRMS	MS	S	VS	SVS	SVS	MS	MR	MR	APW
Grenade CL Plus	MR	MRMS	S	S	MR	S	S	MSS	MSS	S	S	MRMS	MR	MSS	AH
Havoc	S	MR	S	MSS	S	MRMS	–	S	MSS	MS	S	MS	MS	MS	AH
Illabo	MS	RMR	S	MSS	MRMS	MS	–	MRMS	MSS	MSS	SVS	–	R	MS	AH
Impala	MR	MR	SVS	VS	MSS	MSS	–	R	SVS	S	S	MSS	S	MS	Soft
Kittyhawk	MRMS-S	RMR	MS	MRMS	S	MRMS	–	MS	S	S	SVS	S	RMR	MRMS	AH
Kiora	RMR	RMR	MRMS	MS	MSS	MSS	–	MS	MSS	MRMS	S	MS	MRMS	MS	AH
Kord CL Plus	MR	MRMS	MS	MS	MR	MSS	–	MS	MSS	MSS	S	MRMS	MR	MRMS	AH
Longsword	MR	RMR	MSS	MSS	MRMS	MRMS	–	MS	MR	MR	S	MRMS	MRMS	MRMS	Feed
Mace	MRMS	SVS	MSS	S	MRMS	MRMS	S	MSS	MS	MS	S	MS	S	MRMS	AH
Manning	MR	RMR	MS	MR	S	MRMS	MS	MS	MSS	S	VS	SVS	R	SVS	Feed
Orion	MR	MSS	R	MRMS	MS	MSS	S	SVS	MS	S	S	MSS	S	S	Soft / Hay
Razor CL Plus	MRMS	MS	S	SVS	MR	MSS	–	MSS	S	MR	S	–	RMR	MS	ASW
Revenue	RMR	R	VS	S	S	MS	–	R	S	MSS	S	SVS	S	MS	Feed
RGT Accroc	MS	R	S	MS	S	MRMS	–	MRMS	–	–	–	–	–	MRMS	Feed
Scepter	MRMS	MSS	MSS	S	MRMS	MRMS	S	SVS	S	MSS	S	MS	MSS	MS	AH
Sheriff CL Plus	MS	MSS	SVS	S	MS	MRMS	–	SVS	MRMS	MRMS	S	–	S	MRMS	APW
Trojan	MRMS	MR	MR	MS	MS	MSS	MS	S	MSS	MSS	MS	MS	SVS	MRMS	APW
Vixen	MRMS	MRMS	SVS	S	MSS	MRMS	–	SVS	MRMS	MS	S	–	SVS	MSS	AH
Wyalkatchem	MS	S	S	S	S	MR	S	SVS	MRMS	MS	S	–	SVS	MS	APW
Yitpi	S	MRMS	S	MSS	MR	SVS	MSS	MS	MSS	S	S	MS	MR	MS	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, - = Uncertain
- = mixed reaction, ^ = some susceptible plants

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*					
Aurora	RMR	RMR	R	MRMS	MSS	MRMS	S	MSS	MRMS	RMR	VS	MRMS	R	MSS	Durum
Saintly	MR	MR	MRMS	S	MS	MRMS	MS	MSS	MRMS	MR	VS	MS	R	MS	Durum
Spes	RMR	RMR	R	MRMS	MRMS	–	–	S	S	RMR	VS	–	R	–	Durum
Vittaroi	MR	MR	MR	MRMS	MSS	MRMS	–	MR	S	RMR	VS	–	R	MSS	Durum

Triticale	Rust			*Septoria tritici* blotch	CCN Resistance	Yellow leaf spot	Eyespot	Powdery mildew	Root lesion nematodes		Crown rot	Common root rot	Flag smut	Black point ‡	Quality in SA
	Stem	Stripe	Leaf						*P. neglectus*	*P. thornei*					
Astute	RMR	RMR	RMR	R	R	MRMS	–	R	R	MS	MSS	MS	R	–	Triticale
Fusion	R	RMR	RMR	R	R	MRMS	MS	R	RMR	MSS	MS	S	R	MSS	Triticale
Goanna	R	MR ^	RMR	R	R	MR	–	R	MRMS	SVS	–	–	R	–	Triticale
KM10	R	RMR	MRMS	R	S	MR	–	R	MR	MRMS	–	MRMS	R	MRMS	Triticale
Wonambi	RMR	MR ^	R	RMR	MS	MR	–	R	MR	MS	–	–	R	–	Triticale

R = resistant, MR = moderately resistant, MS = moderately susceptible, S = susceptible, VS = very susceptible

Tolerance levels are lower for durum receivals.

^ - Some susceptible plants in mix

‡ Black point is not a disease but a response to certain humid conditions.

Barley	Leaf rust*	Net form net blotch*	Spot form net blotch*	Scald*	CCN Resistance	Powdery mildew	Eyespot*	Covered smut	Common root rot	Root lesion nematodes		Black point
										P. neglectus	*P. thornei*	
Alestar	R-MS	MR-S	MSS	MS-SVS	R	RMR	–	R	MSS	MR	MR	MRMS
Banks	MRMS-S	R-MRMS	MS	MR-SVS	S	MR-MSS	–	MSS	MSS	MR	MR	MRMS
Commander	MS-S	MSS-SVS	MSS	S-SVS	R	MRMS-S	–	RMR	MSS	MRMS	MRMS	MSS
Compass	SVS	MR-MSS	MR-MSS	MS-SVS	R	MRMS-S	MS	R	MS	MRMS	MR	MSS
Fathom	MRMS-S	MS-VS	RMR	R-MS	R	MRMS	MRMS	MR	MSS	MRMS	MR	MSS
La Trobe	MRMS-S	MR-MSS	MSS	R-VS	R	MR-SVS	MRMS-S	MS	S	MRMS	MRMS	MSS
Oxford	R-MS	MR-VS	MS-S	MR-SVS	S	R	MRMS	MRMS	MSS	MR	MRMS	MR
RGT Planet	MR-MS	MRMS-SVS	S	R-S	R	R	–	R	MSS	MRMS	RMR	MRMS
Rosalind	MR	MR	MS-S	MR-SVS	R	MR-S	MS	MRMS	S	MR	MR	MSS
Schooner	S-VS	MR	MS	MS-S	VS	SVS	–	MR	S	MS	MRMS	MS
Scope	MS-SVS	MR	MS-S	MS-S	S	RMR	MS	MS	MS	MRMS	MRMS	MS
Spartacus CL	MR-S	MRMS-S	S	R-VS	R	MR-SVS	MS	MS	MS	MRMS	MRMS	MSS
Traveller	R-MS	R-MS	MS	MR-S	–	RMR	–	MS	–	–	–	–
Westminster	R-MRMS	R-S	S	R-S	–	R *mlo*	–	MR	MSS	MRMS	MS	MRMS
WI4952	MS-SVS	MRMS	MR	S-VS	S	MR-S	–	R	MSS	RMR	RMR	S

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*	*P. neglectus* Nematodes
	Stem*	Leaf*	Resistance	Tolerance	Resistance	Tolerance					
Bannister	MR-S	R	R	I	–	MI	MR-S	MS	MS	S	–
Brusher	MS-S	MS-S	R	MI	MS	I	MR-MS	MS	MS	MS	MR-MS
Durack	S	R-S	R	MI-MT	–	I	MR-S	MS	MS-S	S	–
Forester	R-S	MR-MS	MS	MI	S	I	MS-S	MR	MR-S	MR	–
Glider	MR-S	MS-S	MS	I	R	T	R	MR	MR-S	MR	–
Kangaroo	MS-S	MS-S	R	MT	S	MI	MR-MS	MS	MR-S	MR-MS	–
Kowari	MR-S	R	VS	–	–	I	MR	MS	S	S	–
Mitika	MR-S	MS-S	VS	I	S	I	MR	S	MS-S	S	–
Mulgara	MS	MR-MS	R	MT	R	MT	MR	MS-S	MS	MS	–
Tammar	MR-S	MR-MS	MR	MT	R	T	MR	MR-MS	MS	MR	–
Tungoo	MS-S	MS	R	MT	R	T	MR	MR	MR-MS	MR	–
Wallaroo	S	S	R	MT	MS	MI	S	MS	MS	S	MR
Williams	MR-S	R	S	I	–	I	R	MS	MR-MS	MR-MS	–
Wombat	MS-S	MS	R	T	MR	MT	MR-MS	MS	MR	MS	–
Wintaroo	S	S	R	MT	MR	MT	MR-MS	MS	MR-MS	MR-MS	MR-MS
Yallara	S	MS	R	I	S	I	MR-MS	MS	MS	MS	–

T = Tolerant, MT = Moderately Tolerant, MI = Moderately Intolerant, I = Intolerant, VI = Very Intolerant, – = Uncertain

* = Due to multiple strains of these pathogens, the table provides a range of reactions that may be observed. Different ratings are separated by a -

Improved crop nutrition for disease management and reduced fungicide dependency

Blake Gontar
SARDI, Port Lincoln

Location
Stokes
Rainfall
Av. Annual: 450 mm
Av. GSR: 350 mm
2018 Total: 411 mm
2018 GSR: 338 mm
Yield
Potential: 6.5 t/ha (B)
Actual: 6.5 t/ha
Paddock History
2018: Wheat
2017: Canola
2016: Wheat
Soil Type
Gravelly clay loam over clay
Plot Size
2 m x 10 m x 4 reps
Trial Design
Randomised complete block
Yield Limiting Factor
Nil

Location
Wangary
Rainfall
Av. Annual: 450 mm
Av. GSR: 350 mm
2018 Total: 468 mm
2018 GSR: 406 mm
Yield
Potential: 5.5 t/ha (B)
Actual: 5.1 t/ha
Paddock History
2018: Barley
2017: Canola
2016: Wheat
Soil Type
Deep gravelly sand over clay
Plot Size
2 m x 10 m x 4 reps
Trial Design
Randomised complete block
Yield Limiting Factor
Grazing at key grain filling stages possibly reduced yield

Key messages

- **Improved crop nutrition reduced Septoria in wheat at Stokes and spot form net blotch in barley at Wangary on lower Eyre Peninsula.**
- **Improved crop nutrition did not reduce root disease at either site.**
- **At Stokes, the yield gain due to improved crop nutrition was greater under disease pressure than where disease was managed with fungicide, suggesting an interaction between nutrition and disease.**

Why do the trial?

Disease is a significant cost issue for Eyre Peninsula (EP) growers, causing yield loss and increasing management inputs such as fungicides. At the same time, many crops grown on the EP also have nutrient deficiencies, particularly copper, zinc and potassium. Previous research has demonstrated that these nutrient deficiencies not only reduce growth and yield directly, but can also affect the capacity of plants to resist or tolerate disease.

While the benefits of addressing nutritional requirements are becoming better understood and adoption by growers has increased, most research is carried out under low disease conditions. It is possible that the response to improved crop nutrition will be greater under moderate disease conditions. Addressing an underlying nutrient problem could reduce the need for some fungicide application. A two-year project has been established with funding from South Australian Grains Industry Trust (SAGIT) to assess the disease management benefits of improving crop nutrition.

How was it done?

Two field experiments were established in 2018 on lower Eyre Peninsula, at Stokes and Wangary. The Stokes site had low-marginal copper and low phosphorous status, while at Wangary, potassium was low and sulphur was marginal. At Wangary, Spartacus barley was sown on 14 May, while at Stokes, Scepter wheat was sown on 15 May. At each site, six nutrient treatments were applied at seeding either with or without fungicide to manage disease. Treatments sown without fungicide were also artificially inoculated with Rhizoctonia to ensure an even and significant amount of this root disease. The experiments were designed in consultation with a statistician (Statistics for Australian Grains Industry, SAGI) and were of a randomised, complete block design with four replicates of each of the 12 treatment combinations (Table 1).

At Wangary, nitrogen and phosphorous were balanced using di-ammonium phosphate and triple superphosphate to ensure each treatment received equal amounts of these nutrients in an available form, while at Stokes, nitrogen only was balanced (with urea), as phosphorous rate was a treatment.

Table 1 Treatment details at Stokes and Wangary in 2018

Stokes				Wangary			
P (kg/ha as DAP)	Cu (kg/ha as CuSO4)		Disease	K (kg/ha as MOP)		S (kg/ha as SOA)		Disease
0	0	×	Fungicide	0	×	0	×	Fungicide
15	5		Inoculated	30		20		Inoculated
30				60				

In 'disease-free' plots, Uniform was applied to fertiliser and soil and Vibrance was applied to the seed and Prosaro applied to foliage from late tillering stage, all at the highest label rate, to achieve relatively low levels of disease. In the 'disease' plots, soil was inoculated with Rhizoctonia and foliar diseases including Septoria and yellow leaf spot at Stokes and spot form net blotch at Wangary were allowed to develop from naturally-infected stubble present in the paddock. Weed and nitrogen management throughout the year were representative of district practice, with 225 kg/ha and 175 kg/ha of urea applied at Stokes and Wangary respectively.

Tissue tests were conducted on above-ground biomass ('whole tops') sampled at late tillering to confirm any response to nutrients. Approximately forty plants were collected from each plot, with tests conducted on a single sample per treatment, bulked across replicates.

Root diseases were assessed visually for all plots at 'late-tillering' and 'full head emergence'. Forty plants per plot were assessed by collecting four 10 cm lengths of row dug from both ends of each plot to a depth of 20 cm, the roots were washed and disease severity scored on a 0-5 scale (0 = no disease, 5 = all roots totally rotted). Foliar disease was assessed at 'booting' and 'early dough' growth stages by randomly sampling 20 leaves per plot and recording percentage leaf area affected.

Plots were harvested on 16 November at Wangary and 4 December at Stokes, and yields were recorded. Yield data at Wangary could have been affected by sheep grazing the site late, during key grain formation stages.

Data were analysed using Genstat (19th Edition) in consultation with a statistician from SAGI with all treatment differences tested using ANOVA at the $\alpha = 0.05$ significance level.

What happened?

Both sites received good early rainfall around 3 May, allowing good establishment in both trials. Growing season rainfall totalled 338 mm at Stokes and 406 mm at Wangary (Cummins median GSR = 315 mm).

Tissue tests conducted on whole above-ground biomass confirmed phosphorous and copper deficiency at Stokes. All nil phosphorus treatments had low tissue P, with marginal P in the 15 kg/ha treatments and sufficient P in 30 kg/ha. Copper was deficient in plots where copper was not added, except in the nil phosphorous plots. At Wangary, all treatments had sufficient potassium but sulphur was marginal.

Root disease

Nutrient treatments did not affect root disease score at either site (Table 2), however the differences in root disease score between inoculated (no fungicide) and fungicide treatments demonstrate that the inoculation was highly effective, but the fungicide treatment was only partially effective. Inoculation with Rhizoctonia and use of fungicides was effective at creating low and high Rhizoctonia levels.

Leaf disease

At Stokes, in late July, Septoria tritici blotch (*Zymoseptoria tritici*) and some yellow leaf spot (*Pyrenophora tritici-repentis*) began to develop in all plots including those treated with fungicide, however disease pressure was low overall. Nutrient treatments had a significant, but minor effect on early leaf disease development in the fungicide-treated plots (P = <0.001) (Table 3).

Table 2 Average root disease scores of fungicide treated or inoculated treatments on crown and seminal roots at late tillering and full head emergence at Stokes and Wangary in 2018

Site	Late tillering				Full head emergence	
	Crown		Seminal		Crown	
	Fungicide-treated	Inoculated	Fungicide-treated	Inoculated	Fungicide-treated	Inoculated
Stokes	0.67	4.04	0.83	1.65	0.86	2.87
Wangary	2.09	4.05	1.77	2.95	1.56	3.36

Table 3 Early leaf disease percentage at Stokes in 2018

Nutrient treatment	Leaf Disease (%)	
	No Fungicide	Fungicide
P0C0	1.18e	0.82de
P0C5	1.11de	0.74cd
P15C0	0.96de	0.34bc
P15C5	1.21de	0.27ab
P30C0	0.94de	0.16ab
P30C5	0.85de	0.07a

Table 4 Early leaf disease percentage at Wangary was generally low but was affected by nutrient treatments without fungicide

Nutrient treatment	Leaf Disease (%)	
	No Fungicide	Fungicide
K0S0	7.25g	0.10a
K0S20	4.88e	0.32b
K30S0	3.43d	0.11a
K30S20	3.82d	0.20ab
K60S0	5.99f	0.10a
K60S20	1.24c	0.11a

Table 5 Late leaf disease percentage at Wangary was affected by nutrient treatment for no fungicide treatments

Nutrient treatment	Leaf Disease (%)	
	No Fungicide	Fungicide
K0S0	26.97cd	1.49a
K0S20	16.89b	1.17a
K30S0	25.83bcd	0.89a
K30S20	19.35bc	1.02a
K60S0	30.32d	1.44a
K60S20	16.92b	1.34a

By the second assessment, no nutrient effects on leaf disease were evident. The disease level in the no fungicide treatment was low, approximately 2.5% leaf area, and less than 0.01% in the plus fungicide treatments.

At Wangary, spot form net blotch began to develop in the no fungicide treatments in late July. Disease levels were low and were affected by nutrient inputs ($P<0.001$). The highest level of disease was in the nil added potassium and sulphur treatments. All combinations of sulphur and potassium reduced spot form net blotch, with the highest rates of both nutrients limiting disease to 1.24% compared to 7.25% in the nil added nutrient treatments (Table 4).

At the second assessment, nutrient treatments significantly reduced leaf disease percentage ($P<0.001$), however results were inconsistent. Potassium alone at either rate did not reduce diseases compared to the control treatment. Sulphur reduced disease from 27% to 17% and the combination of sulphur 20 kg/ha and potassium 60 kg/ha reduced disease to 17%. The combination of sulphur (20 kg/ha) and potassium at the lower rate (30 kg/ha) did not reduce leaf disease percentage below the nil treatment, although did reduce disease below one other treatment without sulphur.

Yield

At Stokes, both P and Cu input significantly affected yield of wheat (Table 6). Copper improved wheat yield only at the highest rate of phosphorous in the inoculated treatments and appeared to reduce yield at the lowest rate of phosphorous in the fungicide treatments. Phosphorous effects were more consistent, improving yield over the nil phosphorous treatments both with inoculation and with fungicide. However, the percentage increase in yield was consistently greater for the inoculated treatments than for the fungicide treatments, suggesting an interaction with disease.

At Wangary, nutrient inputs did not have an effect on yield of barley. Plots treated with fungicide yielded 5.1 t/ha, while diseased plots yielded 4.07 t/ha. However, barley plots were affected by unintended grazing on two separate occasions, leading to significant variability between replicates, and it is possible this the yield data does not reflect treatment effects.

What does this mean?

There were no clear benefits of nutrient inputs on root disease at either site. Root disease scores were high in inoculated plots, with generally all crown roots in all treatments at both sites displaying some disease.

Yields were still above average in disease plots, with 6 t/ha of wheat at Stokes and 4 t/ha of barley at Wangary. Visually, these plots appeared healthy throughout the growing season and only appeared affected by root disease when compared to fungicide treated plots alongside.

This is an important result as it demonstrates the difficulty of relying on top growth to indicate significant root disease effects in commercial paddocks. Plants need to be dug up and roots washed and inspected to determine the presence of root diseases.

Table 6 Yield at Stokes was affected by nutrient treatment and the percentage increase in yield was greater in disease treatments than in no-disease treatments.

Treatment	Inoculated Mean Yield (t/ha)	Increase over P0C0 'Control' (%)	Fungicide-Treated Mean Yield (t/ha)	Increase over P0C0 'Control' (%)
P0C0	3.59	-	4.15	-
P0C5	3.91	not significant (P<0.05)	3.77	-9.17
P15C0	5.27	46.45	5.95	43.49
P15C5	5.43	50.90	5.70	37.43
P30C0	5.58	55.16	6.12	47.49
P30C5	5.96	65.79	6.41	54.68
	LSD = 0.34			

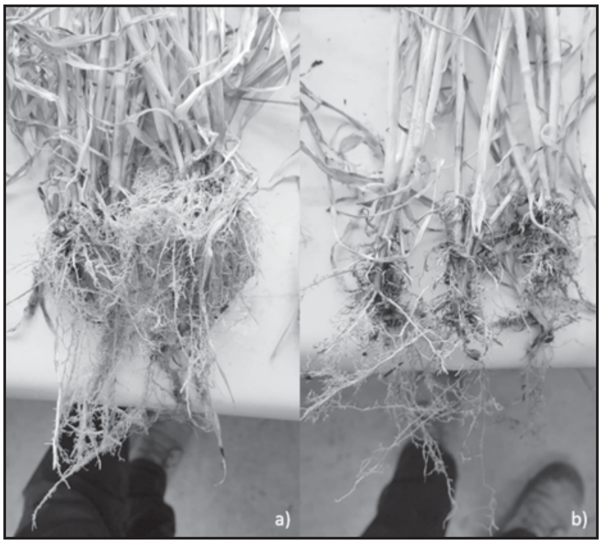

Figure 1 Example of plant roots at Wangary with a) low Rhizoctonia and b) very high Rhizoctonia infection

These effects also highlight the importance of the relationship between root disease effects and seasonal conditions. These crops did not experience significant moisture stress throughout the growing season which set up good yield potential. Even the high disease treatments produced yields likely to be accepted by many growers.

However, under low overall foliar disease levels, there was some evidence that phosphorous influenced foliar disease at Stokes, and sulphur reduced spot form net blotch at Wangary. Whilst not significant, there did appear to be a trend towards lower foliar disease percentage with the addition of copper at Stokes too.

Yield data for this site seems to support the hypothesis that nutrient inputs can compensate for reduced root systems caused by rhizoctonia, with the overall percentage increase in yield due to nutrient inputs greater in diseased treatments than in fungicide treatments. However, this additional benefit appears to be the result of improved supply to badly affected root systems (in inoculated plots), rather than due to actual disease reduction or root stimulation.

At Wangary, where the foliar disease response to sulphur was clearer, there was no yield response to any fertiliser treatment. However, it is unclear whether this is due to effects of the unintended grazing, or simply due to a lack of relationship between foliar disease and yield in this season.

The results of these experiments indicate the relationship between nutrition, root and leaf disease, and yield is highly dependent on environmental conditions, and the effect of disease on yield can be affected by nutrition. These experiments will be repeated in 2019.

Acknowledgments

Thank you to SAGIT for providing funding for this project (Project S818), Alan McKay and Nigel Wilhelm (SARDI, Waite) for assistance with trial planning and management, Helena Oakey (SAGI, University of Adelaide) for assistance with statistical design and analysis and to Graeme Charlton and John Richardson for providing field trial sites to conduct this research.

SARDI

SAGIT

SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE

Integrated disease management for crown rot in bread wheat crops on upper Eyre Peninsula

Margaret Evans and Hugh Wallwork
SARDI, Plant Research Centre, Urrbrae

Location
Mitchellville
Anthony and Paul Kaden
Franklin Harbour Agricultural Bureau
Rainfall
Av. Annual: 281 mm
Av. GSR: 192 mm
Soil Type
Light sandy clay loam
Diseases
Crown rot
Plot Size
1.8 m (6 row) x 12 m x 4 reps
Yield Limiting Factors
2015 - delayed sowing
2016 - frost and an extreme heat event in August
2017 - extremely low rainfall

Key messages

- **Emu Rock (early maturing) is a good choice of variety for Upper Eyre Peninsula as it consistently yielded best in the presence and in the absence of crown rot when compared with Mace (early to mid maturing) and Trojan (mid maturing) at Mitchellville 2015-2017.**
- **Neither lower plant densities (significantly decreased yields in 2015) nor lower nitrogen application at sowing (results were limited and inconsistent) can be recommended for reducing crown rot expression or yield losses due to crown rot.**
- **Rancona® Dimension is unlikely to be an economic option for managing crown rot as it did not reduce crown rot incidence or severity, even though for Emu Rock it gave a slight yield improvement.**
- **Integrated disease management using pyramided treatments in-crop is unlikely to be economic and cannot be recommended unless more effective treatments (e.g. seed treatments with good activity on crown rot) become available.**
- **Many findings from this research challenge our understanding of how crown rot management affects crown rot expression and yield losses due to crown rot.**

Why do the trials?

Management options available for in-crop reduction of yield loss due to crown rot have only a limited effect, but it is sometimes necessary to sow bread wheat into a paddock with medium to high risk of yield loss from crown rot. This work contributes to understanding the effects of crown rot management options used singly or in combination (integrated disease management or IDM) in-crop in the low rainfall environment of upper Eyre Peninsula.

PreDicta B results for the 2017 Mitchellville NVT trial site showed there were high levels of crown rot present at the site, as is common in this area. Andrew Ware and the Franklin Harbour Agricultural Bureau saw this as an opportunity to assess options for managing crown rot when bread wheat must be sown into a paddock with this disease.

Best management practice options were selected on the basis that they were suited to the area and its agricultural practices and were simple to implement. The practices assessed included nitrogen application, plant density, variety resistance, fungicide seed treatment, and time of sowing. Options were used alone or in combination, with the "control" being based on NVT trial protocols and district practice.

How was it done?

Trials were undertaken in 2015, 2016 and 2017. All trials were co-located with the National Variety Trials at Mitchellville and provided a good opportunity for extension of information about crown rot to local growers and industry representatives. Treatments in 2015 (Table 1) were selected based on best management practice recommendations for crown rot. In 2016 and 2017 treatments were modified yearly on the basis of findings from previous year(s) and all treatments were sown with and without added crown rot.

Trials were undertaken in plots 12 m long x 6 rows wide using a completely randomised block design with 4 replicates. In 2015 (25 May) and 2016 (26 May) trials were sown late in the local sowing window to encourage crown rot expression. In 2017, the effects of time of sowing were examined.

The first time of sowing was early/mid (2 May 2017) in the local sowing window but the second time of sowing (planned for about 26 May), was extremely late (5 July 2017) due to lack of rain.

Treatments were selected to quantify the effects of current best-practice crown rot management recommendations on disease expression and yield on upper Eyre Peninsula:

- Variety selection - well adapted to local conditions, with a range of crown rot resistances and maturity categories. Mace as the "control" – susceptible to crown rot, early to mid season maturing; Emu Rock – moderately susceptible (MS) to crown rot, early maturing; Trojan - MS to crown rot, mid maturing.
- Fungicide seed treatment for crown rot suppression.
- Basal stem application of fungicide to suppress the rate of crown rot development.
- Lower plant density to reduce early crop bulk and moisture stress during grain fill.
- Lower nitrogen rates to reduce early crop bulk and moisture stress during grain fill.
- Sowing time - early in the local sowing window, later in the sowing window (to increase moisture and heat stress during grain fill).

Plant samples were collected at early grain fill for assessment of plant density, head density, whitehead expression and browning on main stem bases. Plot yield was recorded. Crown rot expression (extent of basal stem browning on main stems) was scored visually on a 0-5 scale:

0 = 0% - No yield loss

1 = 1-10% - Possibility of minor yield loss

2 = 10-25% - Possibility of some yield loss

3 = 25-50% - Probably some yield loss

4 = 50-75% - Significant yield loss likely

5 > 75% - High yield loss likely

What happened?

Trials established well and weeds, other diseases and pests were adequately controlled. In 2015 rainfall was good early in the season, but during grain fill there was significant moisture stress. In 2016 there was adequate rainfall, but there were frosts and also extreme heat conditions in August. In 2017 rainfall was very low and resulted in yields being below average, particularly for the second time of sowing.

Table 1 Treatments applied at Mitchellville in 2015, 2016 and 2017. Varieties assessed over that period: Mace - susceptible to crown rot, early-mid maturing; Emu Rock - moderately susceptible to crown rot (MS), early maturing; Trojan – MS, mid maturing.

	Treatment name	Seed dressing	Plant density (/m^2)	N at seeding (kg/ha)	In-crop sprays	Time of sowing (ToS)
2015 - Mace, Emu Rock						
1	District practice	None	180	14.4	Nil	-
2	Low density	None	90	14.4	Nil	-
3	Low N	None	180	7.3	Nil	-
4	Rancona D[1]	Rancona D	180	14.4	Nil	-
5	Seed trt 1 and 2	New products	180	14.4	Nil	-
6	Best CR[2] practice	Rancona D	90	7.3	Prosaro[3]	-
2016 - Mace, Emu Rock. All treatments with and without added crown rot[4]						
		Rancona D	180	14.4	Nil	-
		None	180	14.4	Nil	-
		Rancona D	180	7.3	Nil	-
		None	180	7.3	Nil	-
2017 - Mace, Emu Rock, Trojan. All treatments with and without added crown rot						
		None	180	14.4	Nil	Early
		None	180	14.4	Nil	Later

[1] *Rancona® Dimension (registered for crown rot suppression) @ 320 ml/100 kg of seed.*
[2] *CR = crown rot.*
[3] *Prosaro® 420 SC @ 300 ml/ha to plant bases at early tillering and at anthesis.*
[4] *Crown rot inoculum applied at 2 g/m row of sterilised grain colonised with crown rot.*

2015

Detailed results and discussion for the 2015 trial can be found in the EPFS Summary 2015 (p 93-96). Crown rot incidence (19%-46% of main stems affected) and expression were low (basal stem browning score less than 0.7) and would have been unlikely to significantly affect yield. The main findings (Figure 1) were that, in the presence of very low levels of crown rot:

- Emu Rock yielded better than Mace.
- Pyramiding management options only resulted in a yield improvement over district practice for Mace.
- Seed treatment did not reduce crown rot incidence or severity, but did improve yields over IDM for Emu Rock. Note: other treatments had no fungicide applied to seed.
- Reducing plant densities resulted in reduced yields.
- Reducing nitrogen applied at sowing increased yields over district practice for Mace but not for Emu Rock.
- An unexpected result was that Mace (S) had lower crown rot expression than did Emu Rock (MS) - data not presented.

2016

Crown rot expression (basal stem browning score) was higher in plots with added crown rot inoculum than in plots without added inoculum (Table 2). This was reflected in a decrease in whitehead expression from 27% to 12% and an increase in yield from 1.63 t/ha to 2.00 t/ha, which translates to a 0.37 t/ha or 19% yield increase where crown rot was at low levels. Again, as was seen in 2015, Mace (S) unexpectedly had lower crown rot expression than did Emu Rock (MS), but only in plots where crown rot inoculum was added (Table 2). The lower nitrogen application rate at sowing decreased whitehead expression from 23% to 16% but did not increase yield.

2017

Crown rot expression (basal stem browning score) was highest in plots with added crown rot inoculum (Table 3) and this was reflected in whitehead expression at both times of sowing (Table 3) and in yields at the early time of sowing (Figure 2). At the early time of sowing, Emu rock yielded significantly better than the other varieties in the presence and the absence of crown rot. At the later time of sowing, Emu Rock and Mace yielded significantly better than Trojan in the presence of crown rot and Emu Rock yielded significantly better than Trojan in the absence of crown rot (Figure 2). At the early time of sowing, Trojan (63%) had the largest percentage yield loss from crown, followed by Mace (46%) and Emu Rock (30%). At the early time of sowing Trojan yielded worse than Mace in the presence of crown rot but as well as Mace in the absence of crown rot, which was unexpected given the relative maturities of these varieties.

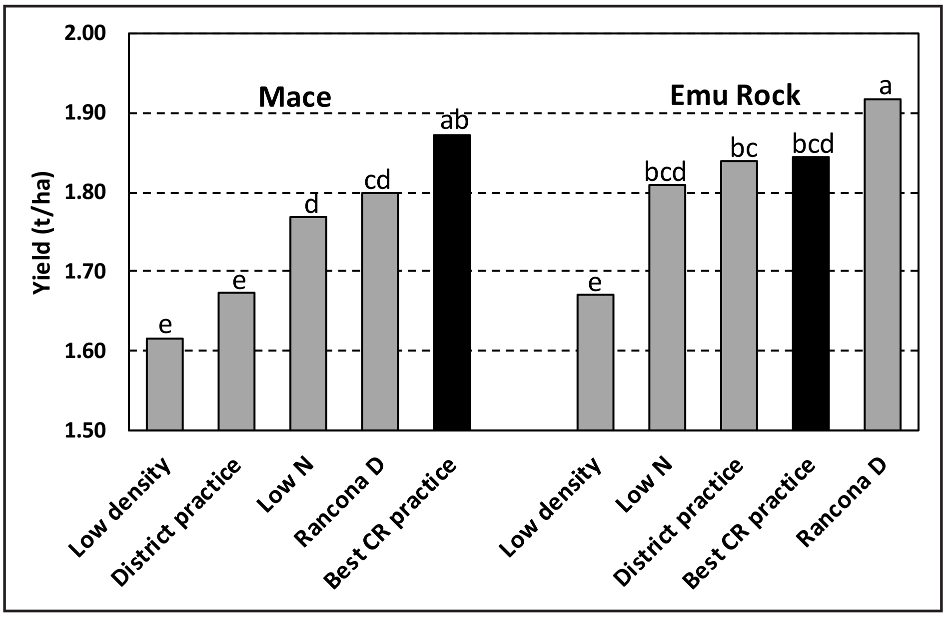

Figure 1 Effects of crown rot management treatments (including varietal resistance) on yields of bread wheat, Mitchellville 2015. District practice – plant density 180, 14.4 kg N. Best crown rot practice – plant density 90, 7.3 kg N; Rancona® Dimension @ 320 ml/100 kg of seed; Prosaro® 420 SC @ 300 ml/ha to plant bases at early tillering and at anthesis.

Table 2 Effects of high and low crown rot levels on crown rot expression in Mace - susceptible to crown rot, early-mid maturing and Emu Rock - moderately susceptible to crown rot (MS) at Mitchellville in 2016

Treatment - variety and crown rot level	Crown rot score
Emu Rock – high crown rot	2.41 a
Mace – high crown rot	1.85 b
Emu Rock – low crown rot	0.94 c
Mace – low crown rot	0.81 c

Table 3 Effects of high and low crown rot levels on crown rot expression at two times of sowing (ToS1 - 2 May; ToS2 - 5 July) at Mitchellville in 2017

Treatment – time of sowing and crown rot level	Crown rot score	Whiteheads (%)
ToS1 – high crown rot	1.80 a	18.0 a
ToS1 – low crown rot	0.08 c	0.4 c
ToS2 – high crown rot	1.08 b	4.0 b
ToS2 – low crown rot	0.05 c	0.7 c

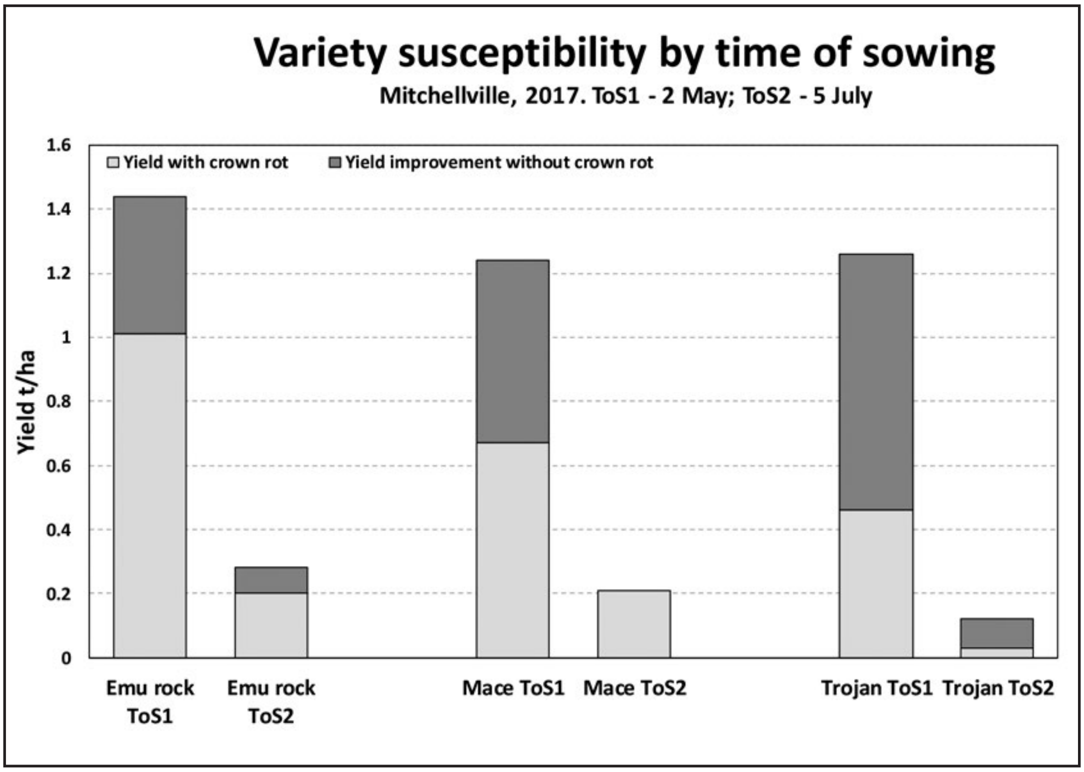

Figure 2 Effects on yield of variety maturity and susceptibility to crown rot at two times of sowing at Mitchellville in 2017. Varieties had the following maturities and susceptibilities to crown rot Mace - early-mid, susceptible; Emu Rock – early, moderately susceptible; Trojan – mid, moderately susceptible.

What does it mean?

Seasonal conditions and times of sowing varied over the period of this research program, but Emu Rock (early maturing) consistently yielded best when compared with Mace (early to mid maturing) and Trojan (mid maturing). Of the management options assessed, variety choice had the most influence on yield in the presence of crown rot on upper Eyre Peninsula, with early maturity being critical for good performance whether or not crown rot was present. In this environment, early maturity (and good adaptation to the locality) is more important than crown rot resistance rating, although this might change if varieties with better levels of resistance to crown rot become available.

There were comparatively low levels of crown rot expression (≤0.70 in 2015, ≤1.80 in 2016 and ≤2.40 in 2017) in the trials undertaken at Mitchellville. In higher rainfall areas, these levels of crown rot would not be expected to result in significant yield losses. However, at Mitchellville in 2016 there was a 19% (0.37 t/ha) loss due to crown rot and in 2017 losses ranged from 30%-63% (0.43-0.80 t/ha) at the first time of sowing. Results from 2015 (where treatments all had crown rot present) also suggest low crown rot expression might have resulted in higher than expected yield losses.

This implies that comparison of varietal yield losses due to crown rot should be undertaken in low rainfall zones rather than assuming that findings from the medium rainfall zone will apply. It also has implications for interpretation of current PredictaB risk categories when applied to low rainfall zones. Further research is needed to quantify yield losses (including the relationship with rainfall during grain filling) due to crown rot and to assess whether PredictaB risk categories need modification for the low rainfall environment of upper Eyre Peninsula.

Even where crown rot inoculum was added to the plots, crown rot expression in-crop was relatively low, although it was associated with significant yield losses. If these low levels of expression occur widely and are related to significant yield loss, then visual identification of crops at risk will be difficult and may result in the magnitude of the crown rot issue being under-estimated in low rainfall zones.

Pyramiding crown rot management options (seed treatment, low plant density, low N application at seeding and two fungicide applications in-crop) reduced crown rot expression but provided limited yield benefits. It is unlikely that pyramiding these management options for crown rot control would be of economic or practical benefit on-farm. Neither lowering plant densities (which decreased yields in 2015) nor lowering nitrogen rates at seeding (which had limited yield benefits in 2015 and none in 2017) could be recommended as part of a crown rot management strategy in the low rainfall environment of upper Eyre Peninsula.

Using plots with and without added crown rot inoculum provided useful insights into performance of bread wheat varieties under crown rot pressure at different sowing times and with low or high nitrogen inputs at sowing. Interestingly, this methodology showed that in 2017 at the early time of sowing, Trojan yielded worse than Mace in the presence of crown rot, but as well as Mace in the absence of crown rot. This is unexpected given the relative maturities of these varieties and the expectation that Trojan would have yielded much less than Mace in both the presence and the absence of crown rot.

Unexpected results were obtained during this research program, including varietal yield responses to added crown rot and the relatively large yield losses in the presence of low crown rot expression. Whether these findings are due to the limited number of trials undertaken or to there being unique responses of crops to crown rot on upper Eyre Peninsula would require further research to clarify. Future research programs in low rainfall environments should include plots with and without added crown rot inoculum to more fully understand the effects of management options on crown rot expression and yield losses due to crown rot.

Acknowledgements

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Farming Systems

Eyre Peninsula Farming Systems 4 - Maintaining profitable farming systems with retained stubble project outcomes

Naomi Scholz and Amanda Cook
SARDI, Minnipa Agricultural Centre

INFO

Why do the project?

In upper Eyre Peninsula farming systems, retained stubble is essential for livestock feed, to improve water conservation and most importantly to minimise soil erosion risk. Generally, our seeding systems can cope with the relatively low stubble loads produced from cereal, oilseed and pulse crops. However, issues can arise in better growing seasons with increased stubble loads mainly in cereals and associated increases in pests and weeds, with growers resorting to burning and other methods to reduce stubble loads and/or remove pests and weeds.

The GRDC funded project 'Maintaining profitable farming systems with retained stubble - upper Eyre Peninsula EPF00001' aimed to produce locally relevant, sustainable management guidelines to control pests, weeds and diseases while retaining stubble to maintain or improve soil health, and reduce exposure to wind erosion. The major outcome to be achieved was increased knowledge and skills allowing farmers and advisers to improve farm profitability while retaining stubble in farming systems on upper Eyre Peninsula via a mix of research and validation trials and extension activities.

How did we do it?

The project commenced in July 2013, with trials commencing in the 2014 season. A total of 19 replicated research trials were conducted on three sites across upper Eyre Peninsula; at Minnipa (stubble management, medic pasture two year breaks and herbicide efficacy), Lock (establishment in non-wetting sands) and Mount Cooper (managing pasture and cereal residues for subsequent crops). Paddock monitoring of harvest weed seed collection into windrows and chaff dumps occurred at nine sites from 2014-17, including Wilksch's on lower Eyre Peninsula (2015-16), by collecting paddock samples after harvest and monitoring the germination of weeds in weed seed trays in the following season.

Activities at the sites focused on addressing local barriers to profitability in farming systems with retained stubble. These issues were identified in conjunction with farmers and included grass weeds (mainly barley, brome and annual rye grass), pests (snails and mice), establishment of crops on non-wetting soils, herbicide efficacy in stubbles, establishment into cereal and medic residues, disease and the use of break crops in rotations. All trial results are published on the EPARF website and GRDC Online Farm Trials database.

Extension activities included presentation of results and useful information at harvest report farmer meetings, field day presentations and 'Sticky Beak' day discussions, e-newsletters to EPARF members, the EP 'Stubble Extravaganza' advisor forum, maintenance of the EPARF website, supporting the publishing of the Eyre Peninsula Farming Systems Summary and the development of 11 locally relevant guidelines and three economic analyses, which have been distributed free as a booklet to all Eyre Peninsula farmers "Guidelines for maintaining profitable farming systems with retained stubble on upper Eyre Peninsula" and are available via the EPARF website www.eparf.com.au/publications.

From 2013-2018, 16 e-newsletters were sent to 300 EPARF members, 1322 growers and advisors attended 53 farmer meetings, 3800 attended 85 field days, 784 attended 17 workshops and 23 technical articles were provided free to 1100 growers, advisors and researchers across southern Australia.

The combined approach was effective in providing growers with information and tools, which increased knowledge and skills to enable them to retain more stubble in their farming systems more often.

The project Steering Committee provided effective and valuable feedback and advice on the project, with 17 project management meetings held during the life of the project by the EPARF Research Review Committee, which is made up of EPARF Board members, MAC research staff and leading upper EP farmers.

What happened?

Changes in knowledge, awareness, skills and attitudes were measured via event evaluation and final project evaluation activities. Practice change was reported by 55% of participants at farmer meetings in 2018, and 67% of participants in the final online survey said they have changed how they managed stubble in the past 5 years. The most common practice changes reported were: adoption of break crops in rotation (often two in a row); cutting stubbles lower; chopping residues; narrow windrow burning; use of chaff carts; sowing on-row in water repellent sands; rolling for snails; changing to disc seeders; and sowing on a slight angle to avoid residue blockages.

84% of advisors surveyed on upper Eyre Peninsula have changed the advice they have given to farmers in relation to retained stubbles in the past 5 years. The highest single influence was access to new information from locally specific R&D, followed by grower group events and increases in profitability.

Key extension messages were generated as a result of the trials undertaken in the project:

- Overall stubble management and seeding position did not impact strongly on weeds, disease or pests with relatively high stubble loads in a low rainfall farming system at Minnipa.
- Stubble management or seed row position had little effect on grass weed numbers in crop, except in non-wetting sands.
- In several seasons removing or low cut stubble lowered snail numbers compared to high cut stubble.
- Including one or two year break phases in low rainfall paddock rotations can increase profitability over maintaining a continuous wheat cropping sequence.
- Standing stubble cut low (15-17 cm) resulted in the highest level of stubble being maintained into the following season and reduces pest and disease pressure.
- Standing stubble is best for retention of soil cover and herbicide efficacy.
- There were no differences in soil moisture at seeding due to stubble management carried out at the previous harvest.
- Manage cereal stubbles leading into a break phase when establishing small seeded break crops such as canola and sown medic; if pests e.g. mice or snails or weeds are an issue.
- If the break phase is a self-regenerating medic pasture for grazing, harvest the cereal stubble higher.
- Maintain adequate N levels in stubble retained systems.
- For sowing into medic residues: Cut or smash medic vine in warm, drier conditions; aim for a vine length shorter than the smallest distance between the tine layout. If using Trashcutter to cut medic vine, do twice at 90 degrees. Sow pasture paddocks in warmer, drier conditions to allow better medic vine flow. If using disc seeders operate in dry stubble and firm soil conditions with a sharp cutting edge with thin disc wedge angle. Use high downward pressure capacity on disc units to match requirements for cutting matted residue and an operating depth optimised for the disc size.
- Sow on or near-row in non-wetting sands in dry conditions.
- Barley grass seeds are difficult to capture at harvest (early shedding).
- Rye grass seeds can be captured at harvest.
- Harvest weed seed control - Don't bother with barley grass, rye grass can be done, but harvest low.
- Burning a windrow is better than a whole paddock burn.
- Stubble loads on upper EP, especially in grazed systems, are not high enough to reduce herbicide efficacy.
- Options to increase herbicide activity in paddocks with high stubble loads include increasing chemical and water rates, changing nozzles to increase spray coverage, and reducing the height of the spray boom or stubble height so that herbicides reach the soil surface more easily and cover the soil more evenly.
- Mice: Ensure harvester set up is adequate to reduce grain loss, graze stubbles to reduce grain availability and monitor pest activity in high risk situations. Use Mouse Alert app.

- Snails: Reduce stubble height, graze stubbles, roll stubbles. If summer rainfall events occur, bait. Autumn is the most effective baiting period. Windrow burning provides an opportunity for reducing pest numbers as windrows act as an over-summer haven.

The project also provided resources, capacity and flexibility to participate in other events, deliver other outcomes beneficial to growers such as the EP Dry Start Forums, and further extension activities such as young farmer development and women's agronomy sessions.

Acknowledgements

Thanks to everyone that contributed, especially all the upper EP farmers that engaged with the project! EPARF Board and Research & Review Committee for project leadership and direction. Research team, Ian Richter, Wade Shepperd, Sue Budarick, Brett Hay, Katrina Brands, Rochelle Wheaton and Steve Jeffs for doing the work. Nigel Wilhelm, Ben Fleet Andrew Ware, Rick Llewellyn, Therese McBeath, for research support and advice. Ed Hunt for economic analyses of practices. Thanks to trial site hosts Stuart Hentchske, Andrew Polkinghorne, Angus Gunn and MAC farm and the farm weed monitoring site hosts Bruce Heddle, Jordan Wilksch, Peter Kuhlmann, Clint Oswald and Matthew Cook.

Photo: EPARF Board members and SARDI Minnipa Agricultural Centre staff at the launch of the 'Maintaining profitability in retained stubbles' project

EPARF EYRE PENINSULA Agricultural Research Foundation

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Maximising dry matter production for grazing systems on alkaline soils

Amanda Cook and Ian Richter
SARDI, Minnipa Agricultural Centre

RESEARCH

Location
Piednippie - Brent & Leanne Cronin
Rainfall
Av. Annual: 379 mm
Av. GSR: 304 mm
2018 Total: 288 mm
2018 GSR: 207 mm
Soil Type
Alkaline grey sandy loam
Paddock History
2018: Pasture
2017: Pasture
2016: Mace wheat
Soil Test
$pH_{(water)}$ 0-10 cm: 8.8
$pH_{(water)}$ 10-90 cm: 9.3
Plot Size
2 m x 12 m x 3 reps

Key messages

- **There is the potential to increase plant dry matter production and grazing using mixtures of plant species.**
- **Kaspa peas produced the greatest dry matter overall with 1.7 t DM/ha, and an oats/medic mix also did well (1.3 t DM/ha). The short season oats variety, Durack, produced the greatest dry matter for oats with 1.1 t DM/ha. Toreador disc medic (bred for sandy soils) produced the best dry matter (0.75 t DM/ha) amongst the pasture species.**
- **In a poor season like 2018, dry matter production in pastures could be improved compared to the current district practice of volunteer annual medics.**
- **Further research needs to be done on regeneration and herbicide tolerance of newer pasture species.**

Why do the trial?

The aim of this trial was to identify plant varieties or mixtures that can increase dry matter production of the pasture break phase on the highly alkaline soils of upper Eyre Peninsula. Current cropping and grazing systems are mostly based on monocultures and the potential feed base of the break phase could be broadened to be more productive for grazing and available for a longer time period in the season. Current oat varieties, mixed break crops and newer pasture species were trialled at Piednippie in 2018 to investigate whether a more productive and prolonged feed base is possible.

How was it done?

There were three separate trials conducted in 2018. Seven oat varieties and one grazing barley variety (Moby), were sown in an oats trial at Piednippie on a 2017 pasture paddock. See article 'Which oat varieties performed best for hay production at Kimba in 2018', for more information on the oat varieties used in this trial. The mixed crops trial consisted of eight combinations of vetch, peas, canola, oats and barley, as listed in Table 1. The pasture and grazing species trial consisted of annual medic species, disc medics, trigonella, clovers, biserrula, serradella and plantain. See the article 'Dryland Legume Pasture Systems: Legume Adaptation', for more information on the pasture species trialled.

Oat varieties were sown at rates estimated to produce a plant establishment of 120 plants/m^2. All pasture species were sown at 7.5 kg/ha except Casbah biserrula and Trigonella balansae (APG5045) which were sown at 5 kg/ha due to smaller seed size.

The trial was sown with SARDI small plot equipment on 7 and 8 June into moist seed bed conditions (wet to 10 cm depth only) with 100 kg/ha of single super fertiliser (0:8:0:11) applied to all trials. The fertiliser treatments in the pasture trial had 100 kg/ha of single phosphate top-dressed at sowing. The trials were sprayed with 1.5 L/ha Spray.seed on 15 June post sowing, pre-emergence to kill regenerating medic. After the rains in mid-August, late germinating Ward's weed was an issue and the oats were sprayed early September with 750 ml/ha Tigrex. Most of the pasture plots were sprayed with Targa @ 170 ml/ha, 500 ml/ha of Uptake and Broadstrike @ 25g/ha. The canola plots and Trigonella plots were sprayed with Targa @ 170 ml/ha and Simazine @ 400 g/ha.

Plant establishment of oats was counted on 2 July, and for the mixed crops and pasture species on 18 July. Dry matter cuts were taken on 3 October. Neither the oat or mixed species trials were harvested for grain yield due to galahs decimating the trial in late October.

Table 1 Establishment and growth of forage and pasture options at Piednippie in 2018

Variety	Plant establishment (plants/m²)	Dry matter (t/ha)
Date	**20 June**	**3 Oct**
Oats (target 120 plants/m²)		
Brusher	100	0.89
Durack	87	1.11
Mitika	88	0.74
Moby barley	88	0.74
Mulgara	86	0.85
Swan	92	0.85
Wallaroo	83	0.77
Wintaroo	83	0.59
Yallara	98	0.84
LSD (P=0.05)	*ns*	*0.20*
Mixtures		
Medic (Angel) 7.5 kg/ha and oats (Yallara) 40 kg/ha	79 (M), 73 (O) 152 total	1.30
Canola (43C80) 5 kg/ha	85	0.84
Peas (Kaspa) 90 kg/ha	60	1.69
Vetch (Volga) 30 kg/ha and barley (Moby) 40 kg/ha	33 (V), 61(B) 94 total	1.02
Vetch (Volga) 30 kg/ha and oats (Yallara) 40 kg/ha	65 (V), 76 (O) 141 total	1.09
Vetch (Volga) 25 kg/ha and oats (Yallara) 30 kg/ha	31 (V), 51 (O) 81 total	0.94
Vetch (Volga) 30 kg/ha, canola (43C80) 2 kg/ha and oats (Yallara) 40 kg/ha	36 (V), 38 (C), 64 (O) 138 total	1.00
Vetch (Volga) 45 kg/ha	65	0.54
LSD (P=0.05)	*ns*	*0.32*
Pasture species (7.5 kg/ha sowing rate)		
Angel (SU tolerant Herald hybrid) strand medic	131	0.31
Angel (SU tolerant Herald hybrid) strand medic topped with 100 kg/ha of single phosphate at sowing	130	0.13
Bartolo bladder clover	251	0.44
Casbah biserrula (5 kg/ha)	243	0.05
Cavalier spineless burr medic	122	0.18
Cobra balansa clover	209	0.13
Harbinger strand medic	73	0.19
Herald strand medic	136	0.55
Margurita French serradella	162	0.07
District practice regenerating medic (Piednippie)	57	0.27
Natural regenerating medic topped with 100 kg/ha of single phosphate at sowing	29	0.26
PM250 strand medic	172	0.58
Ranger plantain	98	0.06
SARDI Rose clover	202	0.37
Toreador disc medic	337	0.75
Trigonella balansae (5045) (5 kg/ha)	192	0.52
LSD (P=0.05)	*94*	*0.20*

The three trials were randomised complete block designs with 3 replications. Data were analysed using Analysis of Variance in GENSTAT version 19. The least significant differences are based on F prob = 0.05.

What happened?

The 2018 growing season rainfall at Piednippie was a decile 2-3, with below average rainfall for all months except August, when good rains were received.

The germination was patchy with not all plots established by 2 July. Plant establishment was lower than targeted, especially in the cereals.

Low levels of *Rhizoctonia* and *Pratylenchus thornei* inoculum were present at the site.

There were no differences in plant establishment in the oats trial with a trial average of only 89 plants/m^2 (Table 1). Durack oats, the earliest maturing variety, produced the highest early dry matter in the oat trial (Table 1), but differences between most oat varieties were small except for production from Wintaroo, which was quite low.

Kaspa peas performed the best at the site with good establishment and growth, and the highest dry matter. The cereal and legume mixes, especially the oats and medic, also performed well producing greater dry matter than pasture species trialled.

What does this mean?

Kaspa peas produced the greatest dry matter at the site in a poor season, and as a legume would provide nitrogen fixation and a good disease break for future cereal crops. Other pea varieties such as Morgan and Wharton may provide even better forage options for grazing. The early maturing oat variety Durack was the most productive oat variety. The oats and Angel medic mix also performed well for dry matter production.

Toreador disc medic, bred for sandy soils, produced more dry matter than the other medic species, although the total amount was still low (<1 t/ha). The production of other legumes such as serradella and biserrula was negligible. Although dry matter was low due to below average rainfall, there was potential for peas and the mixtures of cereals and legumes to improve overall production on grazing systems compared to the current regenerating pasture.

Spreading 100 kg/ha of single phosphate fertiliser at sowing on top of the current best option strand medics did not result in better dry matter production of the strand medics. Recent work at Minnipa and Piednippie has shown P can limit dry matter production and medic nodulation, but more research is needed to find a method to apply phosphorus in regenerating pasture systems without resowing.

This was one season's results in a below average rainfall year so further work needs to be done on some of the newer species, including regeneration, herbicide tolerance and how they fit into current farming systems.

Acknowledgements

Thank you to Brent and Leanne Cronin for allowing the trial to be on their property and to GRDC for funding the trial as part of the EPF00001 Maintaining profitability in retained stubble project.

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Herbicides for Barley grass management

Amanda Cook and Ian Richter
SARDI, Minnipa Agricultural Centre

RESEARCH

Location
Minnipa - John and Clint Oswald
Rainfall
Av. Annual: 325 mm
Av. GSR: 241 mm
2018 Total: 268 mm
2018 GSR: 208 mm
Paddock History
2017: Wheat
2016: Peas
2015: Wheat
Yield
Potential: 1.9 t/ha (W)
Soil Type
Red loam
Plot Size
2 m x 12 m x 3 reps
Yield Limiting Factors
Barley grass and dry start to season

Key messages

- **Infrequent rainfall events, poor weed germination early and dry conditions at seeding resulted in challenging conditions for early weed control and crop establishment in 2018.**
- **In a high Barley grass weed situation herbicide mixes containing Sakura provided good weed control.**
- **Trifluralin (1.5 L/ha) IBS followed by Lexone (metribuzin) (180 g) post emergent caused significant crop damage due to rainfall events following the metribuzin application.**
- **Use as many options as possible to lower grass weed seed banks including two-year breaks.**
- **Regularly test grass populations for herbicide resistance.**
- **Aim to prevent 100% of seed from setting in all phases of the rotation.**

Why do the trial?

Barley grass continues to be a persistent grass weed in low rainfall farming systems and current farming practices have selected for increased seed dormancy. This change in seed dormancy has resulted in Barley grass germinating later, and being much harder to control with knockdown and pre-emergent herbicides. In 2018 a range of herbicide strategies was tested for their effectiveness on a high density population of Barley grass.

The 2018 site was located opposite Tcharkuldu Rock near Minnipa and a replicated small plot trial (randomised complete block design with 3 reps x 12 m plots) was sown into the standing cereal stubble.

Herbicide treatments were applied using a 2 m shielded sprayer at 2 bar pressure with medium-coarse droplets (T11002 nozzles) and 80 L/ha water rate on 12 June for the pre-emergent herbicides. Scepter wheat was sown @ 65 kg/ha with DAP @ 60 kg/ha on 12 June into adequate moisture conditions with 2 mm of rainfall after sowing. The post emergent herbicide treatments were applied on 6 July with 6 mm of rainfall after application, and a total of 30 mm for the month of July.

Measurements taken were stubble load pre-seeding and crop and weed emergence counts. Dry matter production, late grass weed counts, panicle number and size, plus grain yield and grain quality of the crop were also taken during the season.

Data was analysed using Analysis of Variance (and was also compared to a REML spatial analysis to provide confidence in results) in GENSTAT version 19. The least significant differences are based on F prob=0.05. The data for Barley grass (plants/m^2) were analysed using a square root transformation.

What happened?

Weeds and herbicide treatments

Wheat establishment in the control was 178 plants/m^2, with Trifluralin (1.5 L/ha) + Avadex (1.6 L/ha), and Boxer Gold (2.5 L/ha) (pre-emergent) + Sakura (118 g) (pre-emergent) having lower wheat establishment than the control (Table 1). The treatment with Trifluralin (1.5 L/ha) IBS, followed by Lexone (180 g/ha) post-emergent, had rainfall following the application and resulted in significant crop damage.

Barley grass plant numbers on 24 July in the control was 711 Barley grass/m^2. All treatments with Sakura and Avadex resulted in reduced Barley grass weed numbers in a high pressure weed situation and increased yields substantially, by an average of 0.7 t/ha over the untreated control (Table 1 and Figure 1). Poor Barley grass control in a high grass weed situation resulted in significant wheat yield loss.

Table 1 Effect of herbicide options on wheat performance, Barley grass and cost ($/ha)

Herbicide treatment	Group	Chemical cost ($/ha)	Crop establishment (plants/m²)	Barley grass (plants/m²)	Late Barley grass (heads/m²)	Late Barley grass av. seed head length (cm)	Wheat yield (t/ha)
Control Untreated	-	-	178 bc	711 ab	907 c	63	0.32 e
Trifluralin (1.5 L/ha)	D	9	141 b	323 bcd	536 b	68	0.48 d
Trifluralin (2 L/ha)	D	12	153 bc	296 bcd	474 b	61	0.56 cd
Trifluralin (1.5 L/ha) + Diuron 900 (400 g/ha) (pre-emergent)	D+C	14	182 bc	642 abc	420 b	64	0.60 c
Trifluralin (1.5 L/ha) + Avadex (1.6 L/ha) (pre-emergent)	D+J	25	107 a	189 cde	579 b	66	0.64 c
Trifluralin (2 L/ha) + Avadex (1.6 L/ha) + diuron 900 (500 g/ha) (pre-emergent)	D+J+C	28	146 b	156 de	343 ab	60	0.63 c
Trifluralin (1.5 L/ha) + Boxer Gold (2 L/ha) (pre-emergent)	D+B	37	162 bc	794 ab	1089 c	63	0.35 e
Sakura (118 g/ha) (pre-emergent)	K	40	173 bc	126 de	86 a	64	0.98 ab
Sakura (118 g/ha)+ Avadex (3 L/ha) (pre-emergent)	K+J	70	158 bc	74 ef	81 a	58	1.07 a
Boxer Gold (2.5 L/ha) (pre-emergent)	K+J	28	203 c	1547 a	893 c	63	0.33 e
Boxer Gold (2.5 L/ha) (pre-emergent) + Sakura (118 g/ha) (pre-emergent)	K+J	68	122 a	28 f	109 a	65	0.93 b
LSD (P=0.05)			*50.5*	*608*	*278*	*ns*	*0.11*
Post Emergent Herbicide Treatments							
Control Untreated		-	178 bc	711 ab	907 c	58 c	0.32 de
Trifluralin (1.5 L/ha) IBS + Lexone (180 g/ha) (post)	D+C	15	41 a	126 c	542 ab	76 c	0.16 f
Boxer Gold (2.5 L/ha) (post)	K+J	28	150 bc	689 a	532 a	58 c	0.46 b
Glean (20 g/ha) (post)	B	1	134 b	1213 a	916 c	54 bc	0.39 bc
Monza (25 g/ha) (post)	B	10	134 b	534 b	426 a	45 a	0.66 a
Crusader (500 ml/ha) (post)	B	34	137 bc	809 a	911 c	49 ab	0.34 cd
Atlantis (330 ml/ha) (post)	B	29	147 bc	910 a	782 bc	57 c	0.27 e
LSD (P=0.05)			*43*	*117*	*243*	*6.6*	*0.07*

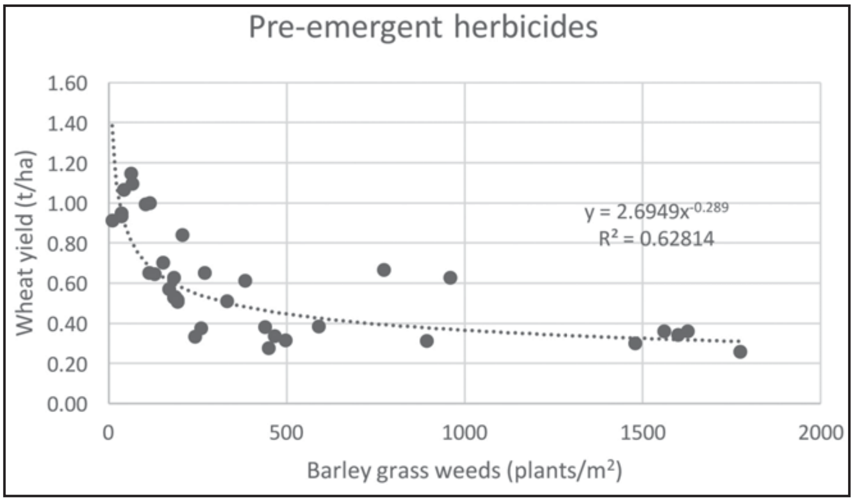

Figure 1 Wheat yield (t/ha) and Barley grass weeds (plants/m²) at Minnipa 2018 in a high pressure weed situation

Trifluralin (1.5 L/ha) IBS followed by Lexone (metribuzin) (180 g), and Monza (25 g/ha) as post emergent herbicide options showed a reduction in Barley grass plant numbers after two months. The treatment with Trifluralin (1.5 L/ha) IBS, followed by Lexone (180 g/ha) post-emergent, had rainfall following PE application and resulted in significant crop damage and death due to the herbicide washing into the crop row but was quite effective against Barley grass. Weed seed head size was also measured pre-harvest to assess any resulting weed suppression. Monza showed a reduction in head number and head size, however has some significant plant back restrictions for following crops and pastures and may not suit all systems.

The wheat yield at the site reduced with increasing Barley grass numbers (Figure 1). Early control of Barley grass achieved higher yields as shown in Figure 1, whereas late control of Barley grass did not increase grain yield (Table 1).

What does this mean?

The dry seeding conditions again at the start of the 2018 season resulted in challenging conditions for both establishing crops and weed control. Many crops were dry sown this season due to the late break resulting in very little pre-sowing grass weed control.

Increased seed dormancy in Barley grass populations may also be limiting early grass control with pre-emergent herbicides.

Previous research suggests that under the production regimes of upper EP, stubble management is unlikely to impact negatively on performance of pre-emergent herbicides. However, adequate water rates should be maintained when applying pre-emergent herbicides when targeting grass weeds in stubble situations. With the low production season in 2017 and scarce feed reserves there were very low stubble residues at seeding in 2018.

The 2018 herbicide trial was sown after the season break into adequate moisture and high Barley grass pressure. The herbicide options with Sakura and Avadex, in mixtures, provided good early Barley grass control. Early grass weed control is important to achieve higher yields. However, other grass weed control methods, particularly crop and herbicide rotations, must also be incorporated into farming systems to reduce grass weed pressure and delay herbicide resistance. Monza may be a useful herbicide post application in paddocks with high Barley grass numbers, but be aware of the plant back restrictions for pastures.

Reducing the weed seed bank is pivotal to managing all grass weeds. Effective two-year breaks during the pasture/break crop phase may be important in paddocks with high grass weed numbers to adequately reduce the Barley grass weed seed bank. Where dormant (later germinating) Barley grass is present, more expensive Sakura based herbicide mixes could be justified despite the added cost, as it provides a longer control period.

If Barley grass herbicide resistance is suspected, the first step is to test the population to know exactly what you are dealing with. To ensure Group A resistance is kept in check, make sure any suspected resistant plants are dealt with in pasture systems by following up with a knockdown herbicide as early as possible to prevent any seed set. Always have follow up options to control any survivors and to preserve group A herbicides. Another option may be to use other chemical groups like propyzamide (in moist conditions) to reduce the Barley grass population before using a group A herbicide. Using alternative chemical groups by including canola or Clearfield systems as a different rotational break may also be an option. The loss of Group A herbicides within current farming systems can result in high Barley grass weed seed bank carry over.

Acknowledgements

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National Paddock Survey - closing the yield gap and informing decisions

Harm van Rees[1], George Pedler[2], Jeremy Whish[3], Elizabeth Meier[3], David Gobbett[3], Roger Lawes[3], Chao Chen[3], Tim McClelland[4], Stephen van Rees[5] and Vicki Lane[5]

[1]Cropfacts/BCG, [2]George Pedler Ag, [3]CSIRO, [4]Model Agronomics/BCG, [5]SquareV

Key messages

- **Intensive monitoring of soils and crops over a rotation sequence has identified why crops do not achieve their potential yield.**
- **Reviewing paddock performance at the end of the season and using paddock records is essential for sustained improvement in agronomic performance.**
- **Preliminary analysis indicated that insufficient nitrogen was the main cause for the yield gap in wheat and barley crops grown on the EP. Frost and heat shock were also likely to be responsible for some yield penalty. Diseases, weeds and insects also contributed, but were less severe in impact.**

Background?

The yield gap is the term applied to the difference between achieved and potential yield, where potential yield is estimated from simulation models. On average, Australia's wheat growers are currently achieving about half their water-limited potential yield (Hochman *et al*. 2016, Hochman and Horan, 2018). Previous research with individual growers in the Wimmera/Mallee in Victoria determined that the long-term yield gap for those farmers was approximately 20% (van Rees *et al*. 2012). For a National overview of the Yield Gap see www.yieldgapaustralia.com.au.

The National Paddock Survey (NPS) is a four-year (2015 to 2018) GRDC-funded project designed to quantify the yield gap on 250 paddocks nationally and to determine the causes for the yield gap. Further, its aim is to establish whether management practices can be developed to reduce the yield gap to benefit farm profitability. The project aims to provide growers and their advisers with information and the tools required to close the yield gap.

How was it done?

250 paddocks nationally, 80 in each of WA and N NSW/Qld, and 90 in S NSW, Vic and SA, were monitored intensively over a four-year rotation (2015 to 2018). Consultants and Farming Systems groups undertook the monitoring. Two zones in each paddock were monitored at five geo-referenced monitoring points along a permanent 200 to 250 m transect. Each monitoring point was visited four times per season (pre- and post-season soil sampling and in-crop at the equivalent crop growth stages of GS30 and 65). Yield map data was obtained for each paddock which enabled the yield of each zone to be determined accurately. Table 1 lists the annual monitoring undertaken in each zone.

All paddocks were simulated with APSIM (Holzworth *et al*. 2014) and, during the season, Yield Prophet was available to all consultants and farmers.

The data set (four years x 500 paddock zones) is being analysed by Roger Lawes, CSIRO for factors primarily responsible for the yield gap in each of the three GRDC regions (Lawes *et al*. 2018).

This paper outlines the results of nine paddocks on the Eyre Peninsula monitored by George Pedler. The results are discussed as a paddock specific yield gap analysis over four seasons focused on outcomes for the farmer and consultant.

Results are presented as the modelled APSIM simulations in which:

- Ya=Actual Yield (as determined for each zone from yield map data)
- Ysim=Simulated Yield (for the same conditions as those in which the crop was grown)
- Yw=Simulated water limited, nitrogen unlimited yield (for the same conditions as those in which the crop was grown, but with N supply unlimited). Yw is considered the potential yield for the crop.

Note: APSIM currently accurately simulates wheat, barley and canola. We have not attempted to simulate the other crop types grown (lentil, chickpea, vetch, field pea).

The Yield Gap is calculated as the % difference between Yw and Ya ((Yw-Ya)/Yw).

Data was entered via the NPS website and stored in a purpose-built SQL Server database.

What happened and what does this mean?

Examples of individual paddock results

Data for two paddock zones in different locations on the EP are presented as examples of outputs as informed by the paddock monitoring.

Table 1 Overview of monitoring and data collected per zone for each NPS paddock

Monitoring	Timing	Monitoring	Timing
Deep soil test 4 depths (0-100 cm)	Pre-sow	Paddock yield and yield map data	Post-harvest
PredictaB (0-10 cm)	Pre-sow	Crop density, weeds, foliar diseases, insects (/m^2)	GS30
Deep soil test 4 depths (0-100 cm)	Post-harvest	Cereal root sample to CSIRO	GS30
Crop and Cultivar		Weeds, foliar diseases, insects (/m^2)	GS65
Sowing date and rate		Cereal stubble/crown for Fusarium	Post-harvest
Fertiliser, herbicide type, rate, date		General observations	
Temp buttons (1 per paddock)	GS60-79		

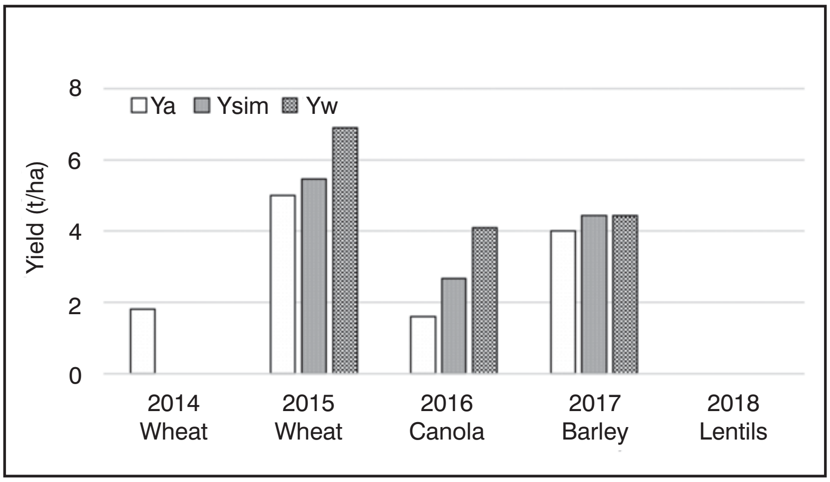

Figure 1 Example a. (EP NPS 3246) sandy loam over clay

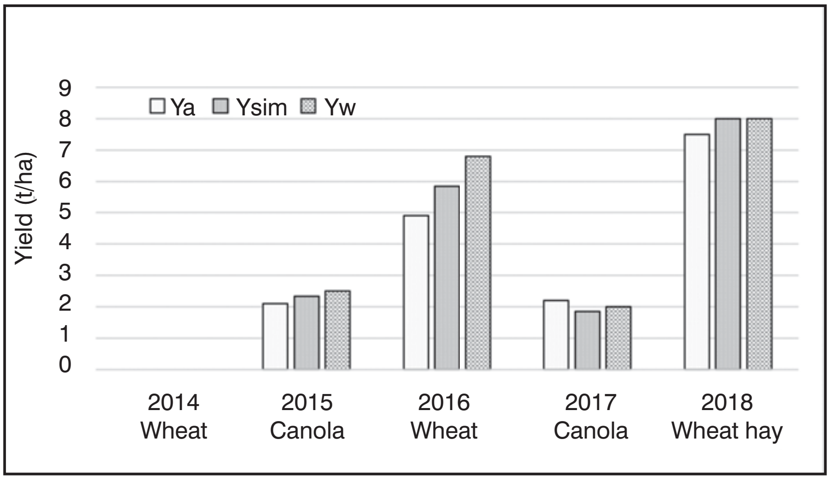

Figure 2 Example b. (EP NPS 3268) sandy loam over clay

Example a.

2014: setup year and no in-paddock measurements were taken, the paddock yield was 1.8 t/ha.

2015: Wheat Ya<Ysim<Yw there was 1.4 t/ha difference between Ysim and Yw which is attributed to insufficient N being available to the crop. The 0.5 t/ha difference between Ya and Ysim is attributed to abiotic and/or biotic stresses. Three days with temperatures above 34°C were recorded during GS60 to 79. The PredictaB soil test showed moderate levels of YLS and Rhizoctonia; Rhizoctonia was also recorded on the roots at GS30 (61% of the roots had a low level of Rhizoctonia), there were no crop diseases, insects or weeds recorded at GS65.

2016: Canola Ya<Ysim<Yw the 1.4 t/ha difference between Ysim and Yw is attributed to N deficiency. The 1.1 t/ha difference between Ya and Ysim is not explainable at this stage – there were no frost or heat shock events recorded, the soil PredictaB test did not show any diseases, and only 10 ryegrass/m^2 were recorded, there were no in-crop diseases or insects recorded.

2017: Barley Ya<=Ysim=Yw. Yw was the same as Ysim indicating N was not limiting. Ysim was slightly higher yielding than Ya (0.4 t/ha) which indicates either simulation variation or some abiotic and biotic stress having a small impact on yield. There was one day of hot weather recorded (+34°C) during flowering and grain-filling, soil PredictaB showed no diseases; no diseases, insects or weeds were recorded at GS65; and the stubble had a low level of Fusarium.

The average yield gap for wheat and barley was 24% in Example a.

Example b.

2014: wheat (no yield data)

2015: Ya=Ysim=Yw. Ya was 0.2 t/ha higher than the simulated yield which is within the error for simulations. There were no crop stresses limiting production. There were no frost or heat shock events recorded between GS60 (start of flowering) to GS79 (end of grain filling). There also were no crop diseases, insects recorded and only a very low level of marshmallow at mid flowering of the crop (3 marshmallow/m^2).

2016: Ya<Ysim<Yw. The 1 t/ha difference between Yw and Ysim is attributed to N deficiency. The 0.9 t/ha difference between Ya and Ysim is attributed to abiotic and/or biotic stresses. There were no frosts or heat shock events recorded, YLS was moderate in the soil PredictaB test, the roots had moderate level of disease and Rhizoctonia was low. The 38% yield gap can be attributed to N deficiency and the rest from low to moderate levels of disease.

2017: Ya=Ysim=Yw the small differences between Ya and the simulated yields (Ysim and Yw) of less than 0.3 t/ha indicates that there were no abiotic or biotic stresses on the crop (no yield gap). YLS was high in the soil PredictaB test, however this disease does not affect canola.

2018: Ya=Ysim=Yw indicates the actual hay yield is the same as the simulated yield (no yield gap). There was no disease recorded in the PredictaB test.

The average yield gap for the crops grown from 2015 to 2018 was 12% in Example b.

Average yield gap for wheat and barley on the EP (2015 to 2018)

The yield gap is defined as the difference between potential and actual yield, where the potential yield is determined through computer simulation. The average yield gap for wheat and barley grown over the 2015 to 2018 project period was 49%. This is preliminary data only – some of the paddock results need verification.

Assessing crop performance: Water Use Efficiency vs Modelling

The first paper on Water Use Efficiency (WUE) was published by French and Schultz in 1984. It was a breakthrough at the time, enabling farmers and agronomists to benchmark crop yield against a target and compare performance against other wheat crops. The French and Schultz WUE equation has since been updated by Sadras and Angus, 2006 and Hunt and Kirkegaard, 2012.

Hunt and Kirkegaard, 2012 calculate Crop Water Available as:

Soil water pre-sowing – Soil water post-harvest + Rainfall during the same period.

WUE is then calculated as Yield (kg/ha) / (Crop water available - 60).

Potential yield is calculated as 22 x (Crop Water Available - 60).

The 2015 to 2018 EP NPS wheat yields are plotted against Crop Water Available in Figure 3. The graph reveals a strong tendency for Ya to increase with Crop Water Available with an upper boundary of yield. The upper boundary is reasonably interpreted as Yw for well-managed crops as available crop water increases. The two lines included on the diagram are the potential yield lines proposed by French & Schultz, 1984 and Sadras & Angus, 2006 - the latter calculated as Potential yield = 22 x (Crop Water Use – 60), with a maximum WUE of 22 kg/ha/mm. For those yield achievements above the S & A line, the most likely explanation is that the crop had access to some water which was not accounted for in the calculation. There were two paddocks which had low WUE (the two most right points in Figure 3) in a very wet season which is not unusual. It is difficult to capitalise on those occasional years of very much above average rainfall, partly because of uncertainty that the good conditions will extend right through to the end of the season. Waterlogging can also occur in these above average conditions which restrict crop performance.

The reasons for improvement in potential WUE, from 20 to 22 kg/ha/mm since French and Schultz (1984) have been due to improved cultivars (semi-dwarf wheats) and higher atmospheric CO_2 levels.

How useful is WUE compared with computer modelled assessments of potential yield, and what will the future hold?

Figure 3 demonstrates a considerable variation in paddock yield relative to the potential, i.e. a considerable yield gap in many crops. Key questions for farmers and agronomists are what is the cause of the yield gap in each individual case and how can it be alleviated?

There are many possible causes that cannot be identified without careful paddock monitoring of abiotic and biotic factors, as attempted in the present project.

We must remember that WUE to assess yield potential is a bucket approach to a complex problem in a system with many interactions. WUE will not explain the causes of a yield gap, nor can it inform on reasons for favourable outcomes. It may identify the presence of a yield gap but not their cause.

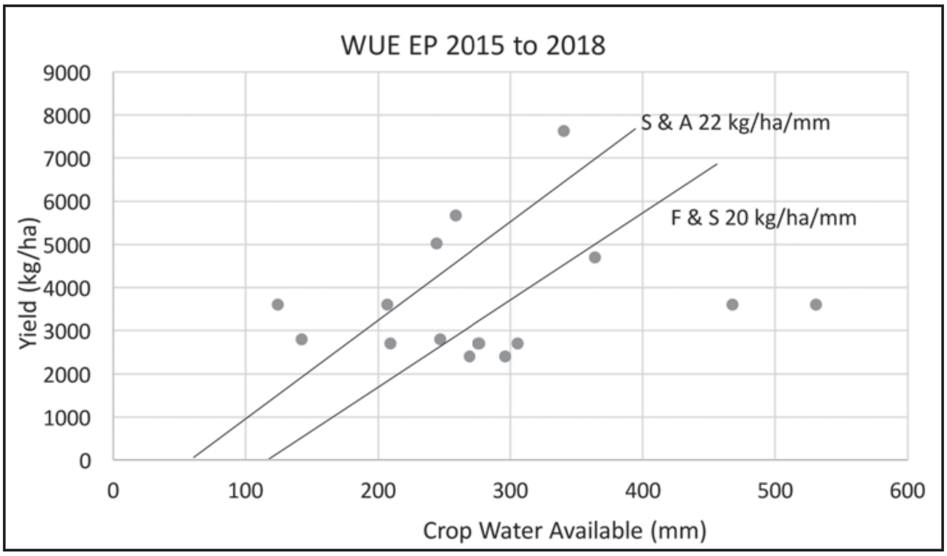

Figure 3 NPS – EP wheat yields (Ya) plotted against available water (2015 to 2018). F & S refers to French and Schultz (1984); and S & A refers to Sadras and Angus (2006).

Causes of yield gaps

Abiotic factors

Variability is a feature of farming in Australia and there are several reasons why crop roots cannot access soil water such as soil type (texture) and physical and chemical limitations. Chemical and physical constraints to root development can have a large impact on potential yield.

Interactions between soil type, available soil water and the amount of water extracted by the growing crop are influenced by crop growth and the distribution and amount of rainfall. If these factors are ignored there is limited predictive capability of yield.

High and low temperatures at critical times of crop development can cause devastating yield loss.

Biotic factors

Crop nutrition appropriate to achieving potential yield (Yw) is relatively well understood and in the case of N, with many examples of successful tactical responses to fertilization. But this is not matched for other nutrients such as P and K, and micronutrients such as Zn.

Major infestations of weeds, pests and diseases can cause dramatic yield loss and less serious infestations may cause greater losses than is commonly appreciated and remain unknown without careful paddock monitoring.

The nature of these biotic causes of yield loss vary greatly from site to site, paddock to paddock and within paddocks.

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GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

Which oat varieties performed best for hay production at Kimba in 2018?

Amanda Cook and Ian Richter
SARDI, Minnipa Agricultural Centre

EXTENSION

Location
Kimba - T, K & R Cliff
Rainfall
Av. Annual: 340 mm
Av. GSR: 220 mm
2018 Total: 222 mm
2018 GSR: 160 mm
Paddock History
2017: Wheat
2016: Wheat
2015: Wheat
Soil Type
Red loam
Plot Size
2 m x 12 m x 3 reps

Key messages

- **All oat varieties tested at Kimba in 2018 produced the same dry matter, hay quality and grain yield.**
- **Durack was the earliest maturing variety (for potential hay cutting and grain), so a good choice in very dry seasons.**
- **In a dry season Moby barley performed well for early dry matter production compared to oats, but performed poorly for grain yield.**

Why do the trial?

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

How was it done?

Seed for seven oat varieties and one grazing barley variety were supplied by Balco. The trial was sown with SARDI small plot equipment on 4 May into moist seed bed conditions (wet to 10 cm only) with 60 kg/ha of DAP fertiliser (18:20:0:0). Seeding rates for every variety were targeted to an establishment of 180 plants/m^2.

Due to no weeds being present, no pre-emergent herbicides were applied to the trial site.

Plant establishment was counted on 20 June, with dry matter cuts taken on 12 July, 22 August, 31 August and 18 September. Plant height was measured on 18 September. Dry matter samples, simulating hay production, from 18 September (except Durack, 31 August) were dried for 48 hours at 40°C and sent for feed quality analysis using FeedTest. The trial was harvested on 8 November.

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

Table 1 Establishment and growth of oaten hay varieties at Kimba in 2018

Variety	Plant establishment (plants/m^2)	Dry matter (t/ha)				Average height (cm)	Grain yield (t/ha)
Date	**20 June**	**12 July**	**22 Aug**	**31 Aug**	**18 Sept**	**18 Sept**	**8 Nov**
Brusher	138	0.18	1.3	2.2	6.6	50.8	1.18
Durack	131	0.15	1.3	1.8	4.7	45.0	1.28
Mulgara	103	0.12	1.0	1.7	5.1	46.8	1.08
Swan	111	0.12	1.4	1.9	5.3	54.6	1.15
Wallaroo	131	0.17	1.6	2.0	6.2	54.9	1.16
Wintaroo	110	0.09	1.0	1.8	4.8	48.0	1.08
Yallara	122	0.08	1.3	1.7	4.6	45.6	1.22
Moby barley	110	0.25	1.4	1.8	5.4	56.7	0.77
LSD (P=0.05)	*20*	*0.08*	*ns*	*ns*	*ns*	*8.2*	*0.25*

Table 2 Feed quality of oaten hay varieties at Kimba in 2018

Variety	Sampling date of tops	Dry matter (%)	Moisture (%)	Crude protein (% of dry matter)	Acid detergent fibre (% of dry matter)	Neutral detergent fibre (% of dry matter)	Digestibility (DMD) (% of dry matter)
Brusher	18-Sep	57	43	10	23	44	73
Durack	31-Aug	79	21	13	23	46	74
Moby barley	18-Sep	56	44	11	24	44	76
Mulgara	18-Sep	58	43	10	22	41	76
Swan	18-Sep	63	37	9	23	44	75
Wallaroo	18-Sep	59	41	12	24	49	71
Wintaroo	18-Sep	59	41	11	21	40	79
Yallara	18-Sep	62	37	11	22	43	75

Table 3 Feed quality of oaten hay varieties continued, at Kimba in 2018

Variety	Digestibility (DOMD) (Calculated) (% of dry matter)	Est. metabolisable energy (Calculated) (MJ/kg DM)	Water soluble carbohydrates (% of dry matter)	Fat (% of dry matter)	Ash (% of dry matter)
Brusher	69	11	29	3	5
Durack	69	11	24	3	5
Moby barley	71	11	28	3	6
Mulgara	71	12	33	3	6
Swan	70	11	32	3	5
Wallaroo	67	11	22	3	5
Wintaroo	73	12	33	3	6
Yallara	70	11	30	3	5

What happened?

The 2018 season was dry with below average rainfall for all months except August, when good rains of 71 mm were received. September and October had low rainfall, but the temperatures were mild during grain filling conditions. 2018 was a decile 3-4 growing season rainfall at Kimba.

The germination was patchy after sowing with not all plots fully established by 31 May. Plant establishment was lower than targeted, with the trial having an average of only 120 plants/m^2 (Table 1).

Moby barley produced the highest early dry matter, but there were no differences in dry matter production between any of the varieties during the rest of the growing season (Table 1). Durack matured earlier than the other varieties and the feed quality test for hay cutting was taken three weeks before the other varieties. There were no differences in feed quality or grain yield between the oat varieties in 2018 (Tables 2 and 3).

Oat variety summary

Brusher

Brusher is an early-mid season hay variety developed by SARDI and commercialised by AEXCO. Brusher is a tall line which is three to seven days earlier to head than Wintaroo and this suits it well to low rainfall areas. It has good early vigour, but slightly less than Wintaroo. Brusher has excellent hay yield in low to medium rainfall zones and has consistently had excellent hay quality to match the yield. Brusher is an improvement compared to Wintaroo for hay quality, stem rust, leaf rust, bacterial blight and septoria resistance. It is resistant but moderately intolerant to CCN and stem nematode. When there is a high CCN population in a paddock with favourable seasonal conditions, Brusher will have significantly lower hay yield than tolerant varieties. Brusher is moderately low in grain lignin, with improved hay digestibility. Brusher has proved to be a popular variety in the earlier regions of SA, WA, and VIC. (SARDI Oat Newsletter 2018).

Durack

Durack is a moderately tall variety similar in height to Carrolup and Yallara measuring between 80 and 90 cm. Durack is a short season maturity, mid-tall variety. It is similar in height and yield to Yallara. Durack is the earliest maturing oat variety of any current milling or hay variety. Durack has good lodging and shattering resistance and good early vigour. Grain yield is similar to the tall varieties Carrolup and Yallara across all states and an improvement compared to tall varieties bred for hay. Grain quality for this line is excellent. Hay yield averaged over low, medium, and high rainfall sites is lower than other longer season varieties. Care will need to be taken to cut this very early maturing variety at the correct growth stage. Monitoring the crop will be the key to achieving the highest hay quality (SARDI Oat Newsletter 2018).

Moby forage barley *(Hordeum vulgare)*

Moby was a selection from Dictator (Heritage seeds), which has now been replaced by Dictator2. Moby is an early maturing, 6 row, white seeded awnless barley with excellent winter growth and rapid establishment. Leaf size varies according to environmental conditions and is more comparable with oat varieties than traditional barley types. Moby will tolerate multiple grazings until the production of the first node. Being winter active, Moby offers an extended sowing window compared to forage oats from mid-autumn to mid-winter. Best time of harvesting for silage or hay is milky-dough to dough stage.

Mulgara

Mulgara was released in 2009 and commercialised by AEXCO. It is a tall mid-season variety with excellent early vigour and good straw strength. Hay yield is lower than Wintaroo, but hay quality is better than Wintaroo. Mulgara also retains good hay colour and resists brown leaf tipping. Grain yield is similar to Wintaroo, but Mulgara has slightly better grain quality with the exception of high hull lignin. The seed size of Mulgara is larger than other hay varieties and similar to Swan. Care should be taken to sow this variety at the correct seed density taking into account its seed weight. Mulgara has excellent disease resistance. It is resistant and tolerant to CCN and stem nematode. Compared to Wintaroo, Mulgara has improved leaf rust, bacterial blight, and red leather leaf resistance. (SARDI Oat Newsletter 2018).

Swan

Older Western Australian hay variety released in 1967 by DAFWA. Swan is a tall, medium maturing oat. Swan is not widely accepted by hay exporters as the stem tends to be too thick. It is grown successfully for export, however, in eastern areas. Grain yield is not as high as others although it does have low husk lignin.

Wintaroo

Bred by SARDI, Wintaroo oat was released in 2003. It is suitable for hay, grazing, and a feed oat. A tall, mid-season variety for all rainfall zones. Susceptible to leaf and stem rust. Resistant and moderately tolerant to CCN and MRMS to *P. neglectus* nematodes It remains a very popular mid-season hay variety continuing to deliver excellent hay yield and quality across the major hay producing regions of Australia.

Wallaroo

Bred by SARDI in 1987. Wallaroo is a hay, grazing and feed oat. Tall, mid-season variety for all rainfall zones.

Yallara

Yallara is a medium tall early to mid-season variety similar to Euro for flowering and maturity. Released in WA in 2009, Yallara is a milling line with slightly better grain quality than Euro but not as susceptible to stem rust. It has bright, plump grain suitable for the milling industry and specialised feed end-uses. Seednet is the commercial partner. Yallara is a Euro look alike with improved leaf rust resistance. It is resistant but intolerant to CCN. It is moderately susceptible to BYDV, bacterial blight, and septoria. Yallara is susceptible and intolerant to stem nematode and susceptible to red leather leaf. Yallara has excellent grain quality. It has high hectolitre weight, low screenings, and high groat percent. The grain is plump and bright and could suit niche markets like the horse racing industry in addition to human consumption. Yallara was evaluated for hay production, and hay yield is similar to popular hay varieties with excellent hay quality.

Yallara Fact Sheet based on National Oat Breeding Program results available from Seednet -

http://www.seednet.com.au/documents/Yallara_Factsheet_Aug_2013.pdf (SARDI Oat Newsletter 2018).

What does this mean?

2018 was a tough season at Kimba. Plant establishment was lower than expected with the trial having an average of only 120 plants/m^2, despite aiming for a plant establishment of 180 plants/m^2. Soil conditions were moist at seeding but only to a depth of 10 cm and conditions were dry for the first few months of the season with little growth until mid-August. Adequate soil moisture and mild spring conditions in late August and September resulted in quick plant growth and high dry matter production.

Durack matured earlier than the other varieties and the feed quality testing for hay cutting was taken three weeks before the other varieties. Growers would need to be aware of this and make sure they are organised to cut Durack for hay at a much earlier time than they may be accustomed to with other varieties. There were no differences in feed quality between the varieties at Kimba in a drier season. There were no differences in dry matter production of all varieties during the rest of the growing season, but all varieties performed very well producing high dry matters with the late winter rains and mild spring conditions.

The oat varieties all had the same grain yield, while Moby barley yielded lower than the oats.

In 2018 in dry seasonal conditions, the commonly grown varieties in the region performed similarly for hay production and quality was the same. However, Swan is not widely accepted by hay exporters as the stem tends to be too thick and is very susceptible to stem rust. All oat varieties achieved over 8% protein and estimated metabolisable energy greater than 9 MJ/kg DM, so would meet export quality standards. Other export standards that need to be met include colour, weather damage and weed seeds.

Moby barley produced more early dry matter so may have potential for early grazing opportunities.

Acknowledgements

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

Reference

For further information:

http://pir.sa.gov.au/__data/assets/pdf_file/0018/334332/SARDI_Oat_Newsletter_2018.pdf

BUCKLEBOO FARM IMPROVEMENT GROUP

SARDI
SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE

Producing export hay on upper Eyre Peninsula

Amanda Cook, Fiona Tomney and Buckleboo Farm Improvement Group
SARDI, Minnipa Agricultural Centre

EXTENSION

Key messages

- **Four out of five growers surveyed currently grow export hay after a break crop (pulse or canola) in their rotation.**
- **Export hay provides a grass weed control option for a second season break.**
- **Paddock selection is important, with firm ground, low grass weed numbers, short stubble, no rocks and accessibility for road trains a high priority.**
- **Yallara, a multi-purpose oat variety, is grown by 3 out of 5 export hay growers, with Brusher and Durack also being popular.**

Why do the survey?

Farmers in the Kimba area have been producing oaten hay for export for several years. The industry has been expanding, with dedicated storage facilities established in recent years on the outskirts of Kimba. To maximise production and quality, the Buckleboo Farm Improvement Group (BFIG) wanted to identify the best fit of oaten hay in the rotation and other issues, through case studies of farmers currently growing export oaten hay in their farming systems.

How was it done?

A survey was sent to seven export hay growers in the Kimba and Buckleboo area and five were returned. The information in the case study surveys were compiled into this article.

What happened?

Farm size in the survey group ranged from 4,500 ha to 7,500 ha. The soil types ranged from heavy red clay loams to sand over clay and grey calcareous sands. The annual rainfall ranged from 290 to 340 mm, with a range of 200 to 220 mm growing season rainfall.

Export hay production ranged from 150-300 ha or 3 to 6 % of the farming area, with one grower planning to expand production in 2019 to 7.5% of the farm area. The growers surveyed have been producing export hay for between 3-5 years.

The growers surveyed intend to grow a portion of export hay each season, with one grazing at least a portion of the area sown to hay in two out of three seasons. Hay production has averaged around 3.5 t/ha. 2016 was a good year, producing around 4 t/ha, although the wet September caused quality downgrades. One grower stated 2017 was a drought, and half the hay crop was not cut, with the remainder yielding about 1.5 t/ha, and 2018 was a drought with yields of 1.5-2 t/ha.

Current crops grown within the rotations were cereals (wheat, barley and oaten hay), canola, legumes (peas, vetch, lentils and lupins on sand) and medic pasture. Three of the farms have livestock enterprises, with one recently going back into livestock and the other sometimes agisting livestock.

Three of the growers are using the multi-purpose oat variety Yallara. One is growing the variety Brusher as the yields have been very good. Another is growing Durack as it is very similar to Yallara but two weeks earlier in flowering, so therefore it can be cut earlier to get better grass weed seed control before maturity. Most growers use the same fertiliser as in their whole cropping program; between 50-70 kg/ha DAP, Croplift12 at 70 kg/ha (containing sulphur) or 50 kg/ha DAP plus 30 kg/ha urea (post cereal).

Growers with livestock believe the oaten hay enterprise compliments their farming system, as failed hay crops or off-spec hay can be utilised by livestock, and early grazing paddocks are available before harvest. Livestock in the system allows a low risk, profitable legume crop to be grown in the rotation. One grower commented that hay is currently the highest gross margin crop so it can be grown on the best prepared paddocks, immediately after a vetch or medic. These paddocks are also the cleanest, and weed free hay is preferred to achieve premium market quality. Hay also gives a second year of grass weed control after the legume, which is helping to reduce grass weed numbers.

Some growers are still working on a best fit for hay within the rotation, with most growing the hay crop after a break crop. One grower is mainly growing hay on canola stubble, but extra care needs to be taken to ensure that canola residue does not enter the bales. Hay should be grown before grass pressures become too high, and is grown where there is good barley grass and brome grass control, however ryegrass may continue to be an issue.

Another grower grows hay after a legume to get as much growth as possible and a second year of grass control. Another grows oaten hay after two wheat crops, with the hay followed by a pea crop. Hay is a very handy tool in reducing ryegrass numbers, and also to ensure income in all years, as crops grow bulk most years, but this does not always convert to grain yield due to frost or dry springs.

Only one grower is growing oaten hay before a legume, following a wheat or barley phase, providing that low barley grass numbers will allow this. Barley grass is the biggest limitation to where hay can be grown, and the hay paddock will be shifted through the rotation planning process to find areas best suited in terms of grass numbers.

Paddock selection

Paddock selection and preparation for export hay is important, with firm ground if possible, low grass weed numbers, the previous stubble harvested as short as possible to minimise stubble getting into the hay; and all rocks (and animal carcasses) picked or crushed prior to planting. Narrow windrow burning reduces grass and stubble so as not to contaminate the hay. Accessibility is also important as road trains need to access the paddocks.

One grower selects a paddock needing a two year break for ryegrass weed control. Using wider row spacing of 30 cm (12”) the grower double sows the hay crop, so that the hay can be held up and sat off the ground once it has been cut.

Another grower plants into legume residue, so there is no need to chain the paddock or harvest low, as the flat steel roller takes care of any remaining cereal or legume residue that may contaminate the new hay. He had trialled hay on the heavier soil types but the yields were generally lower, and even more so in a low growing season rainfall year. Because of the costs/ha in the hay operation, sowing on better soils where the yield is higher results in a lower cost/tonne.

Weed control

Barley grass is the number one weed in export hay production. It is not an option to grow export hay on a paddock that has moderate to high numbers of barley grass as there are no control options for barley grass in oats.

Medic control can also be difficult as Lontrel is not permitted on hay and dicamba can have a large effect on crop biomass. There are very few pre-emergent chemicals available for oats, so good grass weed control prior to growing oaten hay is essential. Broadleaved weeds can also be an issue, so it is important to ensure that weed pressure is low. Many growers have used Amine + Dicamba mixes to control broadleaved weeds.

Weedmaster DST can be used to dessicate the oats and grasses before the cutters come in. It is the preferred weed control option. Metolachlor pre-emergent is also used for some in crop grass weed suppression. At hay cutting, the cutters sever most of the barley grass heads, and if the cut hay gets baled in a timely fashion, the grower had very good results for barley grass weed seed set spraying the paddock immediately after it is stacked.

The nature of hay cutting means at times there is limited notice prior to cutting, and therefore it is hard to spray the area then wait the full two day withholding period prior to cutting. Additionally, if the baling is extremely delayed, then pre-sprayed hay has been seen to go black up to a week earlier than hay that has not been sprayed prior to cutting. It is a trade-off between the timing risk, the baling risk and the risk of missing the weed control opportunity, which is the most important factor because this often affects future rotations.

Hay cutting

Most growers use contractors to cut and bale with the costs being cutting at $50/ha (PTO disc cutters and macerator), raking at $6-7/ha and baling around $30/bale for a high density 700-850 kg bale.

Tele handler hire for stacking and loading is about $110/hr, hay stacker contracted for $150/hr and freight ranges from $14-18/tonne into the Kimba shed, depending on location. Once it is in the Kimba hay shed the hay belongs to the hay exporter as long as the hay quality tests are passed, and the price takes storage into account. It has been suggested by one grower that if the farmer stores the hay on farm for an exporter, they should be paid $20/t.

The export hay is contracted and cores of a representative sample of the paddock is taken whilst baling is occurring, before stacking and transporting. The results of testing determines the final pay grade.

Hay quality

Hay quality was downgraded in 2016 due to significant rain events following cutting, resulting in the hay being the lowest export category 6A. Despite meeting adequate feed quality, it did not meet export colour requirements, and as there was an oversupply of hay at the time, the hay was near worthless ($80/t). Storage was an issue as it needed to come out of the Kimba shed ready for the following season, so it had to be sold immediately. In some seasons the high yields and subsequent volume of hay cut can also lead to storage issues.

One grower stated the dry springs in 2017 and 2018 resulted in good quality hay. In 2017 we had perfect conditions and the hay was baled in a timely manner, and easily met the required specifications. In 2018 the baling was delayed, and possibly the quality wasn't as good as 2017, however it still met specs and received good prices, although during this period far better returns were achievable if it was sold on the domestic market rather than the export market.

If hay does not make export quality there have been opportunities, particularly in the last two seasons, to sell the hay into the domestic market, often at a premium to the contracted export price. In 2016 it was difficult to move the hay that had been downgraded due to the large volume of poor quality hay on the market, but the 2017 drought meant demand quickly developed. Some of the hay was also utilised on farms that have livestock.

The timing of hay operations generally fits well into the seasonal timetable for the growers surveyed, except that waiting for contractors is an issue. One grower has clashes between hay operations and shearing, and others find it can run into the harvest period which is very difficult to manage logistically, and results in competition for trucks between carting hay and grain.

Farmer conclusions

Growers stated that export hay is a great tool to combat grass weeds, especially ryegrass, in the rotation and for achieving a two year grass weed break. It is also a strong performer in seasons with an early start and good winter rainfall to enable maximum biomass, but is also a strong performer given tough spring conditions like frosts, low rainfall or high temperatures.

Two growers commented that the operational costs with hay cutting are expensive and they may look to purchase their own hay equipment, however scale is needed to justify owning the hay equipment. There is also the issue of timing and other farm operations such as shearing. If the long term gross margins are satisfactory, then increasing the area to 250-500 ha/year is possible. There may also be merit in building hay storage sheds on farm and exporting direct from the farm as the freight rate is significant. The parameters around which hay is classified seem very fluid as well as the pricing on forward contracting. For some of these growers, the jury is still out on the future of export hay in their system.

Another grower was concerned about the removal of nutrients from the paddocks. This needs to be quantified to show what nutrition is actually removed and the financial implications over the short and long term.

Overall gross margins have been very good. One grower said that 2016 was their first year of a three year trial in which they had done everything at full contract pricing to make sure that the enterprise stacked up in terms of business profitability and they are looking to expand the area that they use to grow export hay.

As part of this work an economic analysis of hay production at Kimba will also be undertaken for the BFIG farmers.

Acknowledgements

Thanks to the farmers who answered the survey and BFIG for the opportunity to do the work and publish it for farmers on the upper EP.

EPARF
Eyre Peninsula Agricultural Research Foundation Inc.

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Mixed cover crops for sustainable farming

INFO

Mark Stanley
Ag Excellence Alliance

Key messages

- **Crop intensive farming systems are running down soil carbon levels.**
- **Mixed species cover cropping offers a new approach to address the issue.**
- **Farmers lack the basic local knowledge to make informed decisions on incorporating cover crops into their farming systems.**

About the project

Crop intensive farming systems are running down soil carbon levels, requiring increased inputs to maintain or increase yield without necessarily improving profitability. Mixed species cover cropping offers a new approach 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 at the same time but often outside the main growing season to build fertile and resilient soils.

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, they lack the basic local knowledge to make informed decisions.

In this project, a consortium made up of the Ag Excellence Alliance, SANTFA, CSIRO and the Department of Environment and Water will support grower groups to demonstrate the establishment and management of mixed species cover crops across a range of environments in south eastern Australia. The impacts of cover cropping on soil health, nutrient cycling, organic carbon, soil moisture and invertebrate populations will be measured; plant species will be screened for their suitability to be included in cover crop mixes; and the optimum timing and methods to terminate cover crops will be determined.

The project has three components:

1. ***Farm demonstration sites***
   Cover cropping will be examined on 20 farms across south eastern Australia, including four sites on the Eyre Peninsula. On each farm, a replicated demonstration trial will be established from summer late 2018 (dependent on seasonal conditions) and will be monitored until harvest in summer late 2021. Paddocks will be sown with multiple species cover crop (Treatment 1), and will serve as a demonstration paddock. Replicated areas within in the paddock will have two further treatments: Treatment 2 no soil disturbance, no seed added (i.e. business as usual summer fallow) and Treatment 3 single cover crop species sown.
2. ***Cover crop evaluation field trials***
   Two sets of field trials will be conducted. One will evaluate new and emerging summer and winter active plant species/varieties most suited to different environments across south eastern Australia. The other will evaluate the most effective strategies and timings to terminate a cover crop for achieving the optimum benefits for subsequent crops and soil health.
3. ***Extension and communications***
   Extension activities will include field days to be conducted at each of the demonstration sites over the course of the project, and inclusion of updates on project developments at grower group events. Progress on the project will be communicated on SANTFA Twitter, Facebook and Podcast sites, and a dedicated project web site will be hosted by the CSIRO to house project resources as they are produced.

Acknowledgements

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Australian Government
Government of South Australia
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Farming Systems

Section 5

Section Editor:
Brett Masters
Rural Solutions SA, Port Lincoln

Soils

Trafficking a heavy Minnipa soil does not hurt crop production but beware on deep sands

RESEARCH

Nigel Wilhelm[1], Peter Fisher[2], Chris Bluett[3] and Rebecca Mitchell[2]
[1]SARDI, Minnipa Agricultural Centre; [2]Agriculture Victoria, Bendigo; [3]Australian Controlled Traffic Farming Association

Location:
Minnipa Agricultural Centre, paddock S3
Rainfall
Av. Annual: 325 mm
Av. GSR: 241 mm
2018 Total: 244 mm
2018 GSR: 186 mm
Paddock History
2018: Scepter wheat
2017: Volga vetch
2016: Fathom barley
2015: Scepter wheat
2014: Medic pasture
Soil Type
Calcareous red sandy loam
Plot Size
50 m x 3 m x 4 reps

Key messages

- **Over the last four years, trafficking at any level has not decreased crop production on a heavy Minnipa soil so moving to controlled traffic farming on this soil type is not likely to increase crop production due to less trafficking in the paddock.**
- **Trafficking on a deep sand (trial at Loxton in the northern mallee) has substantially reduced crop production for at least 4 years so CTF may have additional benefits on deep sands, especially if ripping is used to correct existing compaction.**
- **Similar to many previous trials, ripping has not benefited production on the heavy Minnipa soil.**

Why do the trial?

Adoption of Controlled Traffic Farming (CTF) in the low rainfall zone (LRZ) of the Southern Region is very low. The GRDC-funded project 'Application of controlled traffic in the low rainfall zone' has been evaluating whether or not this scepticism is justified. To help LRZ growers answer the questions and uncertainties they face when thinking about CTF adoption, the project is conducting research on five sites (R sites) across dominant soil types and agro-ecological zones in the Southern Region LRZ. These trials focus on the impact of trafficking (by heavy vehicles) on crop production and soil condition as well as monitoring how quickly LRZ soils will "self-repair" if heavy trafficking is stopped. Issues of implementing CTF and managing permanent wheel tracks are being addressed in other components of the project.

This article summarises the first four years of crop performance after trafficking was imposed on a red calcareous sandy loam at Minnipa Agricultural Centre (a detailed summary of 2015, 2016 and 2017 results can be found in the 2015, 2016 and 2017 Eyre Peninsula Farming Systems Summaries, respectively). Three other trials similar in design and monitoring have also been implemented across the LRZ - on a deep sand at Loxton (SA), a brown loam near Swan Hill (Vic) and on a deep red earth at Lake Cargelligo (NSW). All these trials except Swan Hill (land ownership has changed) have been maintained for at least the five years of the project. A new trial was set up in 2018 to investigate the role of CTF on a deep sand which has been ameliorated with deep ripping.

How was it done?

The original research trials were designed and implemented to be the same at all four sites. Each trial consists of 5 treatments replicated 4 times:

1. Control (no heavy vehicle trafficking).
2. One pass of a 20 tonne vehicle prior to seeding when soil was dry.
3. One pass of a 20 tonne vehicle prior to seeding when soil was wet.
4. Three passes of a 20 tonne vehicle prior to seeding when soil was wet.
5. Deep ripping (to loosen any historical trafficking).

These passes were implemented in 2015 with 50% overlap of the load bearing wheels to ensure even coverage and were not re-imposed in subsequent years.

The trafficking treatments simulate the effect of compaction caused by trafficking of heavy vehicles, with three passes when the soil is moist as an extreme (soil is always softer when wet so compacts more for the same vehicle weight). A deep ripping treatment was included because we cannot be sure if there is still compaction from previous trafficking in our control areas and the ripping was designed to disrupt any of this historical compaction. Trials were located on farms with soils typical for their district and where wheel track patterns for the previous five years (at least) were the same and were identifiable. The trials are being seeded and managed with the farmers' equipment.

At Minnipa, trafficking treatments were imposed in April 2015, the wet passes and deep ripping following 30 mm of rainfall. Scepter wheat was grown in 2015, Fathom barley in 2016 and Volga vetch in 2017. In 2018, Scepter wheat was sown @ 75 kg/ha on 25 May with 70 kg/ha of Granulock Z (11:22 1% Zn).

Crop performance was monitored at establishment, biomass at several times during the season and at maturity (grain yield, quality and biomass). Grain harvest was conducted by hand to avoid trafficking from a header on treated plots.

What happened?

Emergence of wheat was slow in 2018 due to later seeding and drying conditions in the seed bed, but reasonable plant numbers were finally achieved in all treatments (Table 1). Unlike previous years, seeding depth was consistent across all treatments in 2018. Crop growth was very poor until August when more substantial rains really lifted crop growth and grain yields were surprisingly good (Table 1). Crop performance was similar for all treatments throughout the season.

Vetch hay production in 2017 after trafficking of any type was similar to the control although production after both wet trafficking treatments was better than after ripping (Table 1). Grain yields were very poor (average of 350 kg/ha for the trial) and similar for all treatments.

Trafficking on wet soil substantially increased the yield of barley in 2016. Ripping and trafficking on dry soil resulted in grain yields similar to the control.

Grain yields of wheat in 2015 were similar for all treatments, except for ripping which was lower (mostly due to low plant numbers and substantially deeper seeding).

Soils

Table 1 Performance of Scepter wheat in 2018 after trafficking and ripping at Minnipa in 2015

	Establishment (plants/m^2)	Depth of seeding (mm)	Dry weight of shoots at tillering (t/ha)	Flowering biomass (t/ha)	Grain yield (t/ha)
Control	135	35	0.18	3.64	2.32
Single trafficking on dry soil	130	31	0.22	3.96	2.38
Single trafficking on wet soil	111	36	0.15	3.34	2.13
Multi trafficking on wet soil	118	39	0.14	3.09	2.19
Ripping	140	31	0.21	3.39	2.14
LSD (P=0.05)	*ns*	*ns*	*ns*	*ns*	*ns*

What does this mean?

We have imposed three increasing levels of trafficking in all four research sites to investigate the sensitivity of crop production to compaction caused by heavy vehicles in typical LRZ situations. The ripping treatment is an attempt to remove any compaction already existing in our control areas due to historical traffic.

On this heavy Minnipa soil after four crops, trafficking has not caused any production losses, if anything there has been an increase in production. This suggests that anybody moving into CTF on this type of soil will not see any improvements in crop productivity in the short term. We have no information about longer term effects. Loosening up the soil by ripping has not resulted in any production increases either, a result which has been seen many times with ripping on this type of soil.

On deep sands however, where responses to deep ripping are common and often substantial, CTF is a complementary strategy which should not only increase and prolong the benefits from deep ripping operations but also avoid trafficking issues with deeply loosened and fragile sands. At our Loxton site, crop yields have been severely depressed every year by repeated trafficking on damp soil. The yield decreases have often been more than 50% and in 2018, barley yields were also depressed by a single trafficking pass on damp soil in 2015.

Of the other three trials, the two on lighter soils (typical of mallee environments) are also showing that little crop production is being lost with all but the most extreme trafficking treatment. However, on the heavy and deep red soil of southern NSW, crop production was severely depressed by any trafficking in the first year but in the very wet year of 2016, production was similar across all treatments. Freshly imposed multiple trafficking in 2018 also depressed wheat yields, but the 2015 treatments had no impact. These results suggest that the effect of trafficking on crop production on this deep red soil can be severe but short lived.

The benefits of improved traction and better fuel efficiency from driving on permanent traffic lanes are there, but again with smaller gains than in other zones because trafficability is less of an issue in the LRZ and the traffic lanes are likely to be seeded, reducing the benefits of permanent wheel tracks.

The often poor performance of crops after multiple heavy vehicle passes on wet sandy soils indicates that while most of our cropping paddocks are probably already quite compacted, the current generation of very heavy machinery has the potential to further increase damage into the future on sandy soils. The catch is that physical interventions with operations such as deep ripping will be necessary to fully realise the benefits of non-compacted sands.

Acknowledgements

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AGRICULTURE VICTORIA

ACTFA Australian Controlled Traffic Farming Association Inc

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GRDC GRAINS RESEARCH & DEVELOPMENT CORPORATION

Ameliorating a deep repellent sand at Murlong increased wheat performance substantially in 2018

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

[1]Rural Solutions SA, Port Lincoln and Adelaide; [2]SARDI, Waite

Location:
Murlong - Mark Siviour

Rainfall
Av. Annual: 332 mm
Av. GSR: 249 mm
2018 Total: 220 mm
2018 GSR: 167 mm

Yield
Water-limited yield potential: 3.6 t/ha (W)
Long term average actual yield: 1.6 t/ha

Paddock History
2017: Scope barley
2016: Pasture
2015: Mace wheat

Soil Type
Deep sand over clay
Soil profile: 0-5 cm water repellent, light brown/grey sand; 5-15 cm grey sand; 15-40 cm white sand; 40-70 cm yellow sand; 70-80 cm yellow light clay

Soil Test
See article 'Improving crop establishment in a non-wetting sand with soil wetting agents'

Plot Size
25 m x 2.3 m x 4 reps

Trial Design
Experimental: randomised complete block

Yield Limiting Factors
Severe water repellence, drift, low rainfall in autumn, early winter and spring

Key messages

- **Water repellence resulted in low plant numbers on the control plots. Ripping with inclusion plates substantially increased crop establishment which were further increased by spading, with the greatest plant density on spaded plots with lucerne pellets added.**
- **Physical intervention increased wheat yields on a deep water repellent sand. The controls using best practice agronomy on unmodified sands, yielded 0.5 t/ha. Ripping with inclusion plates to 30 cm doubled yield, ripping deeper to 41 cm delivered an additional 0.4 t/ha and spading to 30 cm delivered a further yield increase of 0.5 t/ha, or 1.4 t/ha better than the control.**
- **The addition of 5 t/ha of lucerne pellets or high rates of fertiliser increased wheat yields when incorporated by ripping to 41 cm or spading, and delivered the highest yields of 3.1 t/ha.**

Why do the trial?

Previous research has shown that physical intervention on compacted sandy soils can deliver significant yield increases. However, deep incorporation can be expensive and can increase erosion risk. The development of inclusion plates attached to deep ripping tynes allows for deep mixing of surface applied nutrients at a relatively low cost and with less risk of soil erosion than spading or mouldboard ploughs. This trial aimed to:

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

How was it done?

The site is located on a broad sand dune running WNW-ESE at Murlong on eastern Eyre Peninsula. The trial comprises 11 treatments x 4 replicates and compares an unmodified control to spading or ripping with inclusion plates (IP) to two depths (30 cm and 41 cm) with and without the addition of high rates of mineral fertiliser or lucerne pellets (Table 1).

Measurements taken include pre-seeding soil water and mineral nitrogen, crop establishment, biomass at flowering, "tea bag" index, yield, yield components and grain quality, and post-harvest soil water.

What happened?

Severe water repellence resulted in low plant numbers where there was no soil disturbance. Deep ripping improved crop establishment with spading delivering the best results. The addition of nutrients and, in particular lucerne pellets, further improved crop establishment (Figure 1).

Strong wind events resulted in some drift and infill of seeding rows. Although this appeared to have the greatest visual impact on spaded treatments it was not reflected in plant numbers or plant vigour.

Table 1 Trial establishment and cropping details at Murlong 2018

19 April	OM and nutrient package	• OM: Lucerne pellets @ 5 t/ha • Nutrient Package: nutrients applied to match lucerne N 167, P 14, K 105, S 12, Cu 0.03, Zn 17, Mn 0.18 kg/ha. NPKS applied as granular and trace elements as fluids Treatments applied evenly across the surface on spaded plots or in bands to correspond with ripper tyne spacings, immediately prior to spading and ripping.
	Soil treatments	• Spading to 30 cm @ 5 km/hr • Ripped: 4 tynes @ 64 cm spacings with inclusion plates, positioned 10 cm below the soil surface @ 5 km/hr • Shallow ripped (corresponding to the depth of spading) to 30 cm with 20 cm inclusion plates • Deep ripped to 41 cm with 30 cm inclusion plates
20 June	Sowing	60 kg/ha Razor CL at 25.4 cm row spacing + DAP @ 60 kg/ha (all treatments) + banded Urea @ 81 kg/ha (on non OM and nutrient package treatments only). RainDrover wetter with the seed @ 2 L/ha.
	Herbicide	Triflurex @ 1.5 L/ha, Roundup Weedmaster (540 g ai) @ 2.5 L/ha, Nail @ 80 ml/ha, LI700 @ 300 ml/ha
12 August		Agrityne 750 @ 1.5 L/ha, Zn 2 L, Cu @ 1 L and Mn @ 3 L/ha
3 December	Harvest	

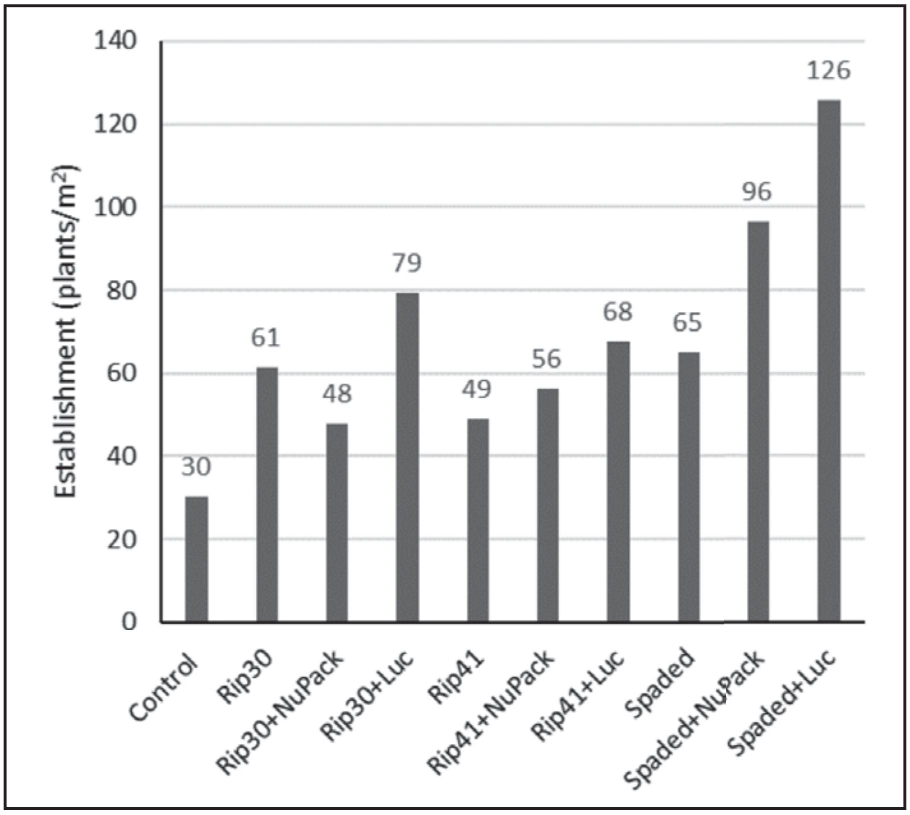


Figure 1 Plant numbers at Murlong, July 2018 (LSD, 5%=24)

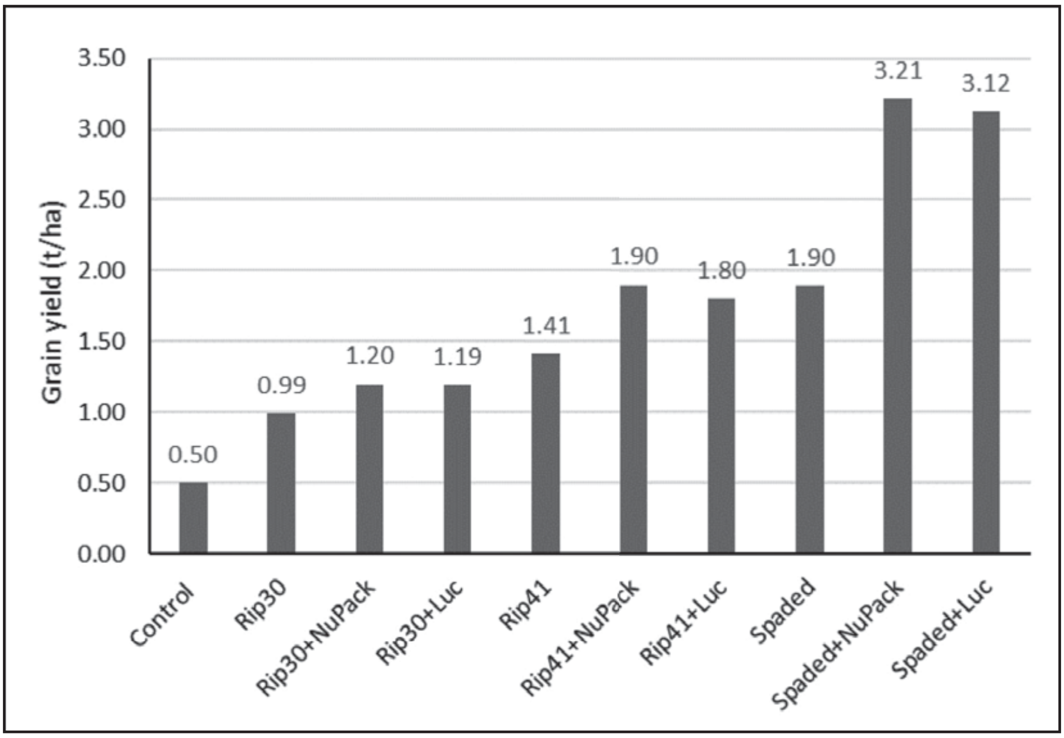


Figure 2 Grain yield (t/ha) at Murlong 2018 (LSD, 5%=0.24)

Plant growth on the spaded and ripped treatments was visibly stronger than the control. The nutrient and lucerne treatments delivered additional growth with the best treatment (spaded + luc) delivering six times the biomass of the controls at flowering (data not shown here).

Differences in crop establishment and biomass were reflected in grain yield with the Rip41 treatments outperforming the Rip30 treatments. Spading yielded more than either ripping treatment with the addition of nutrients or lucerne further increasing yield (Figure 2).

What does this mean?

- Spading and ripping with inclusion plates delivered large economic responses to wheat in 2018.
- The greater levels of soil mixing and physical intervention from spading delivered better results than ripping with inclusion plates in the first year of the trial.
- Consistent with research conducted elsewhere, deeper ripping has delivered better results than shallow ripping.
- The incorporation of organic matter or fertiliser by ripping or spading increased yields above those achieved with soil disturbance alone.
- To confirm the full economic value of these practices, continued monitoring of this site in 2019 and 2020 will be undertaken.

Acknowledgements

Farmer Co-operator: Mark Siviour and family. Spader: University of South Australia, Roger Groocock. This work is funded under the GRDC project "Increasing production on Sandy Soils in low and medium rainfall areas of the Southern region" (CSP00203); a collaboration between the CSIRO, the University of South Australia, the SA state government through Primary Industries and Regions SA, Mallee Sustainable Farming Inc. and AgGrow Agronomy.

Improving crop establishment in a non-wetting sand with soil wetting agents

Jack Desbiolles[1], Lynne Macdonald[2], Nigel Wilhelm[3], Mel Fraser[4], David Davenport[4]

[1]Agricultural Machinery R&D Centre, University of SA; [2]CSIRO, Agriculture and Food; [3]SARDI, Minnipa Agricultural Centre; [4]PIRSA, Rural Solutions SA

RESEARCH

Location:
Murlong - Mark Siviour
Rainfall
Av. Annual: 332 mm
Av. GSR: 249 mm
2018 Total: 220 mm
2018 GSR: 167 mm
Yield
Potential: 1.49 t/ha (W)
Actual yield: 1.02 t/ha
Paddock History
2017: Barley
2016: Pasture
2015: Barley
Soil Type
Grey, non-wetting deep sand
Soil Test
$pH_{(water)}$: 7.7
Predicta B (risk level pre-sowing): Take-All (Low/medium), Yellow leaf spot (medium), Rhizoctonia solani (medium), Common root rot (medium).
Water repellency profile: Water Drop Penetration Test (de-ionised water): Severe to extreme water repellency (0-10 cm), 'strong' (10-15 cm), 'slight' (15-20 cm), and non-repellent below 20 cm depth.
NB: class references: Leelamanie *et al* (2008)
MED test: 2.8 (0-5 cm) and 3.0 (5-10 cm)
Plot Size
25 m x 1.68 m (6 rows)
Trial Design
Randomised complete block design, 4 replications
Yield Limiting Factors
Extreme water repellence at the site, delayed sowing (21-23 June) due to late opening rainfall, poor rainfall over following 5 weeks (27 mm over 11 daily rainfall events, biggest event on 21 July was 6.4 mm).

Key messages

- **The impact of 13 different soil wetter treatments ranged from none to more than a doubling of wheat establishment.**
- **Grain yield benefits ranged from zero to 21% (or 0.22 t/ha).**
- **While higher grain yield generally correlated with better crop establishment, some treatments with low crop establishment were able to generate substantial yield responses, suggesting specific chemistries may promote later season effects.**
- **Combinations of some soil wetters interacted positively to maximize grain yield response.**

Why do the trial?

Previous work on Eyre Peninsula at Wharminda (Wilhelm, unpublished data) investigated the impact of two soil wetter chemistries applied within the seed row on crop establishment and grain yield. This work showed that both wetting agents increased cereal crop establishment in most trials over three years, but this rarely translated into grain yield benefits (1 trial in 6, with 1 wetting agent). This experience contrasts with extensive work in WA (e.g. Davies, 2018) suggesting soil moisture conditions at seeding have a major influence of crop response to soil wetters. Using soil wetters while dry seeding in repellent sands achieved average grain yield increases of 11% (10 trials), and 18% when dry seeding in repellent forest gravels (6 trials). These grain yield responses to soil wetters significantly reduced when seeding occurred after a reasonable rainfall, dropping to non-significant (7 trials) and to 5% average yield benefit (3 trials), respectively.

This 2018 trial was established at Murlong as part of the GRDC funded and CSIRO-led 'Sandy Soils Project' and is investigating water repellence mitigation options at seeding. The trial aims to identify the driving chemistries (surfactants vs humectants) and application techniques (furrow surface, vs seed zone) that are better able to lift crop responses under local sowing conditions. This article reports on the Year 1 data, with more work being planned for the 2019-20 seasons.

How was it done?

Trial details:

- Seeding system: knife point double shoot combined with twin seeding discs with press wheels (row spacing = 0.28 m), sowing speed: 5 km/h, sowing date: 21-23 June 2018
- Crop: Wheat CL Razor wheat sown at 63.2 kg/ha targeting 155 plants/m^2 at 80% establishment, seed treatment: Rancona C + Imidacloprid 600. Targeted seeding depth: 30-35 ±5 mm
- Fertiliser: 20 N+4.3 S as 2:1 Urea:SoA mix at 54 kg/ha deep banded at full furrow depth (100 mm), and 6 N+11P+2S+0.5Zn as Granulock Z at 50 kg/ha shallow banded 20 mm below seeding depth

- Liquids: Fungicides applied at furrow depth: Uniform 400 ml/ha and Intake HiLoad Gold 250 ml/ha applied in 80 L/ha
- Trace elements: Zn @ 2 L, Cu @ 1 L and Mn @ 3 L/ha applied as a foliar spray at late tillering
- Soil wetter treatments: applied in 100 L/ha volume with foam suppressant at 0.05%
- Weed control: Agrityne 750 @ 1.5 L/ha at late tillering
- Harvest date: 3 December 2018

Treatments:

Thirteen treatments were selected to represent a range of costs (i.e. $12-$41/ha), practicalities: i.e. single location (seed zone or furrow surface) vs split application (seed zone + furrow surface), and penetration time pre-tested on Murlong soil samples under laboratory conditions at CSIRO.

This pre-testing quantified a de-ionised water control penetration time of 120 minutes, which was reduced in solutions with the various soil wetters at recommended rates down to 2-3 seconds at best and 82 minutes at worst. This indicated a variable ability of the soil wetter products to act as surfactants (i.e. lowering the surface tension of the solution to drastically improve penetration into the soil). Various modes of action exist within the available surfactant chemistries. Equally important for sands, their ability to act as a 'humectants' (i.e. uniformly spreading out to retain water within a zone of influence) is complementary and forms the basis of the evolution of improved chemistries.

In the trials, the furrow surface applied soil wetters used a Teejet TPU1501 low angle flat fan nozzle behind the press-wheels to produce a 25-30 mm wide band spray, while seed zone applications were obtained with Keeton seed firmers fitted between the twin seeding discs.

The soil wetter chemistries included surfactant only, surfactant/humectant blends, and enriched blends with organics/ nutrients. Split applications included single products applied at 50:50 rate or combined products applied at full rate in their recommended locations. All suppliers were consulted to ascertain the recommended application rates and furrow delivery locations for each product. Table 1 summarises the details of the chemistries, their rate and the furrow application technique used.

These treatments were compared to first/last sown controls, to evaluate the impact of a 43 hour long trial sowing duration.

Measurements:

- Crop establishment at 38 days after sowing (DAS), at 77DAS (not reported here), NDVI (not reported here), grain yield.

What happened?

Selected results are presented below without labelling the chemistries until the full effect of treatments are better understood.

Crop establishment at 38 days after sowing *(Figure 1)*

Crop establishment averaged 24% of seeding rate (48 plants/ m^2) for the two controls indicating very unfavourable conditions at seeding in this severely non-wetting sand. No differences were measured between the two controls.

Soils

Table 1 Soil wetter treatment details for Murlong 2018 trials

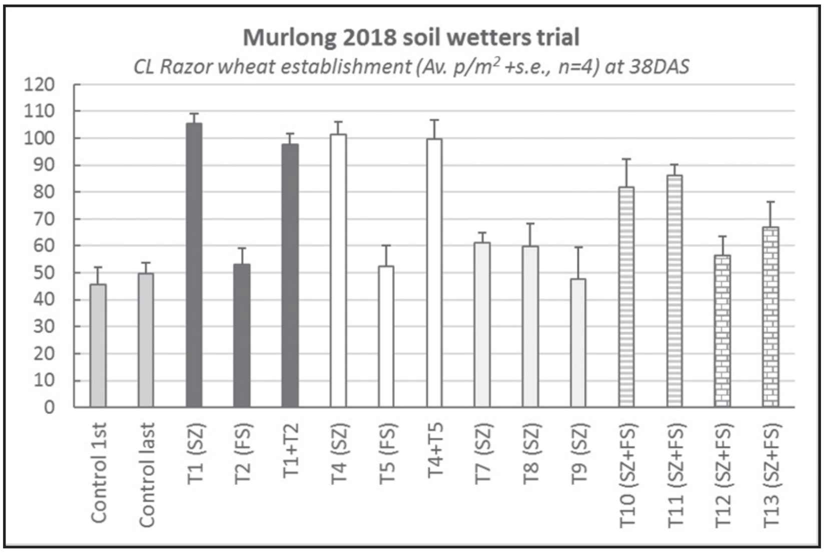
Treatment description	Wetter application details	$/ha
Control: No wetters (Sown first)	n/a	0
Control: No wetters (Sown last)	n/a	0
A: Wilchem RowLoader range *RainDrover*	2 L/ha (SZ)	12
Victorian Chemicals *Soak-n-Wet*	4 L/ha (FS)	14
ICL Specialty Fertilisers *H2Pro TriSmart*	*H2Pro TriSmart* 2 L/ha (FS)	15
B: ICL Specialty Fertilisers *H2Flo*	*H2Flo* 2 L/ha (FS)	16
SST Australia *SeedWet*	2 L/ha (FS)	17
C: SST Australia *Aquaforce*	*Aquaforce* 2.5 L/ha (FS)	20
BASF *Divine-Agri*	1 L/ha (FS) + 1 L/ha (SZ)	20
D: SACOA *SE14*	*SE14* 3 L/ha (SZ)	21
Chemsol GLE *Precision Wetter* and *Nutri-Wet* variant	2 L/ha (FS) + Nutri-Wet 2 L/ha (SZ)	21
SST Australia *Bi-Agra Band*	1.5 L/ha (FS) + 1.5 L/ha (SZ)	22
BioCentral Lab **Aquaboost AG30** Combo	AG30NWS 2 L/ha (FS) + AG30FB 2 L/ha (SZ)	24
= B + A	*H2Flo* 2 L/ha (FS) + Wilchem *RainDrover* 2 L/ha (SZ)	28
= C + D	*Aquaforce* 2.5 L/ha (FS) + SE14 3 L/ha (SZ)	41

Key: SZ=Seed Zone; FS=Furrow Surface

Soil wetters lifted crop establishment by 25 plants/m² on average, with a response range of 0 to 58 plants/m² (a maximum of 122% increase).

Four subgroups of responses were defined, namely:

1. A top level subgroup with four treatments more than doubling plant density, borne out of two humectant chemistries (T1 and T4) applied in the seed zone (NOTE: no improvements were measured when combined with a furrow surface applied surfactant).
2. Two other treatments (T10-T11) achieved an intermediate performance generating 70-80% crop establishment increase, both being applied at 50:50 split rate between furrow surface and seed zone (their relative impacts will need to be unpacked in a future trial).
3. A low response subgroup with three other products generating in the range of 20-40% increase.
4. A no response subgroup with four treatments, which did not produce any significant impact on early plant establishment.



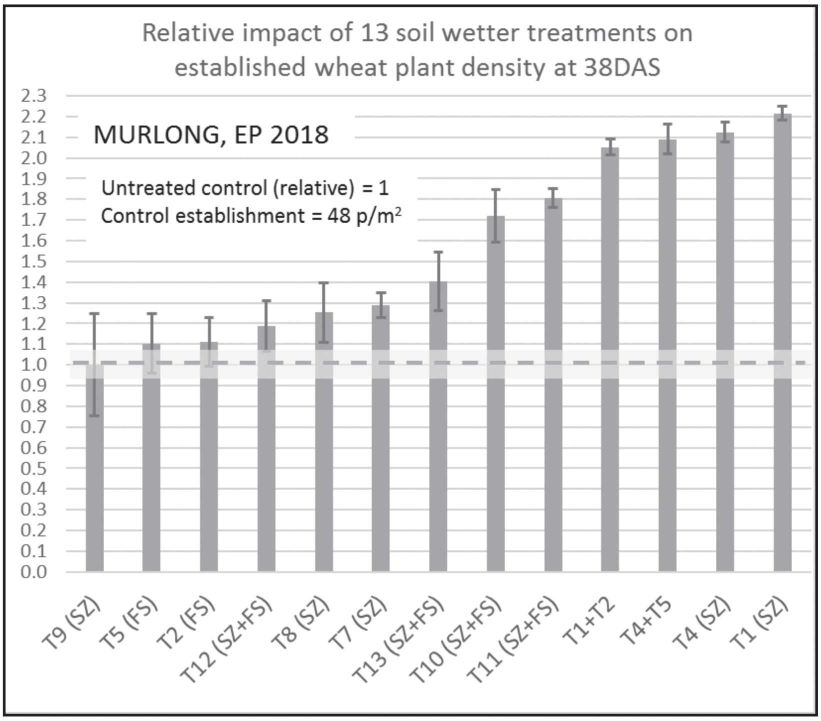


Figure 1 Crop establishment results at 38DAS (TOP: plants/m²; BOTTOM: relative to control)

Note: treatment error bars represent ±1 std error of the mean

Overview of grain yield response *(Figure 2)*

Controls averaged a grain yield of 1.02 t/ha. Treatment grain yield responses ranged from 0 to 21%, a maximum of 0.22 t/ha ($P<0.01$).

There was a significant positive correlation ($r = +0.76$) between grain yield and plant density at 38DAS (Figure 3), whereby the better established treatments tended to achieve higher grain yields. Figure 3 suggests clusters of data points, whereby some high early impact treatments (T1, T4 and T4+T5), which had at least doubled early crop establishment, generated 8-12% grain yield response. In contrast, a similar high early impact treatment (T1+T2 combined) was able to maximise crop yield response to 21.3%, suggesting a later in-season synergy relative to T1 only or T2 only, which yielded significantly less on their own. While T2 alone did not have any effect on crop establishment and no significant impact on yield, only the T1 chemistry drove the early crop response in the combination treatment, and the combined products later synergised to maximise yield gain.

Conversely, an alternative combination of surfactant and humectant products (T4 and T5), compared alone and in combination, did not show a later in-season synergy, suggesting product chemistries have their own signature potential.

Interestingly, intermediate early impact treatments (e.g. in the 40 to 80% crop establishment impact range) could still achieve 10 to 15% grain yield increase. The spread of data in Figure 3 suggests some soil wetters may have the capacity to more effectively impact crop response despite similar impacts on crop establishment. More work is required to validate these observations across contrasting seasons and non-wetting soil types.

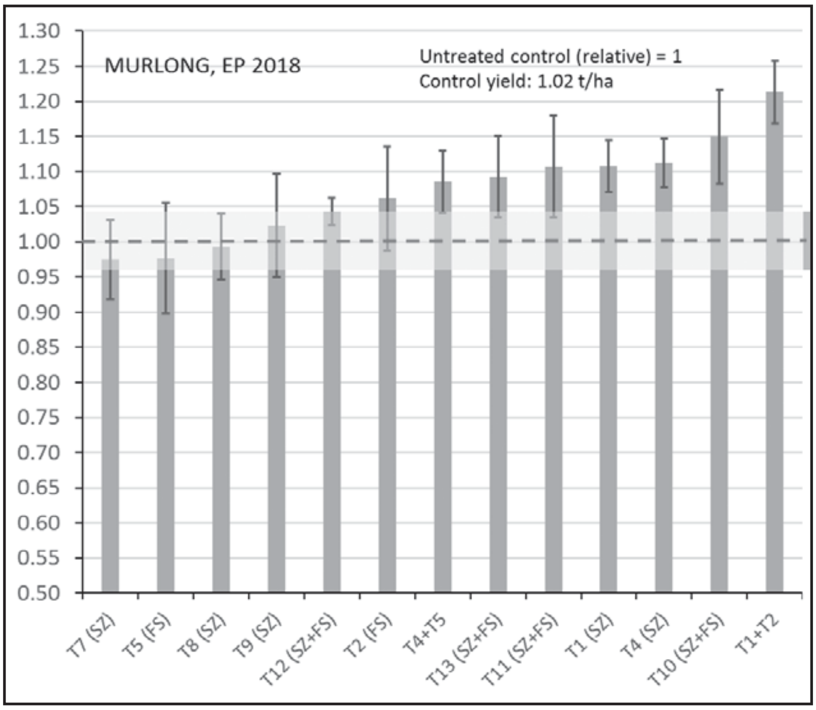


Figure 2 Wheat grain yield overview (relative basis)

NB: dashed line is the relative control ±1 std error of the mean as the shaded zone.

Treatment error bars represent ±1 std error of the mean.

What does this mean?

This first year of trial data show encouraging results on the ability of some soil wetter chemistries to improve seed germination in a highly water repellent sand. Under the seasonal conditions, plant density was a significant factor in generating yield gains at harvest, which correlates well with responses to soil wetters found in WA research using a number of similar new chemistries.

The data also suggest that factors linked to specific chemistries are playing an additional role in-season leading to associated yield gains, and it seems there is a potential to mix product chemistries as a way to generate synergies in responses. More work is being planned over the 2019-20 seasons to help develop recommendations for grain growers. Some validation across different water repellent sands will also be required.

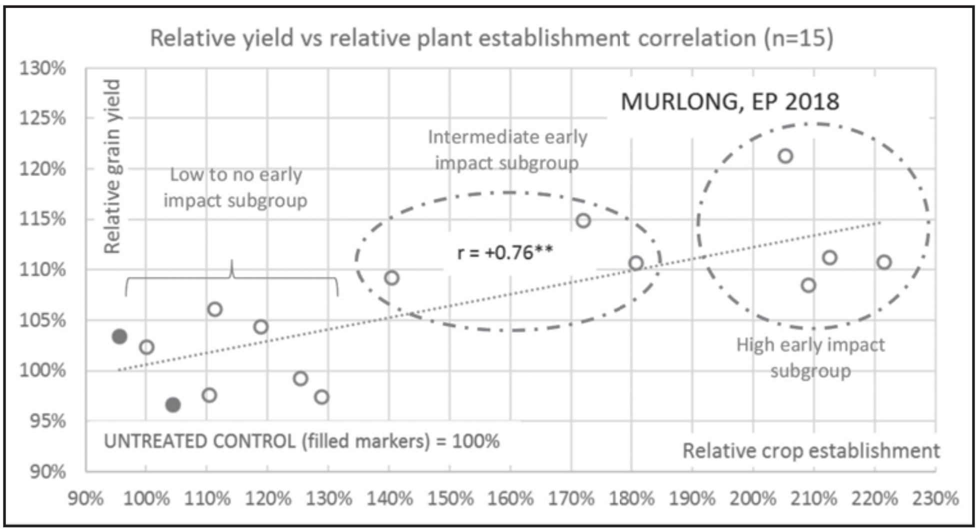


Figure 3 Correlation between grain yield and crop establishment data (relative basis)

Note: relative to a low/no early impact subgroup (left), two treatment clusters may be identified which performed differently at 38DAS but which attained a relatively similar range of grain yield impact (with 1 outlier combination treatment performing best).

Acknowledgements

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SARDI

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GRDC GRAINS RESEARCH & DEVELOPMENT CORPORATION

University of South Australia

"Ripping" results from Mallee Sandy Soils trials

RESEARCH

Michael Moodie[1], Lynne Macdonald[2], Ray Correll[3], Mick Brady[1], Todd McDonald[1], Chris Davies[1], Jack Desbiolles[3] and Therese McBeath[2]

[1]Frontier Farming Systems, Mildura; [2]CSIRO, Waite Campus; [3]Rho Environmetrics, [4]University South Australia, Mawson Lakes

Key messages

- **Deep ripping resulted in a significant increase in yield at the Ouyen site for a second consecutive season.**
- **At Ouyen, annual ripping treatments resulted in a yield increase of 0.6 t/ha while treatments which were only ripped in 2017 still yielded 0.4 t/ha better than the control.**
- **At Carwarp mechanical disturbance to 30 cm by spading or deep ripping provided a yield boost of 0.5 t/ha, however deeper ripping to 60 cm did not provide any significant yield benefits.**
- **Second year yield increases following spading of organic amendments in 2017 were evident for chicken litter (+0.5 t/ha) but not for home grown hay sources (vetch, oaten) at Ouyen in 2018.**
- **Over the two seasons, spaded chicken litter has doubled the yield achieved compared to the non-spaded controls.**

Why do the trials?

Sub-optimal productivity is commonly reported for the deep sands that make up 20 to 30% of the cropping soils in the low rainfall Victorian Mallee region. There is evidence of unused soil water, despite an apparent absence of constraints commonly associated with sandy soils (e.g. non-wetting, soil acidity). Diagnosis studies of local constraints have pointed to low abiotic and biological fertility in the subsoil layers and the physical restriction of rooting depth as the most likely constraints to production on sands in the Victorian Mallee.

To explore this further, four replicated trials were established across two sites; Ouyen (2017-18) and Carwarp (2018). These trials have investigated the interactions between crop water use, physical disturbance (deep-ripping and/or rotary spading), and the incorporation of organic and inorganic amendments. These trials are part of the GRDC project: Increasing production on sandy soils in the low-medium rainfall areas of the southern region. The trials are a collaboration between Frontier Farming Systems and Mallee Sustainable Farming, CSIRO and UniSA.

How was it done?

Two research sites were established in the Victorian Mallee, at Ouyen which commenced in 2017 and at Carwarp which commenced in 2018. The sites have similar soil properties (Table 1), however the Carwarp sand is red in colour while the Ouyen sand is yellow. The annual rainfall at Carwarp is 280 mm per year while the Ouyen receives 25 mm more rainfall per year on average.

At each site two separate trials were established to investigate both mitigation and amelioration strategies to overcome constraints and improve root growth and water extraction from the sub-surface layers. Details for each trial are provided below.

Ouyen

Fertiliser placement trial

This trial compares surface banding of nitrogen (N) and other nutrients (7-8 cm deep) with deeper placement of nutrients, by pre-drilling (20 cm) or deep ripping (30 cm) ahead of seeding (Table 2). Nitrogen (N) was applied at a rate equivalent to 90 kg/ha over the life of the trial, either as urea only or as urea incorporated into a broader nutrient package (P, K, S, Zn, Cu, Mn). Additionally, these nitrogen treatments were applied either as a single application of 90 kg N/ha applied in 2017, or a split application of 30 kg N/ha annually from 2017 to 2019. All treatments also received an additional 20 kg N/ha through a combination of starter DAP and top-dressed ammonium sulphate fertiliser, thus each treatment will receive a total of 150 kg N/ha over three seasons.

Spading organic matter trial (amelioration)

Six different types of organic matter were incorporated to a depth of 30 cm depth in 2017 using a one pass spade and sow operation (Table 3). Each organic amendment was applied at a rate which supplied 2.5 t/ha of carbon, but carbon:nitrogen (C:N) ratio varied. Spaded organic matter treatments were also compared to spading only, spaded urea (supplying equivalent quantity of N as vetch hay) and a non-spaded control.

Table 1 Key soil properties at the Ouyen and Carwarp sites

Depth (cm)	Total Organic Carbon (%)	pH ($CaCl_2$)	Clay (%)	Electrical Conductivity (µ/cm)	Colwell Phosphorus (mg/kg)
Ouyen					
0-10	0.3	6.3	3.8	53.7	18
10-20	0.2	5.1	4.2	20.5	18
20-40	0.1	6.0	4.3	16.1	10
40-60	0.2	7.0	3.8	39.9	-
60-80	0.1	7.3	4.1	35.7	-
80-100	0.1	7.5	4.9	35.2	-
Carwarp					
0-10	0.2	5.7		39.0	17
10-30	-	6.7		31.8	-
30-40	-	7.3		39.3	-
40-60	-	7.6		45.4	-
60-100	-	7.8		47.3	-

Table 2 Key factors in the fertiliser placement trial at Ouyen, incorporating physical disturbance with pre-drilling or deep ripping, nitrogen rate, depth of N placement (banding) and the addition of a nutrient package (P, K, S, Zn, Cu, and Mn) applied with N fertiliser

Description	Physical disturbance	[1]Nitrogen rate (kg N/ha)			Fertiliser placement (cm)			Nutrient package (P, K, S, Zn, Cu, Mn)
		2017	2018	2019	7.5	20	30	
Control	Nil	30	30	30	✓			+/-
Pre drill control	Pre Drill	30	30	30	✓			+/-
Pre drill N (annual)	Pre Drill	30	30	30		✓		+/-
Pre drill N (1 in 3)	Pre Drill	90	0	0		✓		+/-
Deep rip control	Deep Rip	30	30	30	✓			+/-
Deep rip N (annual)	Deep Rip	30	30	30			✓	+/-
Deep rip N (1 in 3)	Deep Rip	90	0	0			✓	+/-

[1]*All treatments receive an additional 20 kg N/ha per year through basal and top-dressed fertiliser inputs*

Table 3 Treatments applied in 2017 in the spading organic matter trial at Ouyen

Treatment	Application rate (t/ha)	C:N Ratio	Treatment N input (kg/ha)
Spaded Vetch Hay	6.0	16:1	156
Spaded Oaten Hay	5.9	72:1	35
Spaded Vetch + Oat Hay	3.3 + 2.7	25:1	102
Spaded Chicken Litter	6.8	16:1	218
Spaded Compost	15.8	10:1	252
Urea	0.34	N/A	156
Spaded control	Nil	N/A	-
Non-spaded control	Nil	N/A	-

Carwarp

Deep ripping x rotation trial (mitigation)

Eight different three-year rotations were established in 2018. Deep ripping to 60 cm was conducted on one half of each plot prior to sowing, creating with or without deep ripping comparisons (Table 4). All treatments received 40 kg N/ha from fertiliser inputs, except for the cereal (High N) treatment which received 80 kg N/ha and lentils which received 20 kg N/ha from starter fertiliser and top-dressed ammonium sulphate.

Organic matter input incorporation x placement trial

The trial compares the incorporation and placement of organic matter (OM) inputs (6 t/ha lucerne) by deep ripping, spading or combinations of the two operations (Table 5). Where organic matter inputs were surface applied, lucerne meal was used and where organic matter inputs were direct injected into the subsoil during the ripping process the lucerne was pelletised.

Management

Low and infrequent rainfall delayed the establishment of trials at both sites in 2018.The Ouyen site was sown to Kord wheat on 31 May 2018 while Carwarp was sown on 7 June to Spartacus barley, except on the canola (Pioneer 43Y92 CL) and lentil (PBA Hurricane XT) treatments (Table 4). All trials received DAP S Z (16:17:0:8; 0.5%Zn) @ 62.5 kg/ha at seeding and 47 kg/ha of ammonium sulphate and a foliar application of copper, zinc and manganese was applied during tillering. Additional applications of N at seeding saw a total of 50 kg N/ha applied to the Ouyen site and 40 kg N/ha applied at Carwarp, except where treatments required a different rate (Table 2 and 4).

What happened?

Seasonal conditions

Growing season rainfall at both sites was sporadic and very much below average, with only 48 mm of in-crop rainfall at Carwarp and 105 mm received at Ouyen during the 2018 growing season. September was very dry, however 10 mm of rain fell during October at Carwarp and Ouyen received 20 mm which provided good conditions for grain fill.

Grain yield

In 2017 deep ripping led to a grain yield increase of 0.85 t/ha relative to the control (2.75 t/ha compared to 1.9 t/ha) (Moodie and Macdonald, 2018). In 2018, the annual ripping treatment (i.e. plots deep ripped in both 2017 and 2018) resulted in a yield increase of 0.6 t/ha more than the control yield of 0.97 t/ha, while treatments which were ripped in 2017 only still yielded 0.4 t/ha better than the control in 2018 (Figure 1).

Table 4 Rotations which commenced at Carwarp in 2018 with and without ripping

Description	2018	2019	2020	Deep rip (60 cm)
Cereal (Low N)	Barley	Wheat	Wheat	+/-
Cereal (High N)	Barley	Wheat	Wheat	+/-
L - W - W	Lentil	Wheat	Wheat	+/-
B - L - W	Barley	Lentil	Wheat	+/-
B - W - L	Barley	Wheat	Lentil	+/-
Can - W - W	Canola	Wheat	Wheat	+/-
B - Can - W	Barley	Canola	Wheat	+/-
B - W - Can	Barley	Wheat	Canola	+/-

Table 5 Organic matter input incorporation x placement trial at Carwarp

Mechanical operation	Depth (cm)	OM placement	OM placement
Nil	Surface	+/-	Surface
Spade	Surface	+/-	Surface
Deep Rip	30	+/-	30 cm
Deep Rip	60	+/-	60 cm
Deep Rip	60	+/-	30+60 cm: Split (50/50)
Deep Rip + Spading	60 + 30	+/-	Surface + 60 cm: Split (50/50)

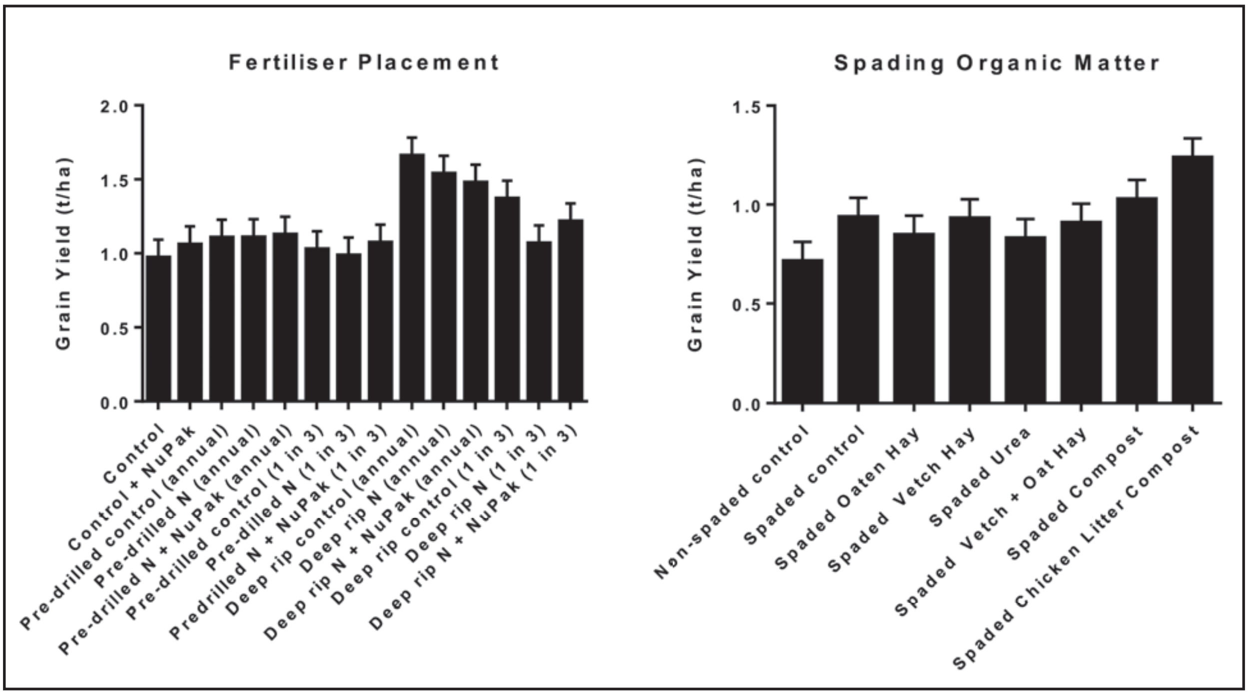

Figure 1 Wheat yields of treatments in the fertiliser placement and spading organic matter trials at Ouyen in 2018. Error bars are Standard Error of Difference.

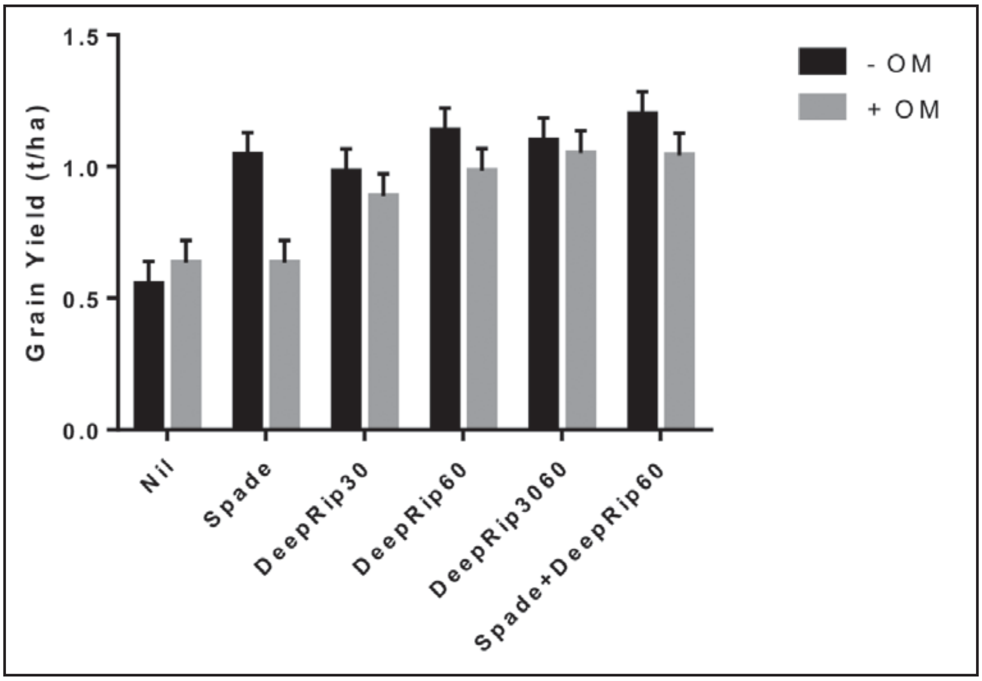

Figure 2 Barley yields of treatments in the organic matter input incorporation x placement trial at Carwarp in 2018. Error bars are Standard Error of Difference.

Soils

There were fewer second year benefits in 2018 from the spading and organic amendment treatments implemented in 2017 (Figure 1). Only the spaded compost and chicken litter treatments had significant yield increases compared to the non-spaded control (0.7 t/ha). The chicken litter treatment resulted in an extra 0.5 t/ha grain yield in 2018, which equates to a cumulative yield of 4 t/ha for the two seasons, compared to only 2 t/ha of grain from the non-spaded control. On-farm organic matter input sources such as vetch and oaten hays did not provide a yield benefit in 2018.

At Carwarp, disturbance by deep ripping and spading significantly increased grain yields however there was no positive impact from the addition of lucerne (Figure 2). There was a negative response to the addition of organic matter in the spading treatment, possibly from more vigorous early crop growth using more water in a season where low rainfall resulted in low soil moisture reserves. Mechanical disturbance to 30 cm by spading or deep ripping resulted in an additional grain yield of 0.5 t/ha compared to the control (1.05 t/ha compared to 0.55 t/ha). Deeper ripping to 60 cm did not provide any significant yield increases in 2018 over working to a depth of 30 cm only.

Both canola and lentil production were adversely affected by the poor seasonal conditions at the Carwarp site with control treatments for these crops yielding 0.45 t/ha and 0.04 t/ha respectively. Deep ripping increased canola yield by 25 percent and although lentil yield on the ripped treatments was four times that of the control, it was still low yielding (0.16 t/ha). There was no additional benefit of higher N inputs to barley with or without deep ripping at Carwarp in 2018.

What does this mean?

Alleviating physical barriers to root growth through practices such as deep ripping and rotary spading are providing the most consistent yield increase on sandy soils in the Victorian Mallee. Thus far, yield responses from physical interventions have generally been more consistent than responses from organic inputs. The chicken litter treatment at Ouyen is the exception to this, where there has been a cumulative grain yield response of 2 t/ha across two seasons. This response from the application of chicken litter demonstrates the potential to improve crop yields by increasing fertility of sandy soils. However, there were not significant yield responses from the addition of home grown biomass, such as vetch and cereal hay on the sites in 2018. Thus, addressing soil physical constraints by deep ripping or rotary spading seems to be a good place to start for farmers looking to increase production on underperforming sands in the Victorian Mallee.

Acknowledgements

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Thank you to the Hastings and Nulty families who have generously provided sites for these long term trials.

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Effects of deep ripping on soil compaction and crop performance in Mallee sands

Brian Dzoma[1], Nigel Wilhelm[2] and Kym Zeppel[1]
[1]SARDI, Loxton Research Centre; [2]SARDI, Waite

RESEARCH

Location
Loxton
Robin Schaefer and family
Rainfall
Av. Annual: 263 mm
Av. GSR: 171 mm
2018 Total: 177 mm
2018 GSR: 105 mm
Soil Type
Sand
Soil Test
$pH_{(water)}$: 8.45
Plot Size
15 m x 2 m 4 reps
Trial Design
Factorial RCBD with 4 reps
Yield Limiting Factors
Moisture

Location
Peebinga
George Gum and family
Rainfall
Av. Annual: 319 mm
Av. GSR: 210 mm
2018 Total: 190 mm
2018 GSR: 116 mm
Paddock History
2017: Fallow
2016: Fallow
Soil Type
Grey sand
Soil Test
$pH_{(water)}$: 7.27
Plot Size
15 m x 2 m 4 reps
Trial Design
Factorial RCBD with 4 reps
Yield Limiting Factors
Moisture

Key messages

- **For sands with subsoil compaction that goes to depth, ripping deeper is better to maximise shoot biomass production and grain yield.**
- **Optimal ripping depth x tine spacing combination was 60 cm x 60 cm on a deep grey sand.**

Why do the trial?

Sandy soils dominate the landscape across the low rainfall region of south-eastern Australia, and anecdotal evidence suggests that compaction is widespread on these soils. Soil compaction is one of the major problems facing modern farming systems on sandy soils mainly because of the use of heavy machinery and intensive cropping. Soil compaction adversely affects soil physical fertility, particularly storage and supply of water and nutrients, through increasing soil bulk density, decreasing porosity, increasing soil strength, decreasing soil water infiltration, and water holding capacity.

Deep ripping or deep cultivation, is an expensive yet important option for addressing soil compaction, destroying hard pans and ameliorating hard setting soils. Mallee sands tend to form hard layers just below the soil surface which limit water infiltration and root penetration, hence in low rainfall South Australian (SA) Mallee farming systems deep ripping has been used to shatter these dense subsurface soil. Deep ripping alone has been shown to increase crop production on sands, but often the effects are not sustained long term (Adcock *et al*. 2007). In a summary of deep ripping trials on Eyre Peninsula from 2006-2008, Paterson and Sheppard (2008) concluded that (i) sandy soils were more responsive to deep ripping than finer textured soils, and (ii) responses did not persist past two years.

Thus, the challenge for growers is quantifying the contribution of deep ripping to crop productivity, refining how best to do it, and if used in combination with chemical, biological and other physical soil ameliorants, can these benefits be improved or prolonged. How crops utilise available moisture and nitrogen after ameliorating soil compaction in these environments is poorly understood. If this gap can be closed, crop productivity and farm profitability could be improved through more efficient use of nitrogen in these moisture limited environments.

The main objective of this project was to investigate the impact of deep ripping compacted Mallee sands on:

1. ***Productivity:*** What ripping depth and tine spacing (narrow vs wide) optimises responses (shoot biomass, yield and grain quality),
2. ***Economics:*** Which combination of ripping depth X tine spacing gives the most economical return, and
3. ***Sustainability:*** For how long do deep ripping benefits last on Mallee sands.

Soils

How was it done?

Two replicated field trials were conducted in 2018. One on a deep red sandy soil (Loxton) and a second on a grey sand over clay (Peebinga). Trial 1 (Table 1), evaluating the impact of deep ripping at different tine spacing and depth, was conducted in the southern Mallee. The main objective of this trial was to identify an optimum depth of ripping where productivity gains can be maximised, and to evaluate whether narrow tine spacing improves the longevity of the operations.

Trial 2 (Table 1), was conducted in the northern Mallee as a crop phase experiment with 3 different crop types. The aim was to assess the impact of deep ripping on crop performance and to determine which crop types (wheat, barley and field peas) respond better to deep ripping in the first, second and third year after amelioration. One tine spacing (50 cm) was used for trial 2.

Deep ripping treatments were imposed using a straight shanked tined ripper (Image 1) on 11 May and 21 May 2018 at Loxton and Peebinga respectively. Penetration resistance readings were taken on 7 August at both sites using a Rimik CP40 (II) cone penetrometer to determine the depth of compaction. In-season assessments of crop density, early and late shoot dry matter (DM), grain yield and quality were undertaken to help quantify the effect of ameliorating compacted sands through deep ripping.

Table 1 Treatment details at Peebinga and Loxton in 2018

	Trial 1: Peebinga	Trial 2: Loxton
Treatments	5 depths (0, 20, 40, 60, 70 cm)	Ripped (50 cm) vs compacted (control)
	2 tine spacings (narrow=30 cm and wide=60 cm)	1 tine spacing (50 cm)
	Total # plots=40	Total # plots=24
	Sowing rate: Scope barley @ 60 kg/ha	Sowing rate: Mace wheat @ 60 kg/ha, Scope barley @ 80 kg/ha, Gunyah peas @ 100 kg/ha
	Fertiliser inputs: 20 kg P/ha and 100 kg N/ha	

Image 1 Deep ripper used at both trial sites

What happened?

With total growing season rainfall of 116 mm (Peebinga) and 106 mm (Loxton), crop growth and productivity was heavily compromised at both sites. However, visual responses in crop establishment and biomass to ripping were evident at both sites.

Penetration resistance

Crop root growth usually begins to be impeded when penetration resistance exceeds 1500 kPa, with severe restriction in sands beyond 2500 kPa. Penetrometer readings in Figure 1 show that at the Loxton site, the deep ripped plots had greatly reduced soil compaction within the top 40 cm of soil. Comparatively, the unripped control had a compaction zone starting from as shallow as 20 cm going down the soil profile.

At Peebinga, penetrometer data show that the compacted layer was shallower; starting from 18 cm (Figure 2). Ripping to 20 cm only addressed surface compaction, having no impact on sub-surface compaction below 20 cm. Soil compaction was greatly reduced when the plots were ripped to a depth greater than 60 cm.

Effect on crop performance

At Loxton, deep ripping did not affect early wheat shoot biomass, however there was a significant increase in barley and peas early shoot biomass (Figure 3, Left). There was no significant increase in wheat or pea shoot biomass at flowering from deep ripping, however there was an increase in the barley flowering DM by 74% compared to the control from deep ripping (Figure 3, Right).

Severe frost damage prevented any grain yield from being taken in field peas. Deep ripping did not improve wheat yields, however barley yields were increased by 100% where soil compaction was ameliorated by deep ripping, compared to the control (Figure 4).

At Peebinga, crop establishment was poor at this site because the top 10 cm of this sandy soil was water repellent. There was an average of only 45 plants/m^2. This, combined with below average seasonal rainfall, contributed to low shoot DM and grain yield.

Across all ripping depths, deep ripping with narrow tine spacing at 30 cm on average resulted in a significant increase in early and late shoot DM. However this did not seem to affect barley grain yield (Figure 5).

Increased grain yield, as well as early and late shoot DM, were generally achieved by increasing the depth of ripping (Figure 6). These highly significant responses ($p<0.001$) were consistent across the 3 assessments, showing that large responses can be achieved by ripping deeper than 40 cm. Ripping to 20 cm with wide spaced tines, gave similar results to the control, indicating that the compacted layer was below 20 cm. However, narrow tine spacings (20 cm) performed better than the control, possibly indicating that shallow ripping had some benefit in treating the water repellent sand.

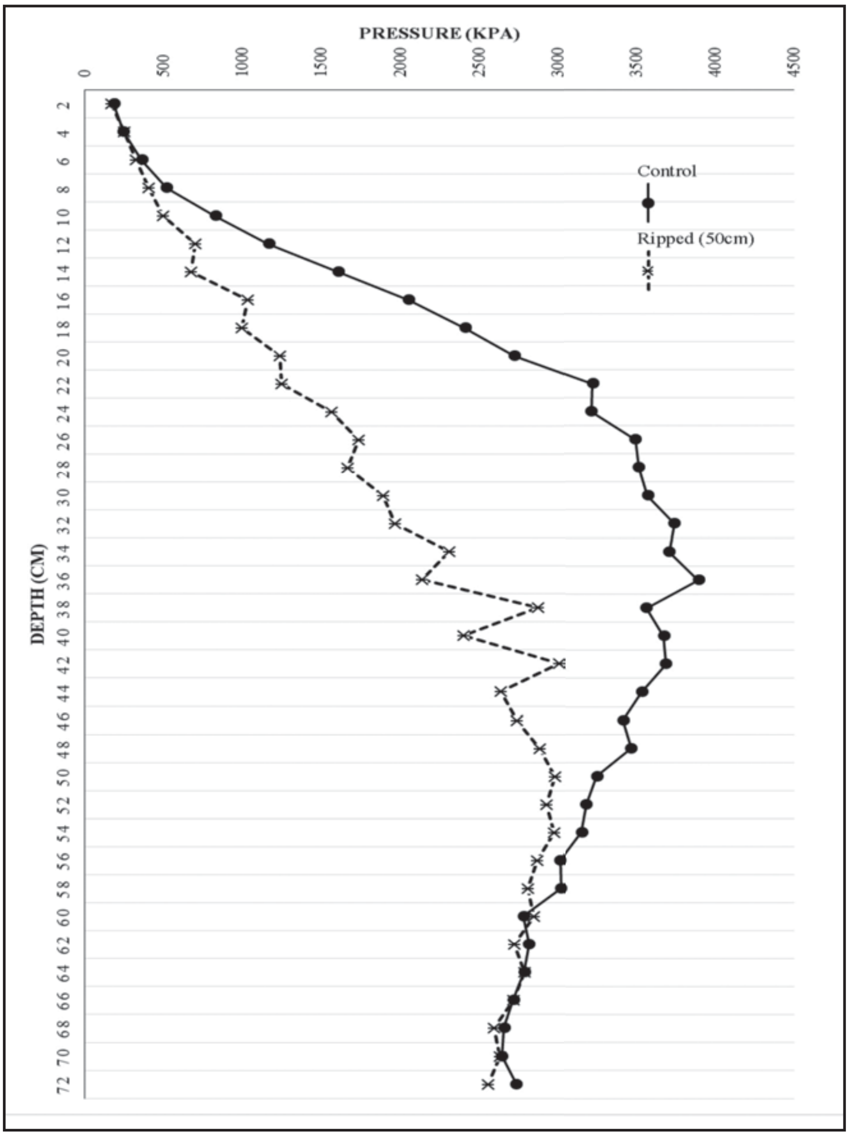

Figure 1 Penetration resistance (kPa) at Loxton

Soils

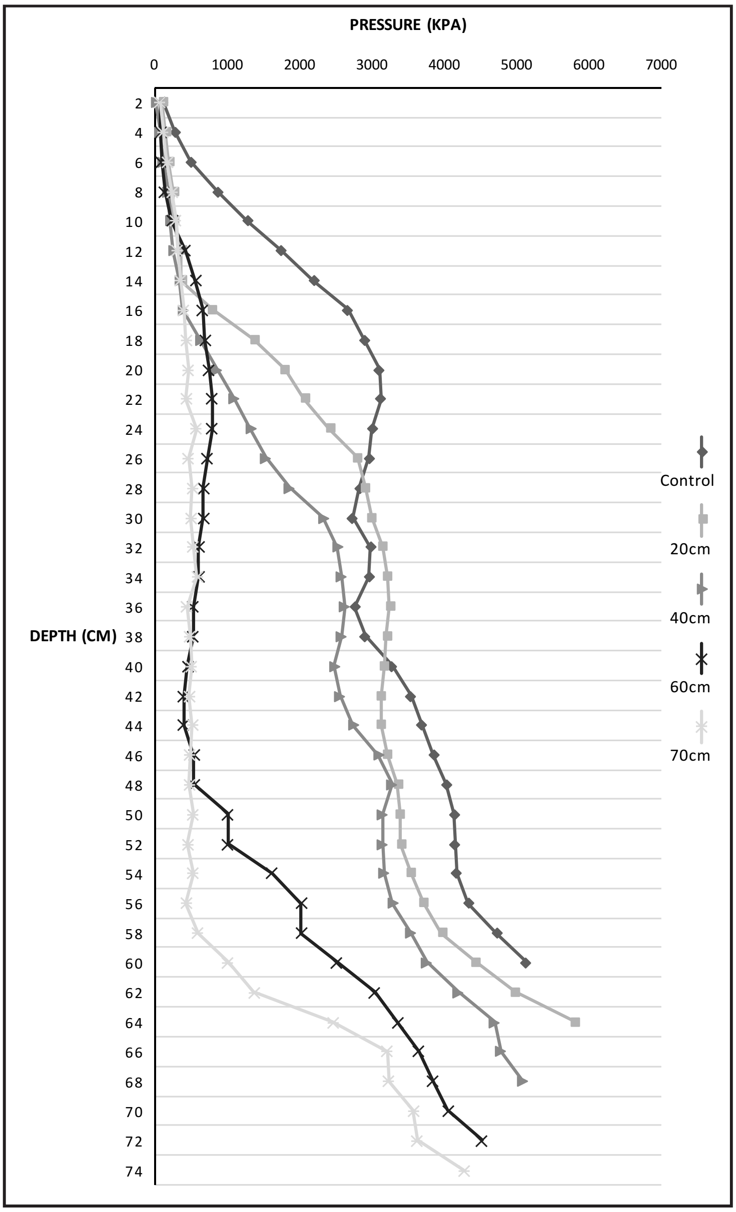

Figure 2 Penetration resistance (kPa) at Peebinga

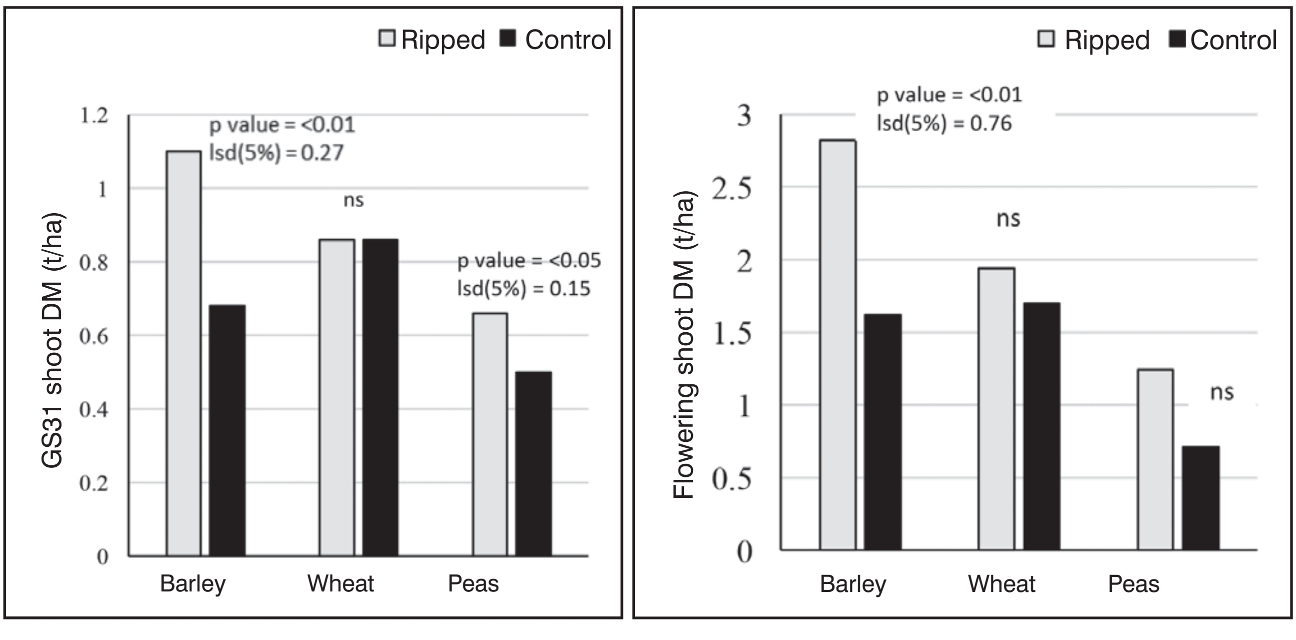

Figure 3 (Left) Effect of deep ripping on early shoot biomass at Loxton in 2018; (Right) effect on flowering shoot biomass

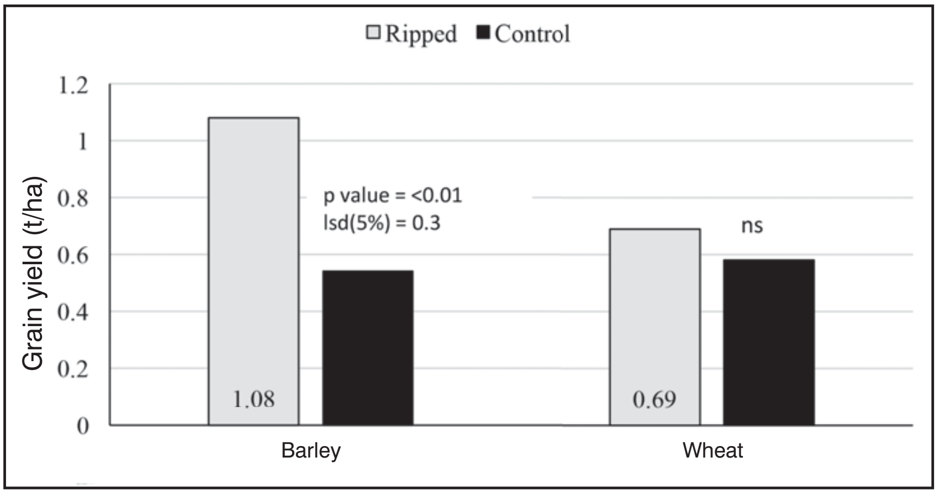

Figure 4 Effect of deep ripping on wheat and barley grain yield (t/ha) at Loxton in 2018

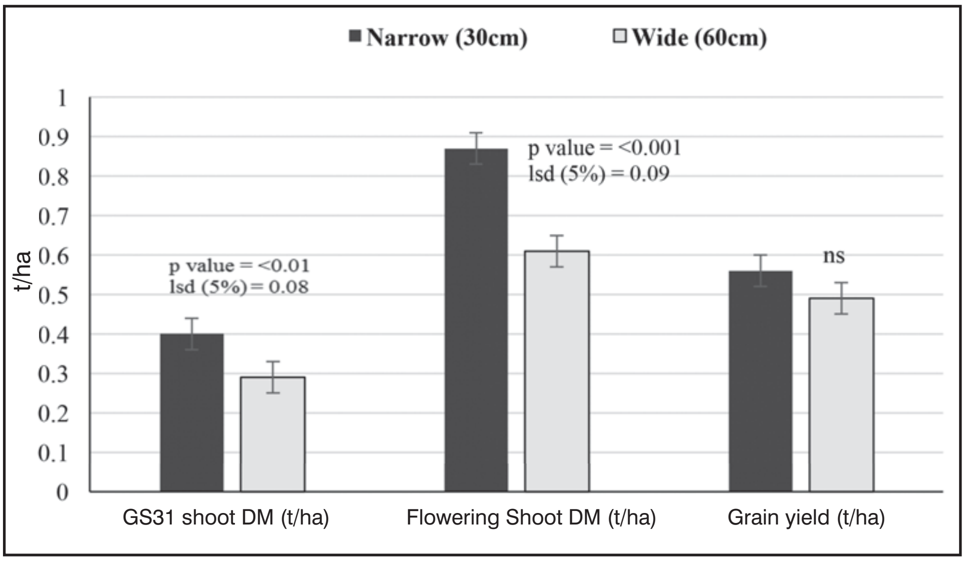

Figure 5 Effect of narrow vs wide tine spacing on early and late shoot DM of barley, and grain yield at Peebinga 2018

Responses from the 9 individual treatments (Figure 7) exploring the best combination of ripping depth and tine spacing, show that ripping with a narrow spacing (30 cm) to a depth of 70 cm resulted in the largest flowering shoot biomass production response (328% more than the control). The results also show that ripping with wide tine spacings, to depths greater than 60 cm gave the largest grain yield responses, increasing yield compared to the control by 155% by ripping to 60 cm depth and 211% by ripping to 70 cm.

What does this mean?

Slow and restricted root growth caused by subsoil compaction can often lead to reduced crop productivity and profitability. It can also result in on and off-farm impacts including increased wind and water erosion, dryland salinity and waterway degradation. Thus, the challenge for growers is to quantify the contribution of deep ripping to improved crop productivity, refining the ripping methodology (e.g. ripper type, spacing, depth), and determining if these benefits are sustainable.

Our trials show that ameliorating compacted sandy soils in low rainfall environments can lead to improved crop biomass and grain yield, and should subsequently lift farm productivity and profitability. In terms of grain yield, ripping with narrow or wide tine spacings gave similar outcomes, therefore wider tine spacings could be used to reduce machinery horsepower requirements. Results of these trials show that when there is deep soil compaction, provided that no chemical constraints are present below the compaction zone, deeper ripping provides larger grain yield benefits. From the individual treatments investigated, ripping with wide tine spacings (60 cm), to a depth of 60 cm is the optimal combination to maximise productivity.

Although there was a trend of higher yields from ripping deeper and with narrower tine spacings, these were not significantly different to the optimal combination. Growers should be aware that the optimal combination of ripping by tine spacing for crop production and grain yield is not necessarily the most profitable or the longest lasting benefit. A gross margin analysis still needs to be done to determine the most economical ripping depth x tine spacing combination, and more data needs to be collected over the next two seasons to determine how long the benefits last for each combination.

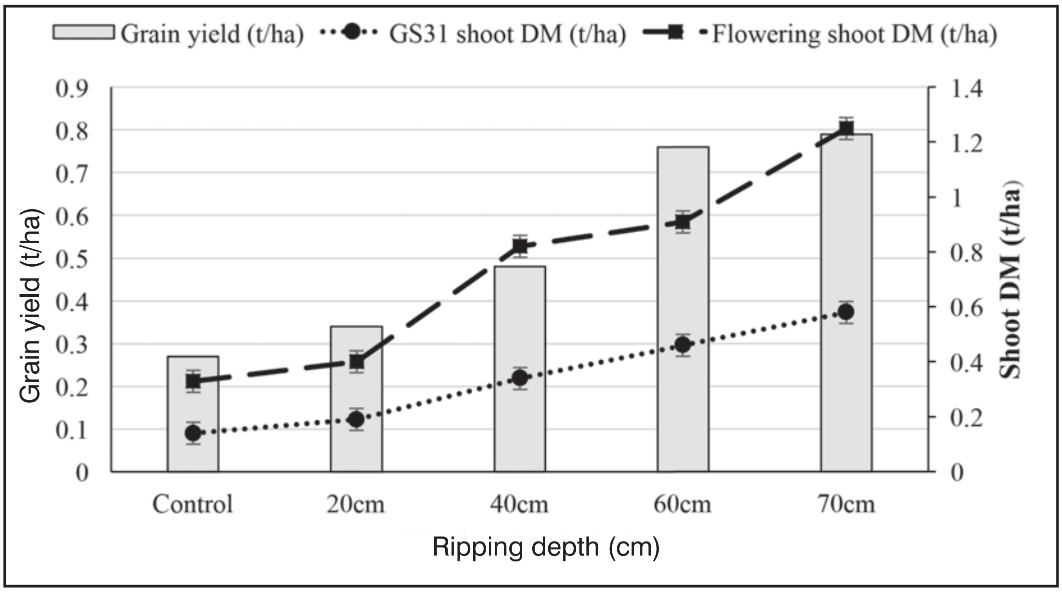

Figure 6 Effect of ripping depth on early and late shoot DM, and grain yield of barley at Peebinga in 2018

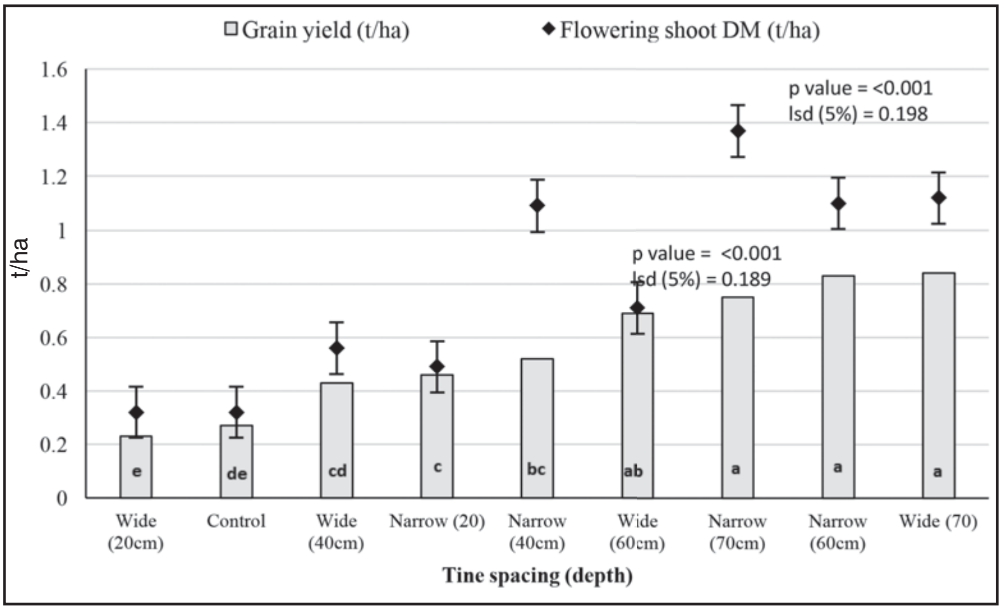

Figure 7 Grain yield and flowering shoot DM responses from individual treatments

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Fertiliser type and placement effects on crop establishment, grain yield and water use efficiency on calcareous soils

Fabio Arsego[1] and Andrew Ware[2]
[1]SARDI, Minnipa Agricultural Centre/Port Lincoln; [2]formerly SARDI, Port Lincoln

RESEARCH

Location
Piednippie - John Montgomerie
Rainfall
Av. Annual: 378 mm
Av. GSR: 225 mm
2018 Total: 233 mm
2018 GSR: 181 mm
Yield
Potential: 3.0 t/ha (Kirkegaard and Hunt 2012)
Actual: 1.96 t/ha
Paddock History
2017: Pasture
2016: Canola
2015: Pasture
Soil Type
Grey calcareous sand
Plot Size
1.6 m x 10 m 3 reps
Trial Design
Randomised complete block
Yield Limiting Factors
1% grain loss at each plot, late harvest

Location
Nunjikompita - Tim Howard
Rainfall
Av. Annual: 299 mm
Av. GSR: 225 mm
2018 Total: 168 mm
2018 GSR: 128 mm
Yield
Potential: 1.93 t/ha (Kirkegaard and Hunt 2012)
Actual: 1.1 t/ha
Paddock History
2017: Medic pasture
2016: Mace wheat
2015: Medic pasture
Soil Type
Red calcareous sand
Plot Size
1.6 m x 10 m 3 reps
Trial Design
Randomised complete block
Yield Limiting Factors
Poor germination at all trials

Key messages

- **Applying MAP with the seed at sowing resulted in a 25% increase in plant emergence compared to using DAP at Piednippie.**
- **Applying MAP at sowing resulted in higher grain yields and better water use efficiency (WUE) in plots which had high seeding rates at Nunjikompita.**
- **In combination with a high seeding rate, a blend of DAP and triple super phosphate (TSP) applied at sowing at Piednippie and Nunjikompita (plus urea) resulted in grain yields which were closer to the crop yield potential than the control.**

Why do the trial?

On the upper Eyre Peninsula (UEP), calcareous soils constitute a high proportion (more than 1 million hectares) of soils used for agricultural production (Bertrand *et al*. 2003). The website 'Yield Gap Australia' (http://yieldgapaustralia.com.au/maps/) identifies that the average grain yield on western Eyre Peninsula (WEP) and UEP is between 41 and 45% of the water limited yield potential (1.5 t/ha for WEP and 1.8 t/ha for UEP). Closing the grain yield gap for wheat on UEP presents a challenge to growers mostly due to nutrient deficiencies, particularly on calcareous soils (Holloway *et al*. 2001). The majority of landholders in the western and upper Eyre Peninsula currently use granular fertilisers, which require good soil moisture conditions to enable uptake of nutrients. Limitations of water availability during the growing season influences grower decisions regarding fertiliser applications, with associated impacts on crop profitability. Consequently, growers often apply lower rates of nutrients than are required to achieve the water limiting yield potential as a risk management strategy (Sadras and Roget 2004; Monjardino *et al*. 2013). A deeper understanding of the multiple factors influencing the efficacy of applied granular fertilisers such as fertiliser position in relation to seed, fertiliser composition and soil structure and moisture can be used to develop alternative strategies for increasing the effectiveness of fertiliser applications (McLaughlin *et al*. 2011). This study aimed to determine the impact of different fertiliser products and placement relative to the seed on crop emergence, crop WUE and grain yield.

How was it done?

Field trials were sown at two sites (Piednippie and Nunjikompita) on calcareous sandy loam soils. There were two trials at each site, designed to investigate the impacts of fertiliser products and fertiliser placement on wheat establishment and grain yield. The design for all trials was randomised complete block with three replicates.

The crop for all trials was Scepter wheat. National Variety Trials (NVT) protocols were followed for the management of weeds, pests and diseases at all sites. Trial management details are provided in Table 1. Treatments are listed in Table 2 and 3.

Table 1 Trial management details at Nunjikompita and Piednippie in 2018

Trial Details	Nunjikompita	Piednippie
Variety	Scepter wheat	
Sowing rate	60 kg/ha (Normal seeding rate) and 80 kg/ha (High seeding rate)	
Sowing date	8 May 2018	6 June 2018
Fertiliser	50 kg/ha Di Ammonium Phosphate (DAP), 50 kg/ha Mono Ammonium Phosphate (MAP), 50 kg/ha Urea, 100 kg/ha Triple Super Phosphate (TSP), 200 kg/ha Single Super Phosphate (SSP), 200 kg/ha Complete Nutrient Mix	
Herbicide	Boxer gold @ 1.5 L/ha, Avadex @ 1.5 L/ha, Roundup @ 2 L/ha, Hammer @ 1.6 L/ha, Broadstrike @ 800 ml/ha (5/6/18 Nunjikompita, 8/5/18 Piednippie)	
Harvest date	5 December 2018	7 December 2018

Table 2 Seeding fertiliser type and placement trial (Trial 1) list of treatments

Treatment #	Treatment Description
1	50 kg/ha DAP + with seed + Normal seeding rate (control)
2	50 kg/ha DAP + 3 cm below seed + Normal seeding rate (control)
3	50 kg/ha DAP + with seed + High seeding rate
4	50 kg/ha DAP + 3 cm below seed + High seeding rate
5	50 kg/ha MAP + with seed + Normal seeding rate (control)
6	50 kg/ha MAP + 3 cm below seed + Normal seeding rate (control)
7	50 kg/ha MAP + with seed + High seeding rate
8	50 kg/ha MAP + 3 cm below seed + High seeding rate.

Table 3 Fertiliser combinations and placement trial (Trial 2) list of treatments

Treatment #	Treatment Description
1	Normal seeding rate (control treatment)
2	High seeding rate
3	50 kg/ha Urea + Normal seeding rate
4	50 kg/ha Urea + High seeding rate
5	100 kg/ha TSP + Normal seeding rate
6	100 kg/ha TSP + High seeding rate
7	100 kg/ha TSP + 50 kg/ha Urea + Normal seeding rate
8	100 kg/ha TSP + 50 kg/ha Urea + High seeding rate
9	200 kg/ha SSP + Normal seeding rate
10	200 kg/ha SSP + High seeding rate
11	200 kg/ha complete nutrient mix (N, P, K, S, Ca, Cu, Zn, Mn, Mo, Fe) + Normal seeding rate

What happened?

Plant establishment was assessed at emergence for all trials. Plant counts were undertaken either side of a 50 cm ruler placed at random between two central crop rows at three locations within the plot. This data was extrapolated to plants per square metre.

At all trials, gravimetric soil moisture was measured on three random replicates within each block at sowing and per plot at maturity. Soil sampling at Piednippie was hindered by limestone below 30 cm, whilst 60 cm was the maximum sampling depth at Nunjikompita.

Water use efficiency (WUE) was benchmarked against water limiting yield potential.

At sowing, soil moisture content was significantly higher at Piednippie compared to Nunjikompita (Table 4). Soil nutrients and exchangeable cations were also higher at Piednippie (Table 5), particularly organic matter and exchangeable calcium (93% and 40% higher than Nunjikompita, respectively). The trials at Piednippie had significantly higher crop establishment and grain yield (Figures 1a and 1b) compared to Nunjikompita, which might have resulted in part from higher soil nutrient levels and rainfall (181 mm at Piednippie vs. 128 mm at Nunjikompita, Table 5).

Trial 1

Establishment

At both Piednippie and Nunjikompita, crop emergence was affected by seeding rate, type of fertiliser and fertiliser positioning at sowing (Figures 2a and 2b). Where DAP was positioned below the seed at Piednippie, there was a significant (25%) increase in emergence counts compared to DAP with the seed (Figure 2a). This might result from the hygroscopic nature and high salt index of DAP, whereby the granule attracts moisture away from nearby seeds. At Nunjikompita, the effect of MAP and DAP fertilisers on crop establishment was not significant (Figure 2a) and might result from the lower levels of soil moisture at this site compared to Piednippie (Table 4).

Where MAP was used in combination with high seeding rates, emergence was 16% higher at Piednippie compared to using DAP and 25% higher at Nunjikompita (Figure 2b). At normal seeding rate, emergence was not affected by the type of fertiliser at either site (Figure 2b, 60% and 44% establishment rate at Piednippie and Nunjikompita, respectively).

Grain yield and water use efficiency

At Piednippie, the negative effects of DAP on seed germination were independent from final grain yield. Plots with 50 kg/ha of DAP did not have significantly different grain yield and WUE to plots with 50 kg/ha of MAP (Figures 3a and 3b). The percentage of crop yield potential achieved also did not significantly differ between treatments (Figure 3c). Low fertiliser application rates and dry conditions might have contributed to poor WUE, resulting in poor grain yields compared to the water limited yield potential.

At Nunjikompita, grain yields reflected the trends observed at emergence (Figure 2). The MAP treatment had 6% more plants at emergence compared to the DAP treatment (Figure 3a). Grain yield was significantly higher (more than 8%) on the plots with high seeding rates compared to normal seeding rate (Figure 3a), and this trend was also reflected in significantly higher WUE (Figure 3b) and percentage of potential yield achieved (9%, Figure 3c). Fertiliser placement (with or below the seed) did not significantly affect grain yield and WUE at either trial, suggesting that plants may have been able to recover from the negative impact of fertiliser placement on crop emergence.

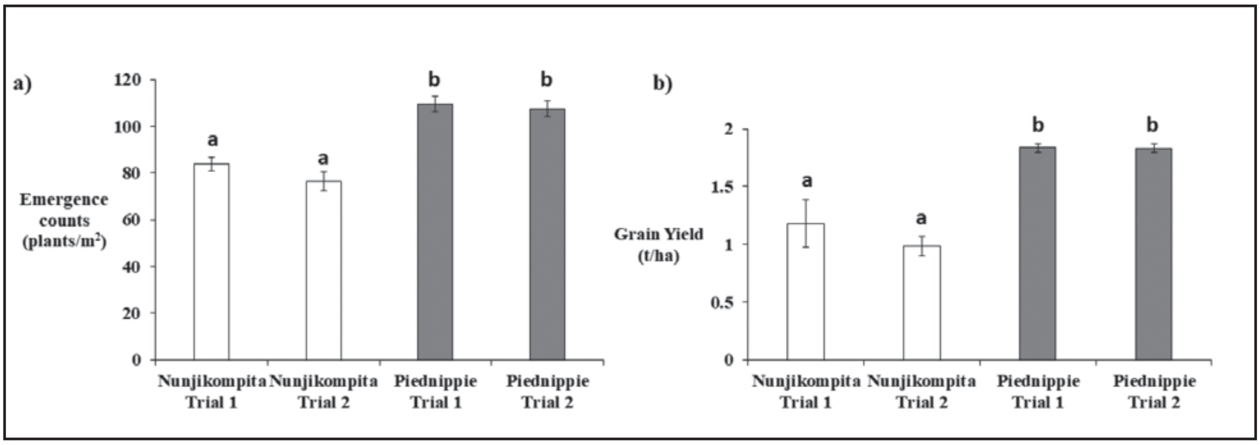

Figure 1 Differences in average emergence counts (a) and grain yield (b) between Nunjikompita and Piednippie at trials 1 and 2

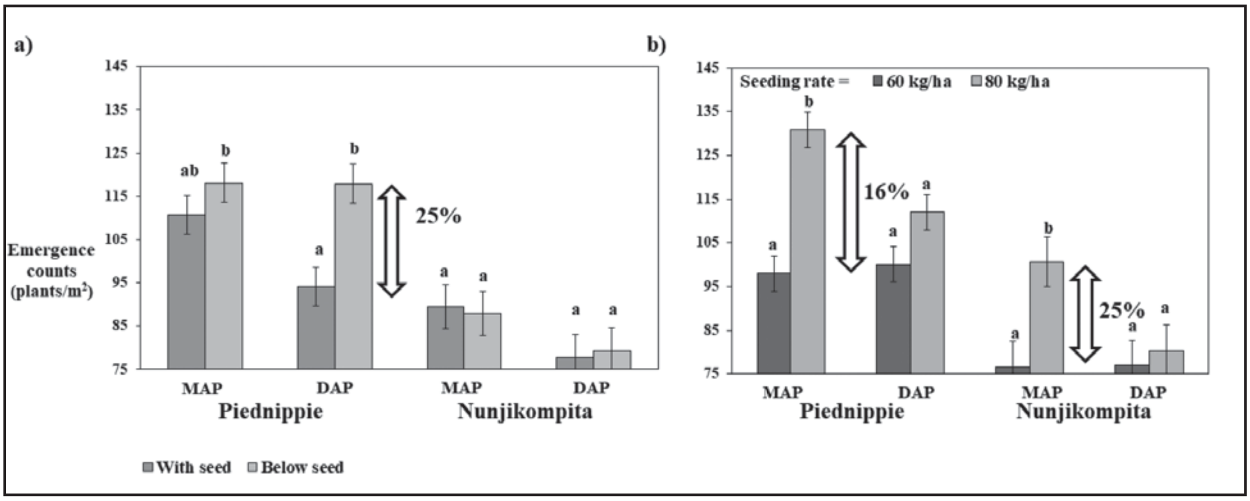

Figure 2 Effect of type of fertilisers (a-b), fertilisers positioning (a) seeding rate (b) on emergence counts at Piednippie and Nunjikompita Trial 1

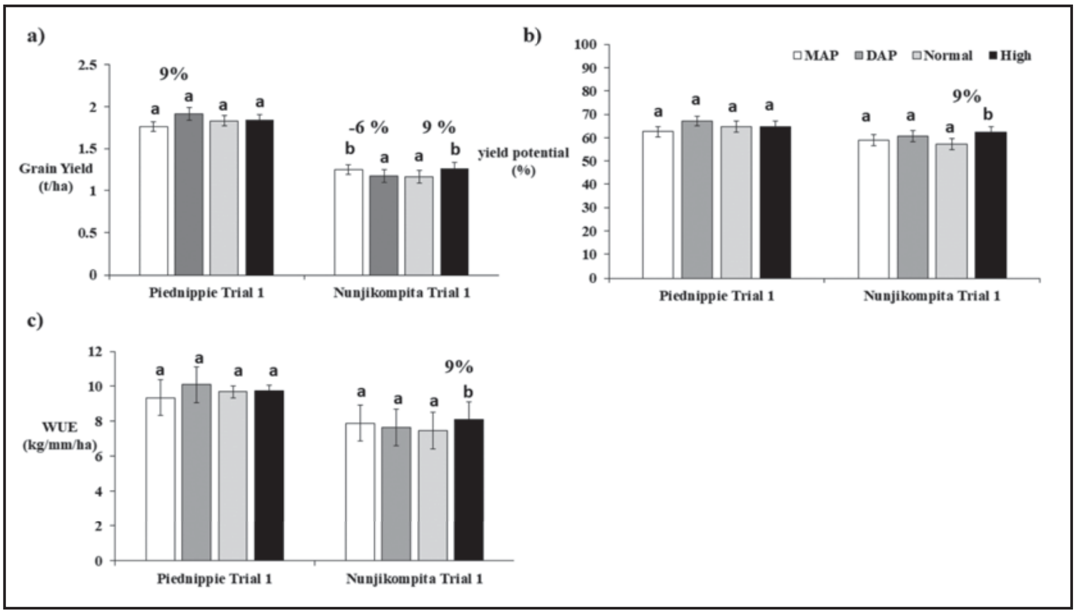

Figure 3a-c Effect of type of fertilisers, and seeding rate on grain yield (a), water use efficiency (WUE) and % yield potential achieved (c) at Piednippie and Nunjikompita Trial 1

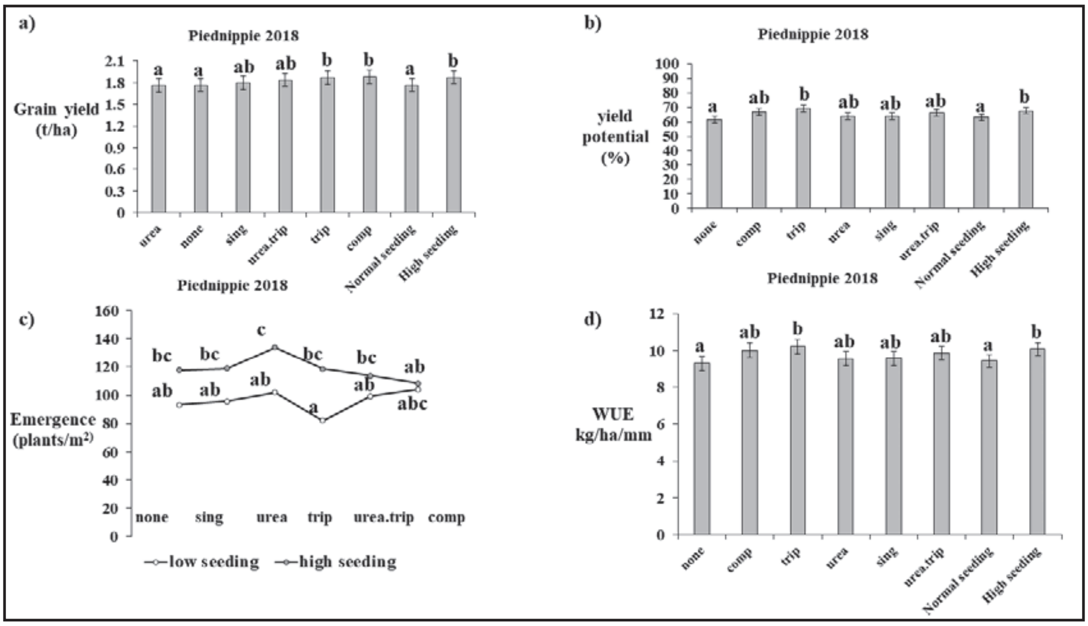

Figure 4a-d. Effect of type of fertilisers, and seeding rate on emergence counts (a), grain yield (b), % yield potential achieved (c) and water use efficiency (WUE, d) at Piednippie Trial 2

sing=single super phosphate, trip=Triple super phosphate, comp=Complete nutrient mix, urea.trip=urea plus triple superphosphate

Trial 2

Establishment

At Piednippie, high seeding rates, in combination with either urea (32%) or TSP (45%), had significantly higher plant numbers at emergence compared to normal seeding rates (Figure 4c). This might have resulted from the placement of fertilisers below the seed, minimising fertiliser "burn".

At Nunjikompita, urea and TSP had an inverse effect on crop establishment. Plant numbers on the Urea treatment were less than all other treatments, (Figure 5c), while TSP and the control had the highest plant numbers. The ammonia released by the urea fertiliser might have had a negative impact on germination.

Grain yield and water use efficiency

At Piednippie, the high plant numbers observed at crop emergence on the high seeding rate treatment carried through to higher grain yield and WUE, irrespective of fertiliser treatment (Figure 4ab-d). This might present an opportunity to increase crop ground cover, which in some years might result in higher grain yields and WUE. TSP and Complete Nutrient Mix gave the highest grain yield response (7% more than the control), of all fertiliser treatments. Higher WUE and percentage of potential grain yield achieved were also measured on these treatments (10% and 12% higher than the control respectively, Figure 4b-d). It is suggested that these products (TSP and Complete Nutrient Mix) might have had some benefit in providing nutrients to the crop in a plant available form.

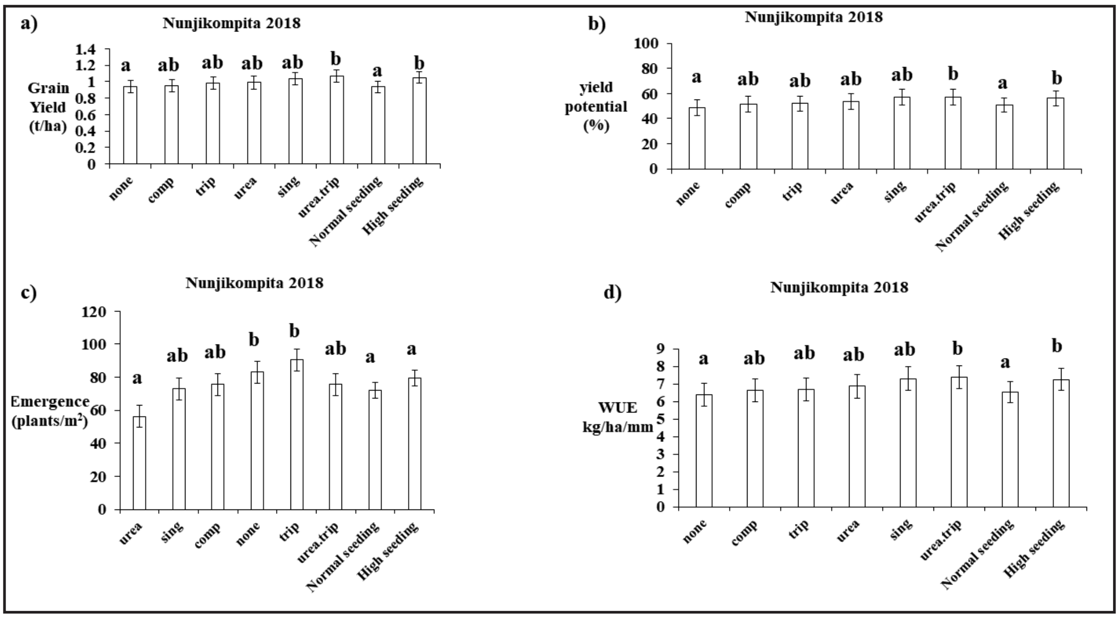

Figure 5a-d Effect of type of fertilisers, and seeding rate on emergence counts (a), grain yield (b), % yield potential achieved (c) and water use efficiency (WUE, d) at Nunjikompita Trial 2
sing=single super phosphate, trip=triple super phosphate, comp=complete nutrient mix, urea.trip=urea plus triple superphosphate

Table 4 Tukey's test of soil moisture at sowing in Piednippie and Nunjikompita at both Trials 1 and 2

Sites/Trial number	Soil moisture at sowing (mm)
Piednippie/1	29.6 a
Piednippie/2	28.0 a
Nunjikompita/1	22.7 b
Nunjikompita/2	22.5 b
Significant Sites difference	*P<0.05, P<0.01*
LSD (P=0.05)	*4.04*
Trials WU difference	*P value*
Nunjikompita/1 vs. Nunjikompita/2	*ns*
Piednippie/1 vs. Piednippie/2	*ns*
Nunjikompita/1 vs.Piednippie/1	**
Nunjikompita/1 vs. Piednippie/2	*
Nunjikompita/2 vs.Piednippie/1	**
Nunjikompita/2 vs.Piednippie/2	*

*The letters a and b indicate a significant difference of: *=P<0.05 and **=P<0.01. ns stands for not significant.*

Table 5 Comparison at sowing time of soil nutrient and exchangeable cations to 60 cm depth between Piednippie and Nunjikompita

Trials	Piednippie	Nunjikompita	Difference (%)
Nitrogen (kg/ha)	65.8	50.0	31.5
Phosphorous (kg/ha)	80.0	65.8	21.5
Sulphur (kg/ha)	23.5	17.6	33.5
Organic carbon (%)	2.4	1.3	92.9
Exchange calcium (%)	37.5	27.5	36.3
Exchange magnesium (%)	3.2	2.9	9.3
Exchange potassium (%)	2.3	1.7	35.9
Exchange sodium (%)	1.1	0.8	39.7

Despite no significant impact of seeding rate on crop emergence at Nunjikompita, high seeding rates gave significantly higher (12%) grain yields (compared to the control). This might have been due to the very low soil moisture levels at seeding, which could have delayed plant emergence (Figure 5a). Grain yields were also significantly higher than the control on the urea plus TSP treatment (14% compared to the control, Figure 5a). Consequently, these treatments also had significantly higher percentages of yield potential achieved and WUE (Figure 5b-d). Given the poor soil fertility of Nunjikompita at sowing the extra nitrogen and phosphorous supplied by the urea and TSP treatments might have been beneficial for canopy closure and increased grain yield and WUE (Table 5).

What does this mean?

The results of Trial 1 suggest that differences in soil moisture and soil fertility at sowing may have an effect on the efficacy of MAP or DAP starter fertilisers on calcareous sites. When lower rates (50 kg/ha) of fertiliser (either DAP or MAP) are applied at sowing, the benefits from applying one fertiliser product over the other on grain yield and WUE are marginal (between 62 and 67% grain yield potential achieved, with WUE increased by 0 to 9% only, Figure 3a and c).

The results from Trial 2 at both sites suggest that a high seeding rate is the best treatment for improving grain yield and WUE (Figure 4-5a-d). The differences in response to fertiliser application at Piednippie compared to Nunjikompita are perhaps attributed to differences in soil moisture and nutrient levels at sowing (Table 4-5, Figure 1). Apart from the seeding rate responses described, only the addition of TSP (at Piednippie) and TSP plus urea (at Nunjikompita) resulted in higher grain yield and WUE. It is possible that microsite differences in pH were created through the application of a combination of fertilisers resulting in improved phosphorous diffusion and availability. Low soil nutrient levels at Nunjikompita, might have resulted in improved grain yields and WUE from the fertiliser treatments compared to the control (Figure 5b-d).

Future research on calcareous soils should focus on validating different rates of MAP/DAP, TSP and urea to identify the maximum grain yield and WUE response that might be achieved.

Acknowledgements

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Additional Information

Crop water use (CWU) was calculated as: CWU=Growing season rainfall + (Soil moisture at sowing– Soil moisture at maturity (Soil bulk density was extracted from ApSoil).

Water use efficiency (WUE) was calculated as: WUE=grain yield (kg/ha)/CWU.

Benchmark of grain yield was performed following the formulas from Hunt and Kirkegaard 2012.

Statistical analyses were performed using the R software and the R package asreml to estimate treatments variability and adjust for spatial trends in the trials. Tukey’s test was applied to assess differences between treatments.

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The impact of herbicide residues on selected tolerant and susceptible crop and pasture species

Brian Dzoma[1], Nigel Wilhelm[2] and Kym Zeppel[1]

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

Key messages

- **Conventional crop and pasture species can suffer significant damage from the carryover of herbicides from previous applications.**
- **Non-herbicide tolerant lentil varieties are susceptible to very low levels of imidazolinones and sulfonylurea herbicide residues.**
- **Significant losses can occur in non-Clearfield wheat varieties grown in soils with low levels of carryover Intervix.**
- **Field pea and vetch have zero tolerance to Lontrel herbicide residues.**
- **To avoid crop damage and losses, minimum re-cropping intervals (months after application) should be observed, and growers should be wary of unusual or extreme weather conditions.**

Why do the trial?

The use of potent selective or broad spectrum herbicides has gained widespread use in broadacre cropping systems, with these herbicides likely to remain an important component of weed control in many, if not all sustainable mixed farming systems of Australia. Although there are economic benefits from the use of herbicides, there are issues with some herbicides that can remain active in the soil for weeks, months or years in sufficient quantities that they may damage sensitive crop or pasture species sown in subsequent years, especially when combined with environmental stresses such as drought and waterlogging.

Reports from grain growers in south-eastern Australia of unexpected crop damage within the safe re-cropping window, are becoming more common. This is posing a new challenge to growers, particularly in low to medium rainfall farming systems, as it clearly reduces management flexibility due to increasing uncertainty about the types of crops that can be grown. Without taking action, herbicide residues have potential to result in subclinical crop yield losses and could also influence crop rotations in the future, as much as weed, pest and disease considerations do now.

To investigate this issue, herbicide dose response experiments were conducted in pots of mallee sand under typical northern Mallee growing conditions to identify minimum levels of Lontrel (*Clopyralid*), Intervix (*Imazamox/Imazapyr*) and Logran (*Triasulfuron*) which can cause significant damage to a range of widely used tolerant and susceptible crop and pasture species.

How was it done?

Herbicides were added to pots on 19 June 2018. Required herbicide concentrations were made by first making a stock solution at the recommended field rate for each herbicide, followed by a succession of step dilutions where a known volume (1 ml) of the stock solution was taken and placed into a known volume of distilled water (999 ml). Each of the solutions made were placed into a rotating cement mixer with soil to ensure uniform mixing of the herbicides with the soil. Doses ranged from very low (0.001 of recommended label rate) to the recommended field rate (RFR) for each of the selected herbicides (Table 1). Zincstar fertiliser (N:P:K:S:Zn 10:22:0:2:1) equivalent to 91 kg/ha was added to every pot at a depth approximately 3 cm below the seed. After banding the fertiliser, 10 seeds were sown in each pot, then pots were watered and transferred to an outside location at Loxton Research Centre. Bird netting was used to protect the pots from animal damage.

Experiments 1, 2 and 3 had two treatment factors to be investigated, the herbicide with 6 levels (0x, 0.001x, 0.01x, 0.1x, 0.5x, 1x) and one crop type with 2 levels (susceptible or tolerant variety). The design was a factorial randomised complete block design (RCBD) with 3 replicates. Experiments 4 and 5 investigated the effects of Lontrel, and had one herbicide with 6 levels (0x, 0.01x, 0.05x, 0.1x, 0.5x, 1x) on one crop variety. The trial design for experiments 4 and 5 was a RCBD with 3 replicates.

Table 1 Treatment details

Expt # (crop type)	Herbicide	Varieties	Herbicide rate (relative to RFR)	Simulated residues (product/ha)
1 (wheat)	INTERVIX	**Kord** (tolerant) and **Gladius** (susceptible)	0x	0 ml/ha
			0.001x	0.5
			0.01x	5
			0.1x	50
			0.5x	250
			1x	500
2 (lentil)	INTERVIX	**Hurricane** (tolerant) and **Nipper** (susceptible)	0x	0 ml/ha
			0.001x	0.5
			0.01x	5
			0.1x	50
			0.5x	250
			1x	500
3 (lentil)	LOGRAN	**Hurricane** (tolerant) and **Nipper** (susceptible)	0x	0 g/ha
			0.001x	0.025
			0.01x	0.25
			0.1x	2.5
			0.5x	12.5
			1x	25
4 (field pea)	LONTREL	**Gunyah** (susceptible)	0x	0 ml/ha
			0.01x	3
			0.05x	15
			0.1x	30
			0.5x	150
			1x	300
5 (vetch)	LONTREL	**Volga** (susceptible)	0x	0 ml/ha
			0.01x	3
			0.05x	15
			0.1x	30
			0.5x	150
			1x	300

Note: RFR=recommended field rate

Emerged plants were counted 10 days after sowing (DAS) to determine germination percentage, and at 28 DAS (16 July) all pots were thinned down to four plants per pot. All experiments were terminated at 75 DAS (3 September), and the effects of herbicides on root and shoot biomass (g DM/plant) recorded. A representative soil sample was also collected from each pot to determine the amount of remaining herbicide.

What happened?

Crop emergence

Logran and Intervix did not affect germination of lentils and wheat at all levels of simulated residues. However, at 28 DAS, the establishment of susceptible crop types and varieties was affected at levels above 0.1x of the RFR. Visual impacts were observed on above ground shoots, and negative impacts on root dry matter were measured.

Germination of field peas and vetch was affected by high Lontrel levels. Field peas and vetch did not germinate at the RFR, and establishment was severely affected at herbicide levels over 0.001x of the RFR, confirming how sensitive these legume species are to Clopyralid residues in the soil.

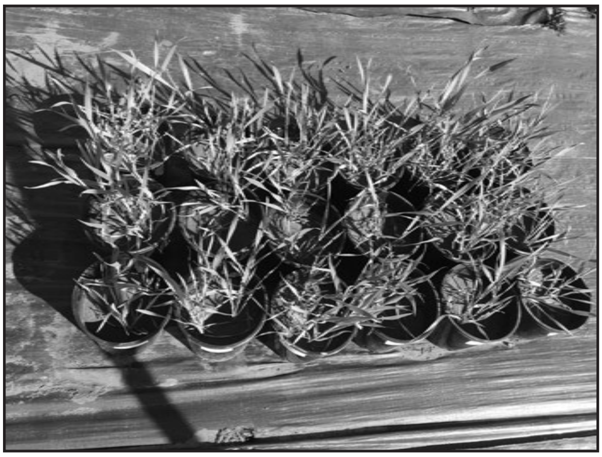
Crop productivity

Intervix did not affect root and shoot dry matter (DM) of Kord CL Plus wheat which is bred to be tolerant to imidazolinone (imi) herbicides (Figure 1a, Table 2). However, root and shoot DM of Gladius was affected by Intervix at and above 0.1x of the RFR (Figure 1b, Table 2). Kord CL Plus is derived from a cross between Gladius and the imi tolerant donor. It carries two genes for Clearfield resistance, providing improved levels of tolerance to imi herbicides, and therefore offers more options for in-crop weed management and crop rotation (Australian Grain Technologies, 2010).

PBA Hurricane XT is a high yielding small red lentil variety with improved tolerance to residual levels of sulfonylurea (su) and imi herbicides (Pulse Breeding Australia, 2013), while Nipper is a small, round red lentil which is sensitive to su and imi herbicides, and more sensitive to double recommended rates of Metribuzin (http://www.pulseaus.com.au/storage/app/media/crops/2011_VMP-Rlentil-Nipper).

Table 2 Effect of Intervix residues on root and shoot dry matter (g/plant) of Kord CL and Gladius wheat

Herbicide rate	Root dry matter (g/plant)				Shoot dry matter (g/plant)			
	Kord CL		Gladius		Kord CL		Gladius	
0x	5.84		4.67	a	1.47	a	1.58	a
0.001x	4.22		2.21	ab	1.41	a	1.55	a
0.01x	2.70		1.84	ab	1.47	a	1.22	a
0.1x	4.80		0.04	b	1.26	a	0.04	b
0.5x	6.23		0.03	b	1.51	a	0.03	b
1x	4.52		0.04	b	1.33	a	0.03	b
LSD					*0.76*			
p value	*ns*				*<0.03*			

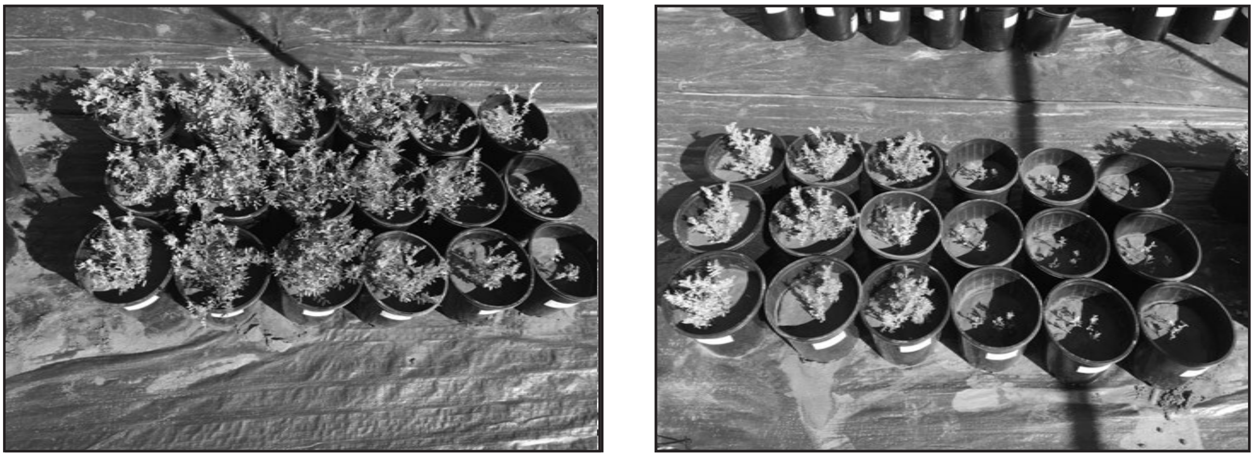


(a) ***(b)***

Figure 1 Visual effects of Intervix residues on Kord CL (a) and Gladius wheat (b). Herbicide residue concentration is from left - zero (control) to right – simulated residues at recommended field rate.

Table 3 Effect of Intervix residues on root and shoot dry matter (g/plant) of Hurricane XT and Nipper lentils

Herbicide rate	Shoot dry matter (g/plant)				Root dry matter (g/plant)			
	Hurricane		Nipper		Hurricane		Nipper	
0x	0.90		0.51		0.74	b	0.33	a
0.001x	0.83		0.96		0.98	a	0.54	a
0.01x	1.04		0.33		0.79	ab	0.39	a
0.1x	0.73		0.06		0.78	ab	0.07	b
0.5x	0.20		0.04		0.22	c	0.06	b
1x	0.11		0.01		0.12	c	0.03	b
LSD					*0.24*			
p value	*ns*				*<0.01*			

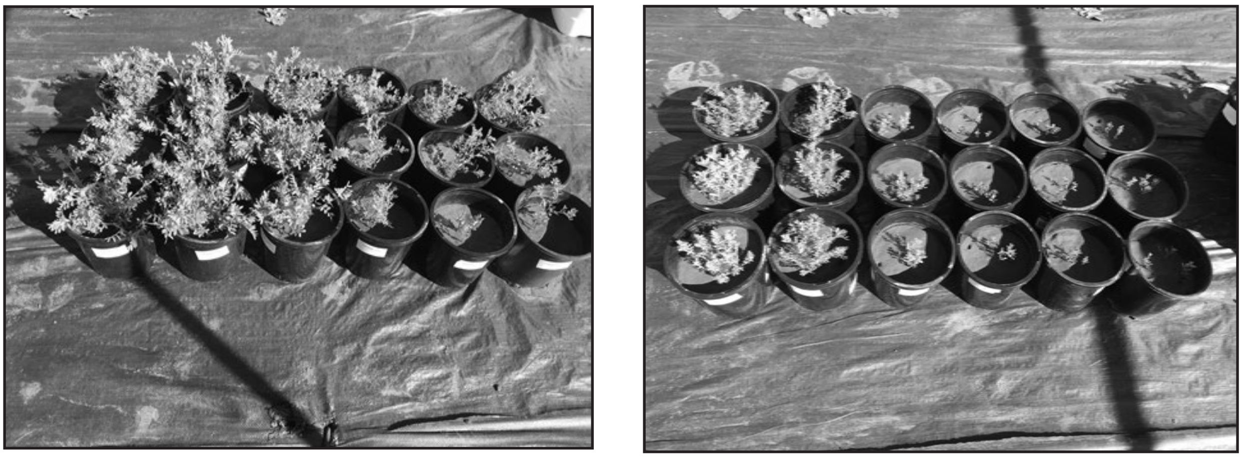


(a) *(b)*

Figure 2 Visual effects of Intervix residues on Hurricane XT (a) and Nipper lentils (b). Herbicide residue concentration is from left - zero (control) to right – simulated residues at recommended field rate.

Table 4 Effect of Logran on root and shoot dry matter (g/plant) of Hurricane XT and Nipper lentils

Herbicide rate	Shoot dry matter (g/plant)				Root dry matter (g/plant)			
	Hurricane		Nipper		Hurricane		Nipper	
0x	0.54	b	0.47	a	0.37	bc	0.61	a
0.001x	0.94	a	0.41	a	0.59	b	0.41	a
0.01x	0.67	b	0.10	b	1.12	a	0.13	b
0.1x	0.25	c	0.06	b	0.18	c	0.05	b
0.5x	0.18	c	0.05	b	0.13	c	0.03	b
1x	0.24	c	0.06	b	0.19	c	0.03	b
LSD	*0.18*				*0.28*			
p value	*<0.04*				*<0.001*			



(a) *(b)*

Figure 3 Visual effects of Logran residues on Hurricane XT (a) and Nipper lentils (b). Herbicide residue concentration is from left - zero (control) to right – simulated residues at recommended field rate.

Intervix residues did not affect root DM of Hurricane XT (Table 3), but had a severe impact on shoot DM when residues were above 0.5x of RFR. This indicates that even though Hurricane XT has been bred with improved tolerance to imi herbicides, its growth can still be affected by high levels of Intervix residues. Nipper had tolerance to Intervix up to 0.01x of RFR but above 0.1x of RFR, root and shoot DM were affected (Figure 2b, Table 3).

Logran decreased growth of Hurricane XT. The most significant impact was on shoot DM at levels above 0.1x of RFR. For the susceptible variety, Nipper, there was a reduction in root and shoot DM at levels above 0.01x of RFR, indicating a lower tolerance to the herbicide (Table 4). As expected, the tolerant Hurricane XT variety grew an average of 160% more biomass (0.47 g DM/plant) than the susceptible variety Nipper (0.18 g DM/plant), which is clearly visible in Figure 3b below.

Lontrel had the largest impact on the growth of the selected crop and pasture species. There was virtually no tolerance by vetch or field peas to rates as low as 0.001x of the RFR (Table 5). Emergence was only affected at the label rate but the plants that emerged at levels below the RFR wilted and dried off 4 weeks after emergence. None of the crops tolerated Lontrel at any higher rate than the control which was the only healthy looking treatment (Figure 4).

What does this mean?

Herbicides that can remain active in the soil for weeks, months or years can be a useful tool in broadacre cropping as it ensures good long term weed control. However, if the herbicide stays in the soil longer than intended it may damage sensitive crop or pasture species sown in subsequent years. Herbicide residues are often too small to be detected by chemical analysis, and the problems for growers are, the difficulty to identify herbicide residues before they cause issues and knowing how seasonal conditions will impact on the rate of herbicide breakdown. In addition, normally safe residue levels may still affect following crops when soil nutrition is low or marginal, when cold and very wet soil conditions prevail, or when soil pathogens or nematodes are present (BASF, 2014). To avoid crop damage and losses, minimum re-cropping intervals (months after application) should be observed. This can be affected by a whole host of factors including the amount of rainfall in the growing season, soil type and pH, and summer rainfall events. Therefore adjustments are necessary, particularly when the season has been drier than normal (such as in 2018), to ensure that herbicide residues have enough time to break down and not cause significant damage to sensitive crops. For products like Intervix and Lontrel, fastest residue breakdown will occur under good soil moisture and warm conditions, which promote microbial activity.

Table 5 Effect of Lontrel on root and shoot dry matter (g/plant) of Gunyah field pea and Volga vetch

Herbicide rate	Shoot dry matter (g/plant)				Root dry matter (g/plant)			
	Pea		Vetch		Pea		Vetch	
0x	1.08	a	1.03	a	2.82	a	0.72	a
0.01x	0.23	b	0.26	b	0.51	b	0.19	b
0.05x	0	c	0.00	c	0	c	0.00	c
0.1x	0	c	0.00	c	0	c	0.00	c
0.5x	0	c	0.00	c	0	c	0.00	c
1x	0	c	0.00	c	0	c	0.00	c
LSD	*0.67*		*0.26*		*1.9*		*0.37*	
p value	*<0.03*		*<0.001*		*<0.05*		*<0.007*	

(a)

(b)

Figure 4 Visual effects of Lontrel residues on Gunyah field pea (a) and Volga vetch (b) Herbicide residue concentration is from left - zero (control) to right – simulated residues at recommended field rate

Soils

Table 6 Herbicide residue lower limit tolerance for wheat, lentil, field pea and vetch

Crop	^ Herbicide residue lower limit tolerance (% RFR)		
	Intervix	Logran	Lontrel
Clearfield wheat (Kord CL)	100%	*	*
Non Clearfield wheat (Gladius)	10%	*	*
Herbicide tolerant lentil (PBA Hurricane)	50%	10%	*
Non herbicide tolerant lentil (Nipper)	10%	1%	*
Field pea (Gunyah)	*	*	0%
Vetch (Volga)	*	*	0%

*^ Tolerance based on effect on shoot dry matter, *Not tested*

For the crops investigated, Kord CL proved to be 100% tolerant to Intervix residues, however, the non-Clearfield variety Gladius was sensitive to residues above 0.1x of the RFR (Table 6). The herbicide tolerant lentil variety Hurricane showed that it is not 100% tolerant of imi herbicide residues as its lower limit was 50%. It has been bred with improved tolerance, and in the pot experiment it has shown that it can be sensitive at higher levels of Intervix residues. This experiment also showed that the tolerance of lentils to sulfonylurea (Logran) is much lower when compared to imidazolinones. Nipper cannot tolerate more than 1% RFR without significant damage occurring. Field pea and vetch are well known to be particularly susceptible to Lontrel residues. For applications over 500 ml/ha, it is not recommended to sow lentils in the season following the application. In this pot experiment there was significant damage to both vetch and field pea at any of the rates investigated.

The susceptibility and tolerance of each of the crop and pasture species investigated will be validated in a replicated field trial in 2019, in two Mallee locations with different rainfall and soil types. Herbicide residues were imposed on 26 July 2018, and with the low rainfall received in the 2018/2019 season there is an expectation that there will be herbicide residue carryover into 2019. Soils will be sampled in autumn 2019 to determine the level of residual herbicides.

The main objective of these trials is to investigate the lower limit level of tolerance of selected crop and pasture species to specific herbicides. The expected outcome is to increase knowledge of the behaviour of herbicides in the soil and the threat the residues pose to below and above ground productivity. In the long-term, better management of herbicides with improved awareness and understanding of how they behave will lead to more sustainable farming systems with improved agricultural productivity, reduced risk of environmental contamination and long-term soil security.

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Acknowledgements

Thanks to the Gum and Buckley family for their enthusiasm in providing soil for pot trials in 2018 and suitable trial sites at their properties for 2019 field trials, and GRDC for funding this trial through the SARDI/GRDC Mallee Bilateral project - Improving sustainable productivity and profitability of Mallee farming systems with a focus on soil improvements (DAS00169-BA).

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Liming to address subsurface acidity at Koppio

Brett Masters and Brian Hughes
PIRSA

RESEARCH

Location
Koppio - Karen, Tyler, Logan & Mitchell Dennis
Rainfall
Av. Annual: 480 mm
Av. GSR: 360 mm (Apr-Oct)
2018 Total: 295 mm
2018 GSR: 247 mm
Yield
Potential: 2.1 t/ha (C) (PIRSA crop monitoring guide 2006)
Actual: 1.2 t/ha
Paddock History
2017: Wheat
2016: Canola
2015: Barley
Soil Type
Shallow ironstone loamy sandy loam on clay: sandy loam A1 to 10 cm, overlying a coarse sandy bleached A2 to between 20 and 30 cm on top of poorly structured yellow/orange clay. Ironstone gravel over 50% abundance in the A2.
Soil Test
Table 2
Plot Size
18 m x 4 m 4 reps
Trial Design
Experimental: complete randomised block.
Yield Limiting Factors
Decile 2/3 GSR in 2018, acidic surface and subsurface layers, high extractable aluminium levels, waterlogging.

Key messages

- **Yield penalty from the sulphur treatment might provide a warning as to the potential impact of further acidification on yield on lower Eyre Peninsula soils.**
- **Yield benefit from application of lime is proving elusive on EP trial sites. Possible reasons for this might be use of varieties with some acidity tolerance in farmer scale trials and it takes some time for neutralisation reaction to take effect.**
- **There are some increased production trends from the ripping treatments (with and without ameliorants), which might suggest compaction as a key constraint on the site.**

Why do the trial?

There are around 186,000 ha (7%) of Eyre Peninsula's agricultural land which has surface soil acidity (0-10 cm depth). A further 500,000 ha (19%) are considered at risk of becoming acidic over the next 10 to 50 years if not treated (Forward and Hughes 2019).

Natural soil acidification rates are accelerated by the growing and removal of agricultural products. Acidification rates are higher in high production systems on low buffering (sandy) soils, particularly in high rainfall areas where nitrate leaching is high. Increased use of nitrogen fertiliser and higher yielding crops have increased the rate of acidification. If not treated by applying liming products, soil acidity can result in:

- Loss of production, particularly for acid-sensitive crop species and varieties. The estimated value of lost agricultural production in the EP region due to acid soils is between \$16 m and \$19 m per year, with most of this (more than 95%) estimated to result from lost crop production (Forward and Hughes 2019).
- Increased leaching of iron, aluminium and other nutrients from the soil, potentially contaminating surface and ground water.
- Reduced soil biological activity resulting in reduced crop fertiliser use efficiency and increased soil acidification.
- Reduced uptake of soil water that can lead to rising water tables and increased soil salinity.

In addition, if surface soil acidity is not treated by applying adequate amounts of lime, it will result in the progressive acidification of subsurface and subsoil layers (pH stratification), which is much more difficult and costly to treat. Around 4% of EP agricultural land is considered to have acidic subsurface layers.

It is estimated that around 21,000 tonnes of lime per year is required to be applied on acid prone soils in EP to balance the annual acidification resulting from agricultural production. An additional 223,000 tonnes of lime is needed to raise the pH of currently acidic soils above the target pH values (5.5 $CaCl_2$ for surface, 5.0 $CaCl_2$ subsurface), which includes approximately 213,000 tonnes of lime for acidic topsoils and about 9,000 tonnes of lime for acidic subsurface soils (10-20 cm depth) (Forward and Hughes 2019).

This trial (funded by GRDC project DAW00252 'Innovative approaches to managing subsoil acidity in the Western Region') aims to measure crop responses from ameliorating acidity in subsurface soil layers by surface application and deep placement of soil conditioners including lime and organic matter.

How was it done?

The trial was established in 2017 on a gently sloping ironstone sandy loam site at Koppio on lower Eyre Peninsula. The trial comprises 11 treatments x 4 replicates consisting of an unmodified control (managed as district practice), a number of surface lime application rates, surface applied sulphur, deep ripping, surface applied lime with ripping and subsurface lime applications, ripping with subsurface lime and organic matter applications (Table 1). Treatments were applied in 2017 only.

Surface rates of lime were based on the standard district application 2.5 t/ha (which is around the average maintenance rate required for 10 years acidification due to agricultural production given current farming practices and average rainfall, and the rate to change pH by 1 unit on this soil type). Double and triple rates were used to see if they provided a faster/ larger pH and crop response and whether they moved deeper into the soil. The subsurface application rate was lower than the surface rate required to increase pH, due to the low buffering capacity of the bleached A2 horizon. The sulphur treatment was applied to provide an indicator of the negative impacts on crop production should the site further acidify.

The trial was sown and managed by the landholder as per the rest of the paddock and was sown with Corack wheat in 2017 and Bonito canola in 2018.

Ripping treatments were applied using a Yeoman's Keyline plough in March 2017 and ripping was undertaken at a depth of between 15 to 20 cm below the soil surface to ensure that the acidic subsurface layer (bleached A2) was ripped into and ameliorants were placed into this layer without bringing up any of the neutral B horizon material. Surface lime and sulphur treatments were spread on the plots by hand. Soil samples were taken to measure the pH on the control plots at the commencement of the trial (Table 2).

Plant emergence counts were taken on all plots 3 to 4 weeks after seeding in both years and dry matter cuts were taken as a measure of peak biomass at flowering. These measurements were taken from either side of a 50 cm ruler at four locations per plot and extrapolated to plant density (plants/m^2) and dry matter (t/ha) respectively. The trial was harvested using the SARDI small plot harvester in both 2017 and 2018 and plot yields extrapolated to t/ha.

What happened?

2017 results

An extremely dry start with opening rains not coming until the last week of June 2017 meant that the paddock was not sown until 4 July 2017. Plant density was variable, particularly on the ripped treatments which had significantly lower plant numbers than the unripped treatments (Figure 1). Plant numbers were also signficantly lower on the treatment where 8 t/ha lime was applied compared to the control and other surface liming treatments.

Plant tissue tests (YEBS) were taken at mid to late tillering in early September 2017. Only the first replicate was sampled so statistical analysis was unable to be undertaken and the results provide a guide only.

Major nutrients

All treatments had plant tissue nitrogen, potassium, sulphur and phosphorus levels above the desired minimum value for wheat. There was little difference in the nitrogen or potassium status between treatments. However, plant tissue phosphorus was lower than the control in most treatments which had lime applied, except when applied in the subsurface in conjunction with deep placed organic matter. Ripped treatments had generally higher sulphur than the control and surface lime treatments (Masters 2018).

Table 1 List of treatments applied in 2017

1.	Nil Control	7.	Surface lime (5 t/ha) + rip+ subsurface lime (2 t/ha)
2.	Surface Lime (2.5 t/ha)	8.	Surface lime (5 t/ha)
3.	Sulphur (elemental S 1 t/ha)	9.	Surface lime (8 t/ha)
4.	Rip	10.	Rip + deep organic matter (10 t/ha pelletised straw)
5.	Rip + subsurface lime (2 t/ha)	11.	Rip + deep organic matter (10 t/ha pelletised straw) + subsurface lime (2 t/ha)
6.	Surface lime (2.5 t/ha) + rip +lime (2 t/ha)		

Table 2 pH of surface and subsurface layers on control plot

Plot #	Surface soil $pH_{(CaCl2)}$	Subsurface $pH_{(CaCl2)}$	Extractable Al (mg/kg)	Extractable Al (mg/kg)
	0-10 cm	10-20 cm	0-10 cm	10-20 cm
8	4.4	4.5	2.79	2.95
17	4.2	4.3	4.58	3.16
27	4.7	4.6	1.24	1.63
36	4.6	4.5	2.14	2.29

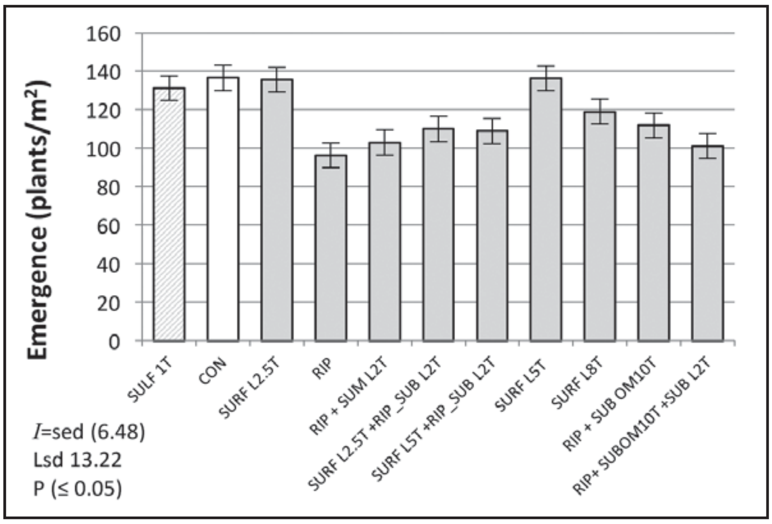

Figure 1 Plant densities (plants/m²) at crop emergence, August 2017

Minor nutrients

Whilst there was little difference in copper and manganese levels in plant tissue between treatments, there appeared to be a general trend of lower iron and zinc levels in the treatments with surface applied lime compared to the control and ripped treatments.

Exchangeable cations

Plant tissue analysis showed a general trend of higher calcium and magnesium % in ripped treatments compared to the control.

Spring biomass

Dry matter cuts were taken on 12 October 2017 at flowering (estimated to be at peak biomass). Dry weights were extrapolated to biomass (t/ha) (Figure 2). Despite lower plant numbers at crop emergence on the ripped treatments compared to the unripped treatments, this did not result in lower spring biomass production, and the only treatment where significant differences in dry matter were observed were in those where organic matter was placed at depth by the ripper.

Grain yield 2017

The site was harvested on 14 December 2017 using the SARDI small plot harvester. A single harvest run (1.5 m wide) was taken along the length of each plot with results extrapolated to grain yield (t/ha). Ripped treatments yielded higher than the control, with rip + subsurface organic matter applications yielding higher than ripping by itself or ripping with subsurface lime applications. Surface lime at 5 t/ha yield had significantly poorer yields than the control.

2018 results

Conditions were again dry during autumn in 2018, with the paddock sown to Bonito canola on 5 May 2018 following rain. Plant emergence counts were undertaken around 4 weeks after seeding. Emergence counts were highly variable with large standard errors, and whilst there were a few treatments that seemed to have higher plant numbers, these were not significantly different to the control and did not show any particular treatment trends (Figure 4).

Despite biomass cuts undertaken at flowering appearing to show a slight trend toward increased dry matter production on the ripped treatments compared to the unripped, these differences were not significant (Figure 5). Large standard errors show the high variability of biomass production in canola.

Grain yield 2018

Despite large variations in crop biomass production there were only small differences between in grain yield between plots at harvest. The only crop yield response which was significantly different to the control was reduced grain yield on the sulphur treatment (Figure 6).

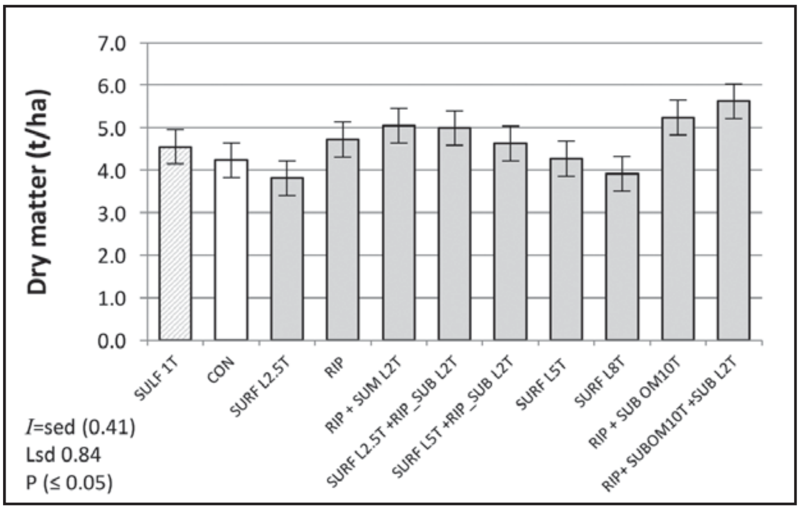

Figure 2 Dry matter (t/ha) at Dennis' site in spring 2017

Soils

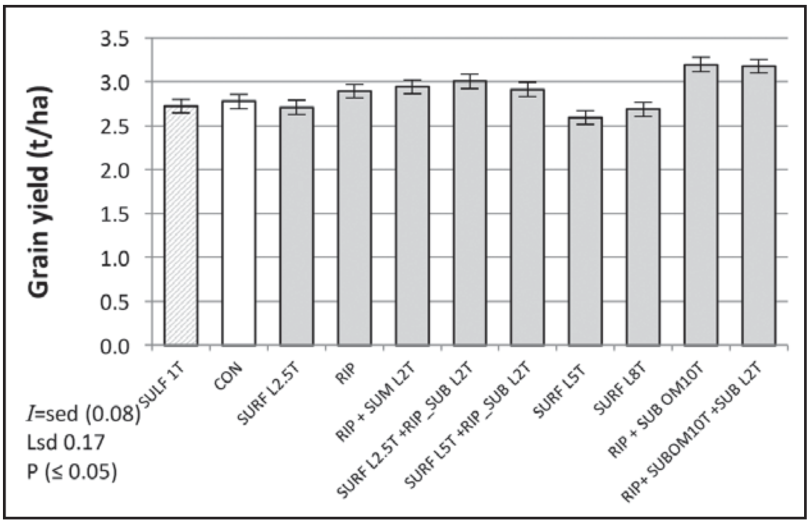

Figure 3 Wheat yield (t/ha) in 2017

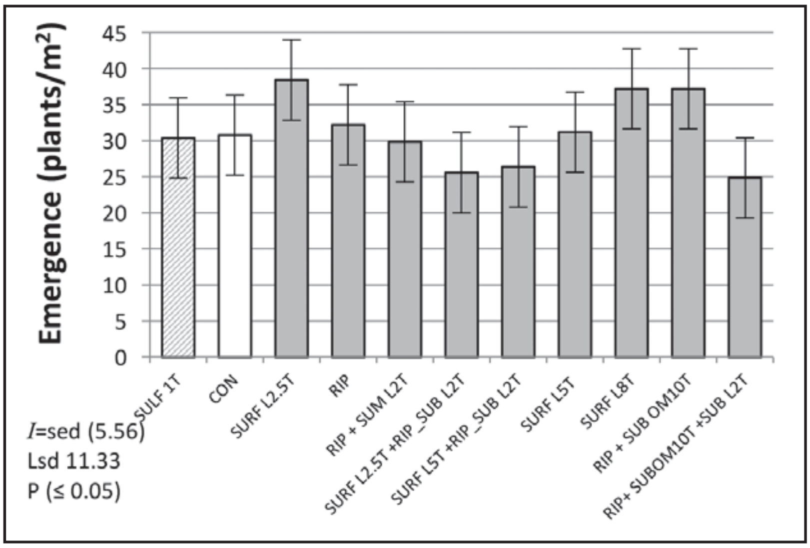

Figure 4 Plant density (plants/m²) at germination, 2018

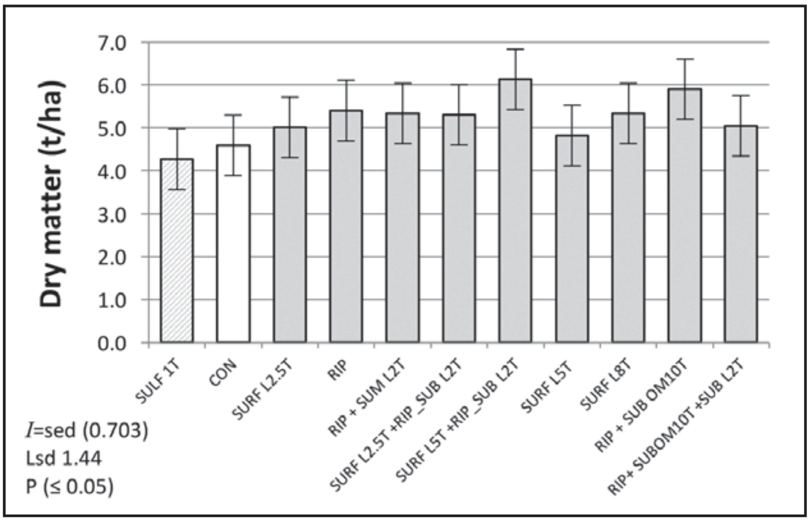

Figure 5 Dry matter (t/ha) at flowering, 2018

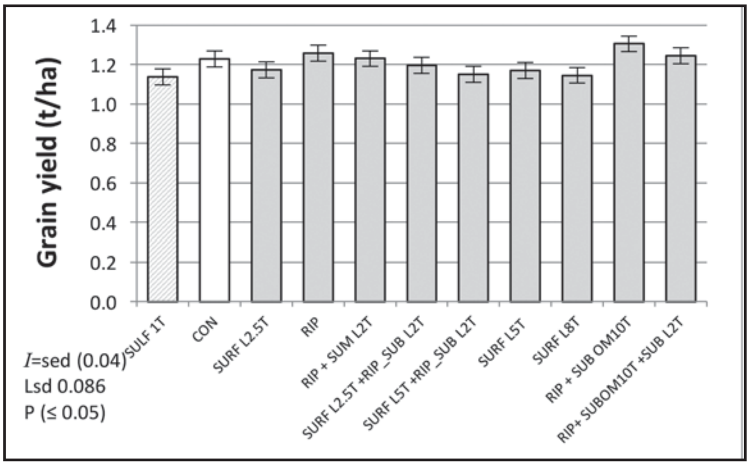

Figure 6 Grain yield (t/ha) in 2018

What does this mean?

Responses to lime treatments were not expected in the first year given that it often takes 12 months or more for the lime to neutralise the acidity. In addition the use of Corack wheat was unlikely to have shown large growth responses as it is a variety that has some tolerance to soil acidity. Similarly, the limited response of canola to the limed treatments in 2018 might have resulted from canola having some tolerance to acidity, with work from NSW (Helen Burns, pers comm November 2018) suggesting that canola roots can growth through acidic soil layers provided that this layer is not greater than 20 cm thick.

In 2017 the ripping treatments had lower plant numbers at crop establishment. This likely due to the severe disturbance of the surface soil by ripping leaving an uneven surface for seeding and crop germination. The large variation in crop emergence across the site in 2018 might have resulted from impact of very dry soil moisture conditions at crop germination on a small seed like canola.

The plant tissue results in 2017 showed some expected trends with lower phosphorus, zinc and iron uptake by plants on those treatments where lime was applied, possibly due to tie up of these nutrients by the lime.

Despite lower plant numbers on the ripped plots at crop establishment compared to unripped plots, this did not affect spring biomass production with only the deep ripped + organic matter treatments having significantly higher biomass. The ripped treatments yielded better than the unripped treatment which is perhaps due to improved crop root development due to ripping through layers of high soil strength and low fertility. It might be useful to undertake some assessment of soil strength on the different treatments to help explain these responses. Placing organic matter at depth gave an increased yield benefit over ripping alone suggesting possible fertility or soil biological activity benefits from the organic matter.

In 2018, although the biomass assessment suggested that there was better dry matter production on ripped treatments compared to unripped, these results were not significant, perhaps pointing to the capacity of canola to cope with some soil acidity under particular conditions. These trends did not carry through to harvest and it is suggested that the penalty compared to the control on the sulphur treatment highlights the impact of further acidification on crop growth.

The trial needs to be monitored to over several years to identify potential;

- further yield declines on the sulphur treatments,
- yield increases when lime treatments become effective,
- impact of ripped treatments once the effect of the initial ripping has settled down,
- pH amelioration down the profile with and without ripping, and
- lasting effect of subsurface organic matter treatments.

Soil sampling will be undertaken in 2019 to measure changes to soil pH. The trial will continue to be monitored in 2019 to assess the impact of the treatments on crop yield.

Acknowledgements

Farmer co-operators; Mark, Karen, Tyler, Logan and Mitchell Dennis.
Project partners; DPIRD WA and PIRSA. This work is funded under the GRDC project 'Innovative approaches to managing subsoil acidity in the Western Region' (DAW00252).

Government of South Australia
Primary Industries and Regions SA

Government of Western Australia
Department of Primary Industries and Regional Development

GRDC
Grains Research & Development Corporation

Soils

Large benefits to wheat performance from adding clay to a sandy soil at Brimpton Lake

David Davenport[1], Mel Fraser[1], Nigel Wilhelm[2] and Brett Masters[1]
[1]Rural Solutions SA, Port Lincoln and Adelaide; [2]SARDI, Waite

Location
Brimpton Lake - Greg & Luke Moroney
Group: LEADA
Rainfall
Av. Annual: 464 mm
Av. GSR: 350 mm (May-Oct)
2018 Total: 374 mm
2018 GSR: 297 mm
Yield
Potential: 6.0 t/ha (W)
Actual: 2.4 t/ha (District average for this soil type)
Paddock History
2017: Lupin
2016: Barley
2015: Wheat
Soil Type
Shallow sand over clay: 0-10 cms light grey, moderately water repellent sand; 10-30 cms bleached white sand; 30-50 cms yellow sodic clay; > 50 cms orange clay with carbonate increasing at depth.
Plot Size
25 m x 2.6 m 4 reps
Trial Design
Experimental: Randomised block
Yield Limiting Factors
Decile 2/3 GSR in 2018, water repellence

Key messages

- **Residual responses to treatments applied in 2014 are still apparent in 2018 with more than double the grain yield on the best treatments compared to the control.**
- **Water repellence resulted in staggered emergence and significantly lower plant numbers on the unclayed treatments. Addition of clay overcame this, resulting in higher plant numbers even with clay mixed into the topsoil only.**
- **Spading increased wheat yields in 2018 by more than 75% over the control, but with no additional benefit from the 2014 addition of clay or high rates of mineral nutrients or lucerne hay.**
- **Spading with lucerne hay in 2014 has provided the greatest cumulative yield across the life of the trial.**

Why do the trial?

Sandy soils on lower Eyre Peninsula (EP) commonly deliver less than half the yield of crops on other soil types. Constraints to production on these soils include water repellence, compaction, low fertility and water holding capacity and low soil organic carbon levels. With support from the EP Farmer Rail Levy, LEADA and PIRSA, a trial site was established in 2014 at Brimpton Lake. The trial aimed to:

- Identify if clay addition increased production,
- Determine if clay mixing using a spader provided better responses than shallow clay incorporation,
- Identify if the addition of nutrients either as fertiliser or as organic matter with or without clay increased yield.

This is one of three trial sites (the others at Karoonda and Cadgee) developed in the New Horizons program and builds on previous research conducted on sands at Ungarra, Edillilie, Wanilla and elsewhere. Soil and production data has been collected annually with the site incorporated into the GRDC-funded Sandy soils project in 2017. Results from these trials have informed development of a site established at Murlong in April 2018.

How was it done?

The site was established in 2014 on a low sandy rise. The trial comprises 12 treatments x 4 replicates consisting of an unmodified control (managed as district practice) and spading with and without a nutrient package and/or organic material, with or without clay (Table 1).

Treatments, applied in 2014 only, were: unmodified control; deep nutrition-banded @ 15-20 cm; shallow clay; shallow clay + nutrient; spading; spading + nutrient; spading + clay; spading + clay + nutrient; spading + lucerne; spading + lucerne + nutrient; spading + clay + lucerne; spading + clay + lucerne + nutrients. Seven key treatments are reported here.

Measurements taken include pre-seeding soil water and mineral nitrogen, crop establishment, biomass at flowering, “tea bag” index, grain yield, yield components, grain quality, post-harvest soil water and crop lower limits.

Table 1 Trial establishment in 2014 and 2018 cropping details

April 2014	Treatments applied	• Clay (40-50 % clay content) applied at an average of 450 t/ha • Spading to 30 cm • OM as lucerne hay @ 10 t/ha • Nutrient package (kg/ha): N 60, P 30, K 50, S 10, Zn 4, Mn 6, Cu 3
10 May 2018	Pre-seeding herbicide	2 L/ha Weedmaster + 2 L/ha TriflurX + 118 g/ha Sakura
	Seeding	Grenade CL wheat @ 80 kg/ha, DAP Zn2 @ 75 kg/ha, SOA @ 126 kg/ha.
4 December 2018	Harvest	

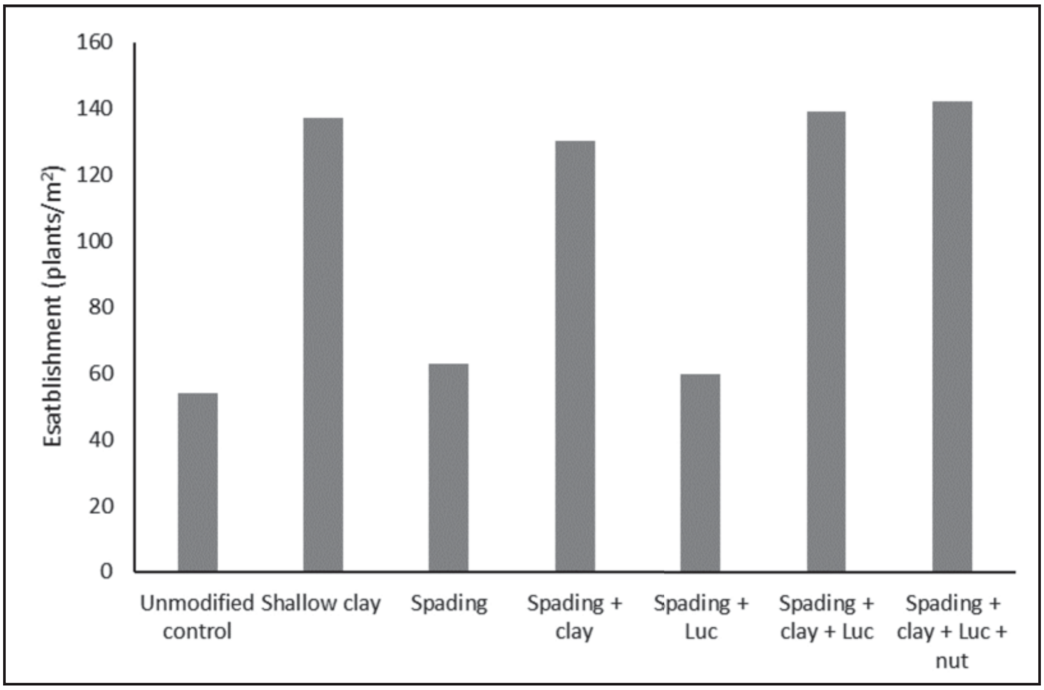

Figure 1 Establishment (plants/m²) of wheat at Brimpton Lake in July 2018, showing the positive impact of clay addition to overcome water repellence and increased establishment (LSD 5%=37)

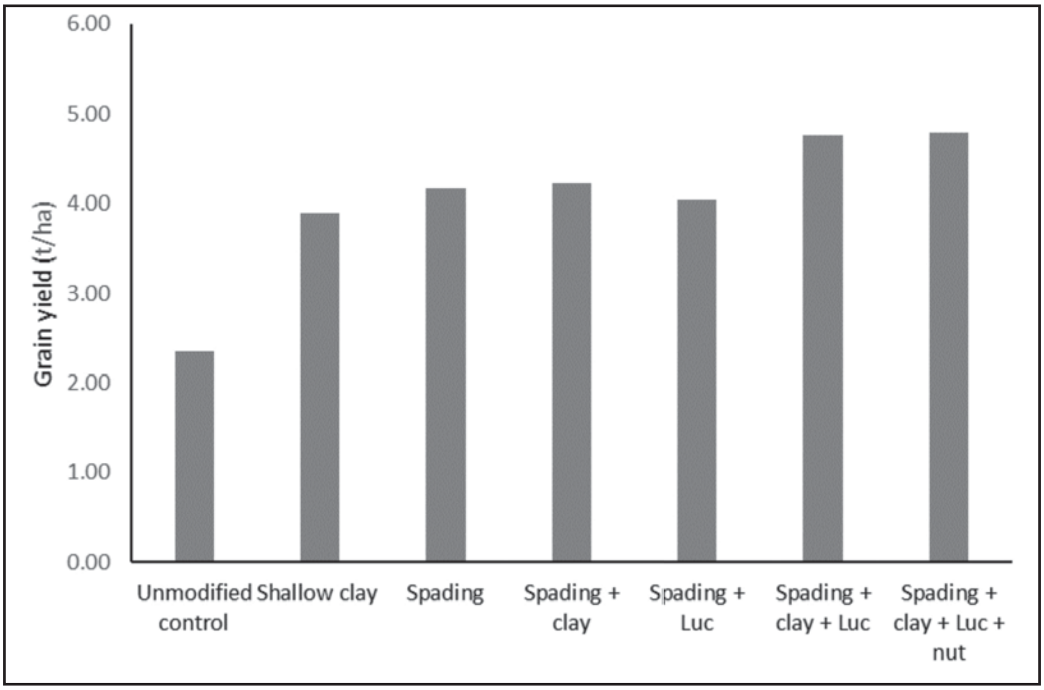

Figure 2 Grain yield (t/ha) at Brimpton Lake in 2018 (LSD 5%=1.05 t/ha)

Soils

Table 2 Annual grain yield (t/ha) for the life of the project (figures in bold are significantly different to the control)

Year	2014	2015	2016	2017	2018	Total yield increase (t/ha)	Yield increase (%)
Crop	wheat	wheat	barley	lupin	wheat		
unmodified (control)	1.40	1.89	3.63	1.07	2.35	10.34	-
deep nutrition	**1.86**	2.18	3.44	1.38	2.85	1.37	13
shallow clay	**2.01**	**2.75**	3.74	1.36	**3.89**	3.41	33
shallow clay + deep nutrition	1.51	2.05	3.71	1.11	3.36	1.40	14
spading	**2.29**	**2.71**	3.67	**1.58**	**4.17**	4.08	39
spading + nutrition	1.56	**2.68**	3.22	**1.97**	**4.52**	3.61	35
spading + clay	**2.48**	**2.85**	3.97	**1.59**	**4.22**	4.77	46
spading + clay + nutrition	**1.69**	**2.48**	3.90	**1.60**	**4.30**	3.63	35
spading + luc	**2.96**	**3.69**	3.94	1.50	**4.04**	5.79	56
spading + luc + nutrition	**2.85**	**3.82**	3.91	**1.66**	**4.58**	6.48	63
spading + clay + luc	**2.62**	**3.42**	3.63	**1.59**	**4.76**	5.68	55
spading + clay + luc + nutrition	**2.81**	**3.38**	4.01	**1.69**	**4.79**	6.34	61

What happened?

A dry start to the season resulted in staggered emergence and lower plant numbers on unclayed treatments (Figure 1).

- Early-mid season vigour was greater on all the clayed treatments (data not shown).
- Although flowering was delayed by 2-3 weeks on the late germinating treatments a cool finish to the season allowed these treatments to fill.
- While physical disturbance from spading appeared to be the major driver of increased grain production (>70%), the surface clay treatment also delivered significantly higher yield compared to the control (Figure 2).
- Some treatments which had poor establishment still produced high grain yields. The spading and spading + lucerne treatments, with lower established plants, still yielded as high as the spading + clay treatment (Figures 1 and 2).

What does this mean?

The 2018 results confirm that treatments addressing major constraints on sands can deliver lasting yield increases. However, the severity of constraints and the subsequent impact on yields will vary depending on seasonal factors and crop type. Analysis of results over the 5 years of the trial show that:

- Physical intervention has provided ongoing yield benefits with spading alone delivering a 4.1 t/ha increase in yield over the 5 years of the trial (Table 2).
- Despite overcoming water repellence and improving plant numbers, clay application has only added an additional 3.4 t/ha.
- The addition of organic matter delivered yield increases in the first 2-3 years following application, but the impact appears to have declined. Overall, the best performing treatment (spading + lucerne + nutrients) delivered a 6.5 t/ha yield increase over the life of the trial.

While this work has delivered large yield increases, these interventions can be costly and further research is required to determine if other cheaper forms of physical intervention (mouldboard ploughing, ripping with inclusion plates, etc.) can provide similar impact and longevity to spading. Also, there is a need to understand the causal relationships to determine if lower rates of organic amendments can provide similar outcomes.

Acknowledgements

Farmer co-operators; Luke and Greg Moroney. This work is funded under the GRDC project "Increasing production on Sandy Soils in low and medium rainfall areas of the Southern region" (CSP00203); a collaboration between the CSIRO, the University of South Australia, the SA state government through Primary Industries and Regions SA, Mallee Sustainable Farming Inc. and AgGrow Agronomy.

Section 6

Section Editor:

Jessica Gunn

SARDI, Minnipa Agricultural Centre

Pastures

Identifying the causes of unreliable nitrogen fixation by medic based pastures

EXTENSION

Fiona Tomney[1], Brian Dzoma[2], Ross Ballard[2], Nigel Wilhelm[1, 2], Ian Richter[1] and Brett Hay[1]

[1]SARDI, Minnipa Agricultural Centre; [2]SARDI, Loxton; [3]SARDI, Waite

Location
Piednippie - Brent Cronin & Family
Rainfall
Av. Annual: 379 mm
Av. GSR: 304 mm
2017 Total: 247 mm
2017 GSR: 199 mm
2016 Total: 485 mm
2016 GSR: 323 mm
2015 Total: 215 mm
2015 GSR: 179 mm
Paddock History
2016: Mace wheat
2015: Mace wheat
2014: Pasture - oats
Soil Type
Calcareous grey sand
Plot Size
8 m x 1.5 m x 3 reps (medic)
6 m x 1.5 m x 3 reps (wheat)

Location
Pinbong - Greg Scholz & Family
Rainfall
Av. Annual: 321 mm
Av. GSR: 227 mm
2017 Total: 307 mm
2017 GSR: 150 mm
2016 Total: 268 mm
2016 GSR: 260 mm
Paddock History
2016: Medic
2015: Barley
2014: Mace wheat
Soil Type
Red sandy loam
Plot Size
6 m x 1.5 m x 3 reps

Key messages

- **Applying phosphorus (P) to a soil with low P reserves when establishing a medic pasture boosts shoot and root dry matter, improves root health and improves nitrogen (N) fixation.**
- **The addition of urea at seeding can reduce nodulation in medic pastures, and hence decrease N fixation.**
- **Residues of the herbicide Logran can severely stunt medic growth.**
- **Applying a full label rate of Agritone 750 late in the growing season decreases pasture production and N fixation in actively growing medic pastures.**
- **Any management practice that reduces medic biomass will reduce N fixation, such as the late application of certain herbicides.**
- **If it is necessary to use herbicides on your medic pastures, it is best to apply them early in the growing season.**
- **In a dry growing season when medic plants are already moisture stressed, herbicides will have little impact on medic production and N fixation.**

Why do the trial?

The broad aim of this three year SAGIT funded project was to investigate if current management tools for medic based pastures, such as herbicides, fertilisers and rhizobial inoculants, are affecting nitrogen (N) fixation by medic pastures under field conditions typical of the upper Eyre Peninsula (EP). These results should also be relevant to other low rainfall Mallee systems where medics are used.

Annual medics (*Medicago spp.*) are self-regenerating legumes that are well-suited to crop rotations on neutral to alkaline soils in the low to medium rainfall areas of southern Australia. They provide highly nutritious feed for livestock, act as a disease break for many cereal root pathogens, and improve soil fertility through N fixation. However, it appears that some of these pastures are not providing sufficient N reserves (as mentioned at local farmer meetings) for the following cereal crops, even where the medic has been quite productive. The longer term decline in protein levels in cereal crops are also of concern.

Location
Minnipa Agricultural Centre - Airport
Rainfall
Av. Annual: 325 mm
Av. GSR: 241 mm
2017 Total: 282 mm
2017 GSR: 155 mm
Paddock History
2016: Mace wheat
2015: Pasture
2014: Kord CLPlus wheat
Soil Type
Red sandy loam
Plot Size
8 m x 1.5 m x 3 reps

Medic pastures are now often sprayed with a range of herbicides and pesticides, both to ensure their productivity as pasture for livestock, and so minimal weed seeds are carried into the following cereal crop. This project examined if commonly used management strategies reduced N fixation by the medic pasture, and consequently mineral N supply to the following crop.

This article summarises three years of these trials. For a detailed summary of the results for the individual years, please refer to the Eyre Peninsula Farming Systems Summary 2015 p 209-213, 2016 p 142-146 and 2017 p 205-208.

How was it done?

There were a total of six field trials conducted over the life of the project, with two replicated field trial experiments established and conducted on the upper EP in 2015, 2016 and 2017. One was on a grey calcareous sandy soil on western EP at Brent Cronin's property at Piednippie, and the other on a red mallee loam of central EP (more typical of mallee environments in SE Australia) at Greg Scholz's property at Pinbong, and in 2017 at the Minnipa Agricultural Centre (MAC) Airport paddock. Medic was sown at 10 kg/ha as soon as a seeding opportunity arose at the start of all trials.

In each season there were post emergent herbicide treatments, chemical residue treatments and nutrition treatments, reported in previous EPFS Summary articles. In the first two years, two medic varieties: Herald and Angel were included, but in 2017 only Herald was grown. A high rate of urea was included as a treatment to simulate how medic would perform if sown into a soil with high N reserves. Herbicide product names are deliberately mentioned in this report as they were the treatments imposed, but we can assume that any other product with the same active ingredient would behave similarly.

Medic establishment and productivity was assessed during the season and fixed N production was monitored in three ways:

1. Scores of viable nodules on roots mid-season.
2. Soil mineral N in the root zone the following autumn.
3. N fixation by ^{15}N natural abundance technique.

Trials were sown as a split plot design in 2015 and 2016, and a completely randomised block design in 2017, with three replications. Trials were re-sown with wheat in the year after medic to assess impact of treatments on subsequent cereal production. Data was analysed using Analysis of Variance in GENSTAT version 18. The least significant differences were based on F probability=0.05.

What happened?

Plant establishment and production

2015

There were only subtle differences in the performance of Herald and its group B herbicide resistant hybrid, Angel, hence results were presented as averages for both varieties. At Piednippie (grey calcareous sand) the mean site plant density was 135 plants/m^2. At Pinbong (mallee soil) the mean plant density was 136 plants/m^2. Plant density was not affected at either site by the treatments imposed. A growth response to P and zinc (Zn) was visible during the early stages of the trial, with the effect more visible at Piednippie. P increased shoot biomass (dry matter (DM)) at both sites. At Piednippie, DM of the control was 0.52 t/ha. Biomass was increased by P to 1.30 t/ha. The Agritone 750 Late herbicide treatment decreased DM to 0.31 t/ha. At Pinbong the DM of the control was 0.96 t/ha. Biomass was increased by P to 1.20 t/ha. Agritone 750 decreased DM to 0.61 t/ha.

No other treatments affected medic growth.

2016

At Piednippie the mean site plant density was 110 plants/m^2. At Pinbong the mean site plant density was 97 plants/m^2. Plant density was not affected at either site by herbicide residues, nor nutrition. At Piednippie a positive early growth response to both rates of P (5 and 10 kg P/ha) was observed. Stunted growth was visible in the Tigrex and Agritone 750 Late herbicide treatments at both trial sites.

At Piednippie, DM in the control was 1.08 t/ha. Biomass was increased by 10 kg of P to 1.59 t/ha. Biomass was decreased by urea to 0.70 t/ha.

At Pinbong, DM in the control was 0.81 t/ha. No treatments increased biomass compared to the control. Agritone 750 Late (0.48 t/ha), Tigrex (0.53 t/ha) and urea @ 100 kg/ha (0.29 t/ha) all decreased the amount of shoot biomass compared to the control.

2017

In very dry seasonal conditions at Minnipa (heavier mallee soil) the mean site plant density was 223 plants/m^2. At Piednippie the mean site plant density was 218 plants/m^2. Plant density was not affected by herbicide residues, nor nutrition.

However, once plants reached the 1-2 trifoliate leaf stage, it became apparent that Logran, applied after seeding to simulate herbicide residues in the soil, was stunting growth, with the effect more pronounced at Minnipa, where most plants failed to develop beyond the first leaf stage.

For other treatments, once plants had progressed to the 2-3 trifoliate leaf stage, P and Zn were observed to have a positive early growth effect, with the effect more visible at Piednippie; but this was not consistent across all treatment replicates. The other residual herbicide treatments of Intervix and Lontrel did not appear to have had any early effect on medic growth.

At Minnipa, DM prior to flowering in the control was 446 kg/ha. Biomass was decreased by the residual Logran treatment to only 34 kg/ha, with the stunted plants never recovering. All other treatments produced biomass similar to the control at this site.

At Piednippie, DM prior to flowering in the control was 134 kg/ha. No treatments reduced biomass compared to the control. In sharp contrast to Minnipa, plants initially stunted by the residual Logran treatment recovered to be similar to the control by the time of sampling. DM was increased by P to 283 kg/ha compared to the control. P + Agritone 750 also increased the DM to 305 kg/ha.

Medic nodulation

Number of nodules per plant averaged 6.7 across all treatments, sites and years. Whilst this is low compared to many other legume species, it is in line with expectations for strand medic which is generally regarded as a 'shy nodulator'. Overall, nodule number increased slightly with the addition of P (from 7.1 to 7.3 nodules per plant) and decreased with the application of Agritone 750 Late (7.1 to 6.7 nodules per plant). This herbicide treatment also increased the percentage of ineffective nodules from 42 to 57%.

2015

At Piednippie, Agritone 750, Ecopar + Agritone 750 and urea lowered the number of effective root nodules and increased the number of ineffective nodules. Agritone 750 Late also increased the number of ineffective nodules compared to the control. P increased the number of effective lateral root nodules, medic shoots and root biomass, and lowered the root health score to 4.1 compared to the control's 6.0 (the lower the score, the healthier the root). The Ecopar + Agritone 750 mix increased the root health score to 7.8.

At Pinbong the number of effective nodules per plant was reduced by Broadstrike, Agritone 750, urea and Ecopar + Agritone 750. These treatments, apart from Broadstrike, resulted in a corresponding increase in the number of ineffective nodules. The Ecopar + Agritone 750 treatment produced the highest number of ineffective nodules with 2.7 compared to the control's 0.9.

2016

At Piednippie, Agritone 750, LVE Agritone and LVE Agritone + Verdict all increased the total number of nodules per plant compared to the control's 7.3. However, these increases were all associated with an increase in the number of ineffective nodules per plant, possibly indicating that the plants' response to the herbicide stress was to produce more nodules to compensate for those that were not working. Agritone 750 and Agritone 750 Late, also increased the number of ineffective nodules per plant compared to the control.

At Pinbong, Agritone 750, Agritone 750 (2) and LVE Agritone all increased the total number of nodules per plant compared to the control's 8.9, however these treatments also increased the number of ineffective root nodules, similar to the results at Piednippie. This may explain why the total number of effective nodules was not affected by any of the treatments.

2017

At Minnipa the total number of nodules per plant averaged 6.3. Nodulation and root weights were not affected by any treatment. Levels of root disease were reasonably low (4.5 out of 15) and did not differ between treatments.

At Piednippie the total number of nodules per plant averaged 7.4. Although treatments had no effect on total nodule number per plant, there were treatment differences in the effectiveness and distribution of nodules on the roots. Generally, LVE Agritone Early and LVE Agritone Late increased the proportion of ineffective nodules to >90%. Similar to Minnipa, the levels of root disease at Piednippie were reasonably low with a score of 5.6 out of 15, and did not differ between treatments.

Nitrogen fixation

2015

At Piednippie the control averaged 9 kg of fixed N/ha in shoots. The amount of fixed N was increased by P to 23 kg/ha. Agritone 750 Late decreased the amount of fixed N to 5 kg/ha. 65% of the N present in medic tops had been fixed.

At Pinbong the control averaged 21 kg of fixed N/ha, however the amount of fixed N/ha did not differ between treatments. More than 90% of the N present in the medic tops had been fixed.

2016

At Piednippie the two controls averaged 25 kg of fixed N/ha. Agritone 750 Late reduced this to 17 kg of fixed N/ha. Urea reduced the amount of N fixed to 15 kg/ha. P at 10 kg/ha increased the amount of fixed N to 39 kg/ha. 83% of the N present in medic tops had been fixed.

Table 1 Total soil mineral N (0-60 cm) kg N/ha in the autumn following the medic trial

2016		2017		2018	
Piednippie	Pinbong	Piednippie	Pinbong	Piednippie	Minnipa
89	101	50	32	48	31

At Pinbong the two controls averaged 23 kg of fixed N/ha. Agritone 750 Late reduced the amount of fixed N to 13 kg/ha. Applying urea to the medic reduced the amount of fixed N to only 7 kg/ha. At Pinbong 92% of the N present in medic tops had been fixed.

2017

At Piednippie the control averaged 2.8 kg of fixed N/ha. P + Agritone 750, P + Tigrex and P, all increased the amount of N fixed/ha to 5.9 kg N/ha, 5.2 kg N/ha and 6.2 kg N/ha respectively. This was probably due to the P producing more biomass, as the amount of N fixed/t DM did not significantly differ from the control for any treatments. The average amount of N fixed in medic tops was 3.9 kg N/ha, and 86% of the N present in medic tops had been fixed.

At Minnipa the control averaged 5.1 kg of fixed N/ha, however the amount of fixed N/ha and the amount of N fixed/t DM did not differ between treatments. The average amount of N fixed in medic tops was 4.1 kg N/ha, and 44% of the N present in medic tops had been fixed.

Soil mineral nitrogen

The trial sites were sampled for mineral N in the root zone in March following each trial year. In 2016, 2017 and 2018, soil mineral N was not affected by treatments in the 0-10 cm or the 10-60 cm zones at any of the trial sites (Table 1).

Wheat

In both 2016 and 2017, the previous years' medic treatments had no effect on plant emergence, late dry matter, or grain protein of the wheat crop sown on the trial sites.

At Pinbong in 2017, the previous year's applications of LVE Agritone + Verdict and Agritone 750 (2) decreased the yield of wheat, even though these treatments had not affected the amount of N fixed by the medic in 2016, nor the amount of soil N present in March 2017.

What does this mean?

One of the reasons for uncertain N contributions from medic pastures could be the late applications of herbicides commonly used for weed control in these pastures. Products such as Agritone 750 at label rates can stunt medics and substantially reduce N fixation. One proviso to this conclusion is that many EP farmers use rates of these herbicides well below recommended label rates, so impacts of these applications may be smaller in commercial situations.

The large benefits of P applications to medic growth and N fixation reinforce the value of sound P nutrition to optimise medic performance.

In general, biomass production and total N contribution from the medic pastures has been low in the establishment year, and likely explains why no significant differences in soil mineral N were able to be measured in the years following the medic pasture. In regenerating medic pasture the treatment impacts on medic growth and N fixation would be greater due to the increased biomass, and therefore likely to have greater impacts on the following cereal crop.

These trials have shown that applying P when establishing medic pastures can substantially increase their productivity, whereas using certain herbicides can significantly damage them, by reducing their ability to grow, maintain effective nodules and fix nitrogen. Herbicides are an essential part of weed management, but their negative effects on medic pasture growth for N production and livestock feed, must be considered from a whole farming systems perspective in relation to the value of the weed control they provide.

Acknowledgements

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Dryland Legume Pasture Systems: Legume adaptation

Fiona Tomney[1], Ross Ballard[2], David Peck[2], Jeff Hill[2], Ian Richter[1] and Naomi Scholz[1]

[1]SARDI, Minnipa Agricultural Centre; [2]SARDI, Waite

RESEARCH

Location
Minnipa Agricultural Centre, paddock S8
Rainfall
Av. Annual: 325 mm
Av. GSR: 241 mm
2018 Total: 269 mm
2018 GSR: 208 mm
Paddock History
2017: Scepter wheat
2016: Medic pasture
2015: Mace Wheat
Soil Type
Red sandy loam
Soil Test
$pH_{(H20)}$ (0-10 cm) 8.4
Plot Size
5 m x 1.5 m x 4 reps

Key messages

- **This is a component of a new five year Rural Research and Development for Profit funded project supported by GRDC, MLA and AWI; and involving Murdoch University, CSIRO, SARDI, Department of Primary Industries and Regional Development; Charles Sturt University and grower groups.**
- **This trial aims to assess a diverse range of annual pasture legumes in order to determine whether there are more productive and persistent options for the drier areas (<400 mm) of the mixed farming zone of southern Australia.**
- **Several new legume species established well under very difficult conditions, but in general were not as productive as the medics or vetch.**
- **In the 2018 growing season, Caliph barrel medic was the best adapted pasture legume species to the conditions at Minnipa.**
- **Astragalus was the best adapted alternative legume species, although it was poorly nodulated.**
- **Zulu arrowleaf clover also performed well, however its peak dry matter production and flowering time may be too late for SA conditions.**

Why do the trial?

Legume pastures have been pivotal to sustainable agricultural development in southern Australia. They provide highly nutritious feed for livestock, act as a disease break for many cereal root pathogens, and improve fertility through nitrogen (N) fixation. Despite these benefits pasture renovation rates remain low and there is opportunity to improve the quality of the pasture base on many low to medium rainfall mixed farms across southern Australia. A diverse range of pasture legume cultivars are currently available to growers and new material is being developed. Some of these legumes, such as the annual medics, are well adapted to alkaline soils and have high levels of hard seed, which allow them to self-regenerate from soil seed reserves after cropping (ley farming system). Other legume cultivars and species are available and being developed that offer improved seed harvestability, are claimed to be better suited to establishment when dry sown and/or provide better nutrition for livestock. Regional evaluation is needed to determine if they are productive and able to persist in drier areas (<400 mm annual rainfall) and on Mallee soil types common to the mixed farming zone of southern Australia.

The Dryland Legume Pasture Systems project will both develop and evaluate a range of pasture legumes together with innovative establishment techniques, measure their downstream benefits to animal and crop production and promote their adoption on mixed farms.

How was it done?

The trial at Minnipa in paddock S8 was arranged in a fully randomised block design, with four replications. Similar trials have been established at Loxton (SA), Piangal (Vic), Kikoira (NSW) and Condobolin (NSW). Data was analysed using Analysis of Variance in GENSTAT version 19. The least significant differences were based on F probability=0.05.

Thirty different pasture legume species (Table 1) were sown to provide a broad range of legume species and attributes. The chosen species are a mixture of old varieties, new varieties, pre-releases, legumes with new traits, and pasture gene-bank selections based on their likely adaptation to rainfall and soil type. Some legume cultivars developed in Western Australia have also been included. These have performed well in WA and more recently in NSW, on their acid-dominant soils, but have had limited evaluation in South Australia where neutral to alkaline soils prevail.

The trial was sown on 27 June under relatively dry conditions, having received 22 mm of rain in the three weeks prior to seeding. All seed was inoculated with the best available strain of rhizobia and lime pelleted before sowing.

Prior to sowing, plots were sampled at 0-10 cm to provide basic soil chemistry and a soil disease profile. The trial site was sprayed before sowing with 1.5 L/ha Weedmaster (Glyphosate) + 80 ml/ha Nail and 300 ml/100 L of LI 700, to kill any naturalized medic plants that had germinated.

The plots were scored for coverage and vigour of growth on 19 September and measured to assess ground cover (using Green Seeker) on 21 September 2018. Plants requiring specific rhizobia: *Astragalus hamosus, Lotus ornithopodiodies* and *Lotus arenarius*; plus the WA cultivars: Margurita French serradella, Casbah biserrula and Bartolo bladder clover, were sampled on 25 September 2018 for measurement of nodulation. Seventeen of the most promising pasture lines were sampled on 26 September 2018 for spring dry matter (DM) production.

Once dried and weighed, the DM samples were sent to Adelaide to be assessed for their nutritive value, however the results are not yet available. Plots were sampled to estimate seed production for all entries on 3 December 2018.

Table 1 Annual pasture legume species sown in the legume adaptation trial at Minnipa in 2018

Pasture species	Notes
Harbinger Strand medic	Old cultivar; West Coast ecotype
Herald Strand medic	Old cultivar; aphid resistant
Jaguar Strand medic	Pod and leaf holding medic from Pristine Forage Technologies
PM250 Strand medic	Powdery mildew resistant; tolerant of sulfonylurea (SU) herbicide residues; specifically developed for SA dryland Mallee farming systems
Pildappa Strand medic	West Coast ecotype, previously considered for release
Caliph Barrel medic	Old cultivar
Cheetah Barrel medic	Pod-holding medic from Pristine Forage Technologies
Sultan SU Barrel medic	Tolerant of SU residues; Boron tolerant; good aphid resistance
Boron Burr medic	Boron tolerant; spineless
Scimitar Burr medic	Old cultivar; spineless
Toreador Disc medic	Developed for sandy soils
Minima medic	Widely naturalised in dry areas; spineless
SARDI Rose Clover	Developed in upper mid-north; not widely sown in Mallee but reports of good performance
Rose Clover Early 35623	Experimental; early flowering and aerial seeded
Bartolo Bladder Clover	WA cultivar; aerial seeded, limited testing in the southern region
Prima Gland Clover	WA cultivar
Zulu Arrowleaf Clover	WA cultivar; earliest flowering line
Tammin Subterranean Clover	New cultivar; high level of hard-seed and tolerant of Red-legged Earth Mite
Balansa Clover X nigrescens clover	Experimental; an aerial seeded hybrid
Volga Common Vetch	Old cultivar
Studenica Common Vetch	New vetch specifically developed for drier areas
Capello Woolly Pod Vetch	Old cultivar
Casbah Biserrula	WA cultivar; with limited testing in the southern region
Margurita French Serradella	WA cultivar suited to acid soils
Santorini Yellow Serradella	WA cultivar; hard-seeded suited to acid soils with limited testing in the southern region
Trigonella balansae 5045	New species, aerial seeded
Trigonella balansae Early 37928	New species, early line; aerial seeded
Astragalus	Experimental Australian Pasture Genebank selection; new rhizobia
Lotus arenarius	Experimental Australian Pasture Genebank selection
Lotus ornithopodiodies	Experimental Australian Pasture Genebank selection

What happened?

Plant establishment and production

Dry (July receiving only 25 mm of rain) and windy conditions delayed plant emergence for approximately one month after sowing. Plant density counts were completed on 7 August (Table 2). Although still small, seedlings of all lines had emerged after 39 mm of rain in first week of August. However, there were differences between the lines for both vigour and number. Many smaller seeded lines such as the Casbah biserrula, Minima medic, Prima gland clover and the hybrid clover (balansa X nigrescens), were less vigorous. Others, including the two lines with the highest plant density counts, Toreador disc medic (177 plants/m^2) and Zulu arrowleaf clover (176 plants/m^2), were very small but healthy, with some seedlings at the one leaf stage. Trigonella 5045 (86 plants/m^2) and the earlier maturing line, Trigonella 37928 (81 plants/m^2) had relatively low plant density counts and were showing signs of moisture stress. Tammin subterranean clover had a very poor emergence with only 42 plants/m^2. This line continued to perform poorly. Caliph barrel medic, the best performing line in the trial, showed early promise with a plant density count of 147 plants/m^2 and healthy looking plots with seedlings at the 1-2 leaf stage.

Following more favourable conditions (38 mm late August) plots were scored (x/100) for coverage and vigour of growth on 19 September. Studenica common vetch had the best score of 90, followed by Caliph barrel medic with 84, with Capello woolly pod vetch, Cheetah barrel medic, Volga common vetch, Sultan barrel Medic, Scimitar burr medic and Toreador disc medic all scoring above 50. PM250 strand medic was just lower with a score of 49. The poorest plots (Margurita French serradella and Tammin subterranean clover) scored less than 10.

Table 2 Plant density (plants/m^2) and growth stage at Minnipa 7 August 2018

Pasture species	Plant density (plants/m^2)	Observation of early growth
Santorini Yellow Serradella	123	Plants small but healthy. Some at 1 leaf.
PM250 Strand Medic	112	Plants fairly small but healthy. Some at 1 leaf.
Studenica Common Vetch	50	Plants vigorous and healthy.
Toreador Disc Medic	177	Plants small but healthy. Some at 1 leaf.
Bartolo Bladder Clover	151	Plants small but OK. Some 1 leaf.
Trigonella 5045	86	Plants still very small. Signs of moisture stress.
Herald Strand Medic	149	Still small but mostly 1 leaf.
Casbah Biserrula	62	Plants still very small. Some 1 leaf.
Pildappa Strand Medic	140	Plants very small but OK. Mostly 1 leaf.
Astragalus Early	112	Small but look healthy. At 1 leaf stage.
Minima Medic	87	Sparse and tiny.
Trigonella Early 37928	81	Very small but some at 1 leaf. Struggling a bit.
Margurita French Serradella	99	Very small but OK. Most at 1 leaf.
Capello Woolly Pod Vetch	59	Recovered really well after rain. Now healthy.
Scimitar Burr Medic	124	Small but vigorous. At 1 leaf stage.
Boron Burr Medic	138	Small but vigorous. At 1 leaf stage.
Lotus ornithopodiodies	138	Very small but looking OK. Some at 1 leaf.
EP Harbinger Strand Medic	131	Uneven in places but doing OK. At 1 leaf.
Tammin Subterranean Clover	42	Struggling. Plants up are OK and at 1 leaf.
Prima Gland Clover	90	Very tiny.
Lotus arenarius	86	Tiny but some starting to show first leaf.
Rose Clover Early 35623	91	Not a lot of plants but doing OK. Mostly 1 leaf.
SARDI Rose Clover	133	A bit uneven in places but doing OK and 1 leaf.
Volga Common Vetch	42	Not a lot of plants but very healthy.
Cheetah Barrel Medic	101	Plots looking healthy. One leaf stage.
Balansa Clover x nigrescens	139	A lot of plants but VERY tiny!
Caliph Barrel Medic	147	Plots looking healthy and at 1-2 leaf stage.
Zulu Arrowleaf Clover	176	Plants very small but OK. Some 1 leaf stage.
Sultan Barrel Medic	146	Plants small but healthy. At 1-2 leaf stage.
Jaguar Strand Medic	99	Plants small but OK. At 1-2 leaf stage.

Pastures

Plots were measured to assess ground cover using a Green Seeker on 21 September. As no lines apart from the Woolly pod vetch had achieved 100% plot coverage, these readings were fairly low. Capello woolly pod vetch, Caliph barrel medic, Studenica common vetch, Cheetah barrel medic and Astragalus had the highest readings.

DM cuts were performed on the seventeen most promising pasture lines (Table 3). Caliph barrel medic and Studenica vetch, produced the highest DM. Caliph barrel medic produced 1.30 t/ha of DM, which was double that of the site mean of 0.65 t/ha. Studenica common vetch produced nearly double the DM of the commonly grown Volga vetch. These results were consistent with earlier observations of ground cover and vigour.

The trial suffered two pest attacks. Firstly by Cowpea aphids which appeared on all lines but at higher density on the vetches, and then by Native Budworm. Fortunately both of these pests were brought under control and did not appear to have caused any lasting damage.

The spring DM cut provided a reasonable assessment of the maximum production of most legumes in the trial, especially the medics; however will have underestimated the production of some species that responded to late rains. The serradellas, biserrula, astragalus, lotus and some clovers, were observed to continue growing after the DM assessment. Most notable, was the growth of Zulu arrowleaf clover which continued throughout November and had not fully senesced at the time of seed production measurements in early December. It would have been interesting to have taken late DM cuts on these later maturing lines, especially on the Zulu arrowleaf clover, although whether the extra production provided by these later flowering and possibly deeper rooted legume species occurs in seasons that lack late rains, needs to be clarified.

Of the medics, the barrel species were the first to senesce, whilst PM250 lasted the longest. In late October it was still reasonably green with lots of flowers.

Table 3 Dry matter (t/ha) measurements at Minnipa 26 September 2018

Pasture species	Dry matter (t/ha)
Caliph Barrel Medic	1.30 a
Studenica Common Vetch	1.20 a
Cheetah Barrel Medic	1.02 b
EP Harbinger Strand Medic	0.93 bc
Toreador Disc Medic	0.88 bcd
Capello Woolly Pod Vetch	0.78 cde
PM250 Strand Medic	0.72 de
Pildappa Strand Medic	0.71 e
Scimitar Burr Medic	0.68 e
Volga Common Vetch	0.68 e
Jaguar Strand Medic	0.65 ef
Astragalus Early	0.50 f
Trigonella 5045	0.30 g
SARDI Rose Clover	0.24 gh
Bartolo Bladder Clover	0.18 gh
Casbah Biserrula	0.12 h
Margurita French Serradella	0.08 h
LSD (P=0.05)	*0.16*

After sampling for DM, it was decided to remove Capello woolly pod vetch from the trial, as there were concerns that it could become an established weed. It was sprayed out with Weedmaster (glyphosate), and hence does not appear as an entry in Table 4.

Seed production was measured on 3 December (Table 4). All lines flowered, with most considered to have set enough seed to enable regeneration next year. Zulu arrowleaf clover had the highest seed production with 44,253 seeds/m^2. Bartolo bladder clover (24,032 seeds/m^2), Casbah biserrula (17,599 seeds/m^2), Prima gland clover (16,182 seeds/m^2), Lotus arenarius (13,219 seeds/m^2) and Astragalus (12,643 seeds/m^2) were also prolific seed producers. The two Vetch lines produced the lowest amount of seed. Regeneration in 2019 will be strongly influenced by the breakdown of hardseed, which varies between legumes and is modified by environmental conditions. Regeneration will be measured as an important aspect of adaptation.

Pasture legume nodulation

Legume species that were likely to be responsive to inoculation, in the absence of any naturalised soil rhizobia, were assessed (six plants per plot) for nodulation (Table 5). Biserrula and the two species of Lotus were found to be adequately nodulated, with these species averaging more than five nodules per plant and not exhibiting any symptoms of nitrogen deficiency. Bladder clover and French serradella were less well nodulated, with individual plants found not to have any nodules. In the case of French serradella, nodulation was similarly erratic at other sites and would probably benefit from an increased rate of inoculation.

The fact that bladder clover was better nodulated at other field sites might be explained by the root disease damage observed on the plants from Minnipa, which may have contributed to the decreased nodulation at this site. Astragalus failed to nodulate, but still managed to grow reasonably well. Further work to overcome the nodulation issue will be needed to enable a valid evaluation of this legume.

What does this mean?

Despite a challenging start with the dry and windy weather, all of the legume lines established, flowered and set some seed; and have therefore provided some indication of their potential in a challenging season.

The ranked performance of the most promising legume species at the Minnipa trial site is shown in Table 6. This was determined by averaging the ranking of each legume for seeding emergence, green seeker, plot vigour, DM and seed production.

Caliph barrel medic has so far proved to be the best adapted cultivar to the conditions on Minnipa Agricultural Centre, producing the most DM, along with Studenica common vetch. It also performed well in terms of plant establishment, plot coverage, vigour and seed production. Studenica common vetch, whilst producing the same amount of DM as Caliph, fell down the rankings for its poor plant establishment and seed production.

Annual medic species occupied the top five positions in the ranking table. These initial rankings may change in the longer term due to factors such as seed set, hard-seeded breakdown and seasonal variations, but nonetheless highlight that the medics performed well under very low rainfall conditions. Several cohorts of improved medic material will be developed further, based on these findings.

Astragalus was one of the better performing alternative legumes, despite issues of poor nodulation. Zulu arrowleaf clover was an excellent performer in terms of plant establishment and seed set, however its peak DM production was in late spring and its flowering time may be too late for low rainfall SA conditions. Bartolo bladder clover had good plant establishment and excellent seed production, however its DM production was very poor. Trigonella was slow to establish and had below average DM production, however it continued to grow vigorously into late spring and produced a large amount of seed.

The potential benefit offered by some of the legume species, including improved ease of seed harvest, improved nutritive value and N-fixation may come at the expense of DM production.

This trial will be allowed to regenerate in 2019. The growth of pasture lines that successfully regenerate will be monitored to determine how their performance differs from the establishment year.

Table 4 Seed assessment measurements at Minnipa 3 December 2018

Pasture species	Average No. of seed pods/m^2	Average No. of seeds/pod	Average No. of seeds/m^2
Santorini Yellow Serradella	691	5	3,404
PM250 Strand Medic	1,344	5	6,181
Studenica Common Vetch	41	4	147
Toreador Disc Medic	1,480	4	5,994
Bartolo Bladder Clover	740	32	24,032
Trigonella 5045	3,254	4	11,795
Herald Strand Medic	1,215	3	3,827
Casbah Biserrula	1,220	14	17,599
Pildappa Strand Medic	1,466	5	7,075
Astragalus Early	617	20	12,643
Minima Medic	2,154	4	7,915
Trigonella Early 37928	2,535	4	9,253
Margurita French Serradella	575	4	2,573
Scimitar Burr Medic	2,001	5	10,106
Boron Burr Medic	1,708	5	8,324
Lotus ornithopodiodies	2,425	4	10,246
EP Harbinger Strand Medic	1,256	5	5,873
Tammin Subterranean Clover	325	2	691
Prima Gland Clover	1,240	13	16,182
Lotus arenarius	1,241	11	13,219
Rose Clover Early 35623	474	9	4,465
SARDI Rose Clover	758	12	9,317
Volga Common Vetch	55	4	227
Cheetah Barrel Medic	1,053	6	6,526
Balansa Clover X nigrescens	643	6	3,935
Caliph Barrel Medic	1,229	6	6,850
Zulu Arrowleaf Clover	495	89	44,253
Sultan Barrel Medic	1,023	6	5,803
Jaguar Strand Medic	910	3	3,003

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Commercial annual legume cultivars are produced by a range of companies and we appreciate them making their cultivars available for this work.

Table 5 Summary of nodulation at Minnipa in 2018

Pasture species	Summary of observations
Bartolo Bladder Clover	Nodulation low, possibly limiting (only at MAC)
Margurita French Serradella	Low nodule number, possibly limiting
Casbah Biserrula	Nodulation satisfactory and not limiting
Lotus ornithopodiodies	Nodulation satisfactory and not limiting
Lotus arenarius	Nodulation satisfactory (but erratic at Lameroo)
Astragalus Early	Nodulation failure, but no signs of N deficiency

Table 6 Ranked performance of legume pasture species at Minnipa (seeding emergence, green seeker, plot vigour, dry matter and seed production)

Rank	Pasture species
1	Caliph Barrel Medic
2	Toreador Disc Medic
2	Scimitar Burr Medic
2	Cheetah Barrel Medic
5	EP Harbinger Strand Medic
6	Astragalus Early
7	Pildappa Strand Medic
8	PM250 Strand Medic
9	Zulu Arrowleaf Clover
10	Bartolo Bladder Clover
11	Studenica Common Vetch
12	SARDI Rose Clover
13	Trigonella 5045
14	Jaguar Strand Medic
14	Volga Common Vetch
16	Casbah Biserrula
17	Margurita French Serradella

Dryland Legume Pasture Systems: Improving nitrogen fixation

Fiona Tomney[1], Ross Ballard[2], David Peck[2], Jeff Hill[2], Ian Richter[1] and Naomi Scholz[1]

[1]SARDI, Minnipa Agricultural Centre; [2]SARDI, Waite

RESEARCH

Location
Minnipa Agricultural Centre, paddock S8
Rainfall
Av. Annual: 325 mm
Av. GSR: 241 mm
2018 Total: 269 mm
2018 GSR: 208 mm
Paddock History
2017: Scepter wheat
2016: Medic pasture
2015: Mace wheat
Soil Type
Red sandy loam
Soil Test
$pH_{(H20)}$ (0-10 cm) 8.4
Plot Size
5 m x 1.5 m x 4 reps

Key messages

- **This trial aims to investigate opportunities for symbiotic improvement.**
- **Inoculation will be critical to the establishment of new legume species, where they have not previously been grown. The extent to which inoculation can still improve medic nodulation is being investigated.**
- **There was no response to medic inoculation in the 2018 trial, even when the inoculation rate was doubled.**
- **Trigonella was better nodulated and produced greater root weights than the medics.**
- **These results cannot be fully interpreted until the N-fixation data becomes available.**
- **Medic breeding lines with improved N-fixation capacity are being developed as part of the Dryland Legume Pasture Systems project and will be tested in 2019.**

Why do the trial?

Legume pastures have been pivotal to sustainable agricultural development in southern Australia. They provide highly nutritious feed for livestock, act as a disease break for many cereal root pathogens, and improve soil fertility through nitrogen (N) fixation. Despite these benefits, pasture renovation rates remain low and there are opportunities to improve the pasture base on many low to medium rainfall mixed farms across southern Australia. There are also reports of poor protein levels in wheat following medic pastures and many reports of poor medic nodulation. Previous work has shown that substantial responses to inoculation are possible in the Victorian Mallee, which is possibly linked to the poor N fixation capacity of some populations of soil rhizobia. The extent to which inoculation can still improve medic nodulation on Eyre Peninsula requires clarification.

The Dryland Legume Pasture Systems (DLPS) project aims to develop recently discovered pasture legumes together with innovative management techniques that benefit animal and crop production and promote their adoption on mixed farms in the low and medium rainfall areas of WA, SA, Vic and southern NSW. One objective within this work program is to increase the amount of fixed N provided by the pasture.

This is a component of a new five year Rural Research and Development for Profit funded project supported by GRDC, MLA and AWI; and involving Murdoch University, CSIRO, SARDI, Department of Primary Industries and Regional Development; Charles Sturt University and grower groups.

How was it done?

The trial at Minnipa in paddock S8 was arranged in a fully randomized block design, with four replications. A similar trial has also been established at Lameroo, SA.

The experiment comprised three inoculation treatments (no rhizobia applied or, standard and high rates of inoculation) and four legumes. The legume species were Herald strand medic, representing an ‘old’ medic; PM250 strand medic, representing a ‘new’ medic; Z2447 medic, a medic with putative improvements in N-fixation capacity; and trigonella, a new legume that is also nodulated by medic rhizobia. The high rate of inoculation was applied as a double rate of recommended label rates of peat inoculant on seed and supplemented with inoculated glass micro-beads also inoculated at double rate and sown at 10 kg/ha with the seed.

Prior to sowing, plots were sampled at 0-10 cm to provide basic soil chemistry and a soil disease profile. The trial site was sprayed prior to sowing with 1.5 L/ha Weedmaster (glyphosate) + 80 ml/ha Nail and 300 ml/100 LI 700 to eradicate any naturalised medic plants already present.

The trial was sown on 27 June under relatively dry conditions, having received only 22 mm of rain in the three weeks prior to seeding.

Trial plots were measured to assess ground cover (using a Green Seeker) on 21 September 2018. As no plots had achieved 100% coverage, these readings were very low. On 24 September twenty plants per plot plus two canola plants, were removed and sent away for assessment of nodulation and determination of shoot and root dry weight. These samples will also be tested for N-fixation using the ^{15}N natural abundance method.

What happened?

In the 2018 season, the 'Improving N Fixation' trial was more negatively affected by the dry and windy weather than the 'Legume Adaptation' trial (EPFS Summary 2018), despite the two trials being in adjacent locations and sown on the same day (27 June). Plant emergence counts were completed on 9 August 2018. Some of the newly emerged seedlings had been buried by soil blown across the plots, with the trigonella particularly affected, resulting in a lower plant density (Table 1). Subsequent rainfall (89 mm in August) boosted the growth and vigor of all plants in the trial.

There was no response to inoculation (Figure 1), even where the inoculation rate on seed was doubled and additional inoculant was provided on glass beads. In total, this provided more than forty times the industry standard of 1000 rhizobia per seed.

Table 1 Legume, inoculation rate, number of rhizobia added and plant density in the N-fixation trial at Minnipa in 2018

Legume	Inoculation rate	Rhizobia (no./seed)	Plant density (plants/m^2)
Trigonella balansae	No rhizobia	0	37
Trigonella medium	Standard	11,000	49
Trigonella high	High*	22,000	47
Z2447 nil	No rhizobia	0	66
Z2447 medium	Standard	15,500	83
Z2447 high	High	33,500	75
PM250 nil	Nil	0	90
PM250 medium	Standard	12,200	103
PM250 high	High	29,000	79
Herald nil	Nil	0	75
Herald medium	Standard	16,750	80
Herald high	High	33,500	116

**High inoculation rate treatments also supplemented with glass beads inoculated with rhizobia.*

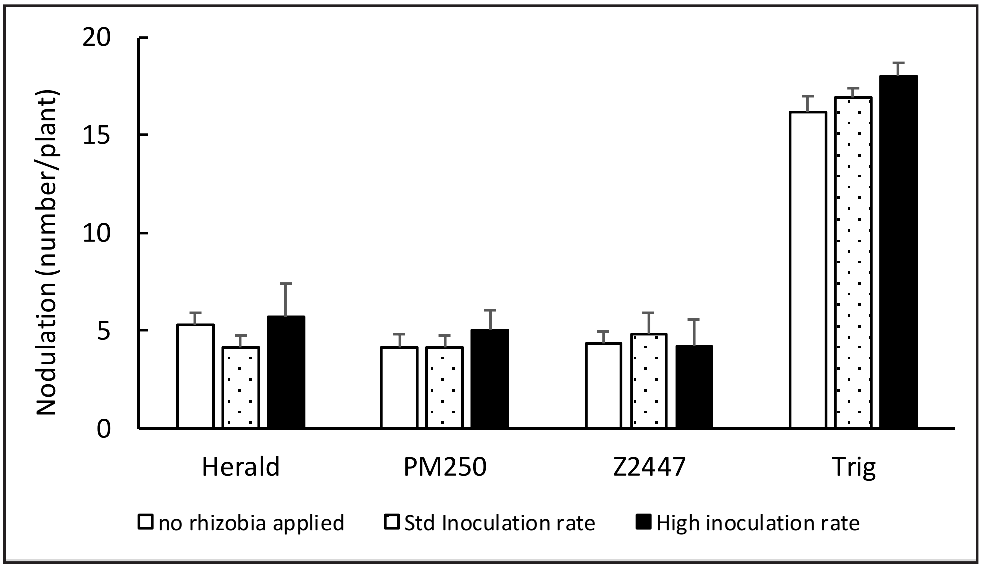

Figure 1 Effect of inoculation treatment on the number of nodules per plant at Minnipa. Bars above columns indicate standard error of the mean. LSD for comparison of all means is 2.6.

For nodulation, the three medics: Herald, PM250 and Z2447 were similar, having 4-5 nodules per plant. The trigonella had a greater number of nodules (≥16 per plant) when compared to the medics. This higher level of nodulation occurred even when reliant on the background rhizobia, i.e. in the nil rhizobia treatment.

The trigonella had 40% greater root weight than the three medic species. Shoot dry weight did not differ between the four legumes.

The results for percent N-fixation are not yet available.

What does this mean?

Plant samples are still being processed to determine N-fixation percentage. This measure is important for interpreting the differences observed in nodulation between the medics and trigonella. It is possible that fewer nodules are needed by the medics because they are more efficient at fixing N than trigonella. Alternatively, the low numbers of nodules on the medics might be limiting the amount of N they are able to fix. The N-fixation data will allow the calculation of fixed N/ha.

The medic line Z2447, previously selected for improved N fixation potential, performed below expectation. It was included in this trial due to seed availability. Other medic lines with improved N-fixation capacity have been developed and will be tested in 2019.

Acknowledgments

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 10 grower groups.

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Pastures

Dryland Legume Pasture Systems: Quantifying benefits of novel legume pastures to livestock production systems

Jessica Gunn (née Crettenden)[1], Ross Ballard[2], David Peck[2] and Naomi Scholz[1]

[1]SARDI, Minnipa Agricultural Centre; [2]SARDI, Waite

Location
Minnipa Agricultural Centre, paddock S8
Rainfall
Av. Annual: 325 mm
Av. GSR: 241 mm
2018 Total: 269 mm
2018 GSR: 208 mm
Paddock History
2017: Scepter wheat
2016: Medic pasture
2015: Mace wheat
Soil Type
Red sandy loam
Soil Test
$pH_{(H20)}$ (0-10 cm) 8.4
Plot Size
6 treatments x 2 ha x 3 reps

Key messages

- **Novel legume species and genotypes have the potential to reduce feed gaps and provide other farming systems and livestock benefits in low to medium rainfall regions of southern Australia.**
- **The five-year large scale grazing systems trial established at Minnipa in 2018 is the main livestock field site for the national Dryland Legume Pasture Systems project. Five annual legume species are being tested.**
- **The priority for this trial in 2018 was to optimise seed set given the poor seasonal conditions, and therefore no grazing was undertaken in the establishment year, but instead will commence with sufficient pasture growth in 2019 to determine the best legume option for livestock production.**

Why do the trial?

In southern Australian mixed farming systems, there are many opportunities for pasture improvement, providing positive impacts to both cropping and livestock systems. Dryland legume pastures are necessary in low to medium rainfall zones to support productive and healthy livestock, along with optimal production in crops following these pastures. The majority of pasture species used in these mixed farming systems are short-lived annuals that complete their lifecycle from winter to early summer, with dry seasonal conditions resulting in a shorter growth window between germination and senescence. This is a major issue for livestock producers in these regions due to unreliable rainfall patterns leading to fluctuating legume growth, and the subsequent impact on feed supply and quality for grazing animals.

Innovative and improved legume species and pasture systems have the potential to fill existing nutrient gaps, thus reducing supplementary feed required for optimum ruminant performance, and maintain or improve livestock productivity through growth rates, fertility or product quality.

The Dryland Legume Pasture Systems (DLPS) project aims to boost profit and reduce risk in medium and low rainfall areas by developing recently discovered pasture legumes together with innovative management techniques that benefit animal and crop production and farm logistics. A theme of the DLPS project involves 'Quantifying the benefits of novel legume pastures to livestock production systems' and aims to maximise the advantages that pastures provide to livestock through increased animal growth and reproduction by extending the period of quality feed and reduced supplementary feeding. The animal systems research within the project will also assess areas of understanding anti-nutritional factors and 'duty of care' for new pasture species, providing opportunities for improved weed management and evaluate the main benefits of novel self-regenerating pasture legumes in crop rotations on animal production, health and welfare.

This theme is a component of a five year Rural R&D for Profit funded project supported by GRDC, MLA and AWI; and involving Murdoch University, CSIRO, SARDI, Department of Primary Industries and Regional Development; Charles Sturt University and grower groups.

A five-year grazing system trial was established at the Minnipa Agricultural Centre (MAC) in 2018 to examine this theme and is the main livestock field site for the DLPS trial in the southern region of Australia.

How was it done?

The large-scale (36 ha) grazing system experiment, measuring pasture production, legume seed bank dynamics and animal benefits from different pasture species was established in paddock South 8 at MAC and fenced in early 2018. The trial, which consists of six treatments arranged in a randomised block design with three replications, with each 'plot' 2 ha in size, was established to allow grazing during pasture phases and on stubbles after harvest in cropping years.

Soil borne disease tests were completed on soils collected on 26 June, with soil sampling for water content, basic nutrition and nitrogen undertaken on 2-3 July. Four permanent sampling points were marked out per treatment area (plot) for future measurements.

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. For this reason, 2018 was intended to be the pasture establishment year with the aim to maximise seed set, followed by pasture regeneration in 2019, wheat in 2020, with options of another crop or pasture phase in 2021, depending on seasonal conditions.

Pasture species for the trial were selected after greenhouse tests of their adaptation to Minnipa soil. Twelve different legume species were tested prior to the 2018 growing season. Some clover, biserrula and serradella varieties were excluded from the trial after these experiments due to poor germination and/or growth. Treatments selected for the field trial were a continuous cereal (control 1, Scepter wheat in 2018), naturalised medic (control 2, sown Harbinger strand medic seed sourced locally), vetch (Volga), strand medic (new powdery mildew resistant and SU herbicide tolerant medic PM250), Trigonella balansae (a new aerial-seeded legume with expected good nodulation, closely related to medic) and clover (SARDI Rose, an aerial seeded variety). Table 1 presents the varieties chosen in addition to sowing information.

Table 1 Sowing information for the large-scale grazing trial at MAC in 2018

Species	Germination (%)	Sowing rate (kg/ha)	Fertiliser DAP (kg/ha)	Inoculation*
Wheat	100	75.0	50	Nil
Naturalised medic	58	8.6	50	RRI128 peat @ 250 g/25 kg seed
Vetch	90	44.4	50	WSM1455 peat @ 250 g/100 kg seed
Strand medic	93	5.0	50	RRI128 peat @ 250 g/25 kg seed
Trigonella	90	4.4	50	RRI128 peat @ 250 g/20 kg seed
Clover	77	7.8	50	WSM1325 peat @ 250 g/50 kg seed

**all inoculation treatments were applied with sticker @ 1.5%, lime and fungicide of 350 g/L Metalaxyl-M (ApronXL 350 ES) @ 1 ml/kg seed*

Sowing was delayed due to lack of rainfall, which was required to allow naturalised medic to germinate at the trial site. A pre-emergent herbicide was used two days prior to sowing (2 L/ha Roundup DST + 40 ml/ha Hammer + 118 g/ha Sakura) to eradicate any naturalised medic plants already present, in order to reduce competition with the sown crop and pasture treatments. The 36 ha site was sown between 5 and 7 of July. Wheat and vetch (5 July) were sown first, followed by Harbinger medic (pasture control) and PM250 medic (6 July) and SARDI Rose Clover and Trigonella (7 July) using a disc pasture seeder. Sowing rates were calculated based on recommended rates, % germinable seed and the amount of seed available for each variety, with an insufficient amount of seed available for the PM250 strand medic (sown @ -0.37 kg/ha of the recommended rate).

Plant emergence dates were recorded and counts were taken on 4 September at each permanent sampling point, recording grass and broadleaved weeds and assessing the density of naturalised medic that germinated. Flowering and pest infestation were both monitored during the growing season. Biomass cuts were undertaken on 29 October for later spring (maximum) dry matter production and pasture composition and estimates of the percentage ground cover were also recorded. The herbage was sub-sampled for both nutritive value and N fixation after processing (these samples will also be tested for N-fixation using the ^{15}N natural abundance method), with both of these measures still being analysed. Soil sampling for water content and nitrogen was undertaken after legume senescence on 17 December. At this time, anthesis biomass and pasture composition was measured and samples were collected for pod count, pod weight and seed weight, and are still being processed.

Given the poor start to the season, late sowing time and aim to maximise seed set of the legumes, grazing was not undertaken on the trial in 2018, however baseline livestock measurements have been recorded on animals that will be used for grazing the trial in the 2019 season.

What happened?

Conditions were dry and dusty on the first day of sowing but improved with 4 mm of rainfall on the second and third days. In total, 12 mm of rainfall was received in the week of sowing, with another 5 mm the following week. The wheat (control) emerged 12 days after sowing, the vetch 14 days after sowing, the medics and clover 18 days after sowing and the Trigonella 20 days after sowing. Windy conditions caused some soil to blow into the sowing furrows, which slowed plant emergence and resulted in patchy germination, particularly with some of the smaller seeded species, including the trigonella and medics. A substantial rainfall total of 86 mm over August consolidated the establishment and supported some pasture growth.

Results of the plant emergence counts undertaken in early September are displayed in Table 2. The amount of naturalised medic that germinated in each treatment has also been recorded, with the amount in some treatments observed to affect the establishment and growth of sown legumes due to competition. The vetch had less plants but more early vigour than other legume species, with the smaller seeded species struggling to push through the soil that had covered the furrows after windy conditions. It was difficult to distinguish between the sown Harbinger medic and the naturalised medic regenerating form soil seed reserves.

Table 2 DLPS large-grazing trial sown legume plant counts, plant size, grass weed counts and naturalised regenerated medic plant counts in early September 2018

Species	Plants/m² average (range)	Plant size average (range)	Av. Grass weeds/m²	Av. Regenerated medic/m²
Scepter wheat	154 (142-164)	Z22 (Z16-23)	0	0.5
Harbinger medic	116 (80-144)	5 cm (3-6 cm)	1.5	6.0
Volga vetch	64 (54-80)	10 cm (4-12 cm)	1.8	8.0
PM250 strand medic	105 (82-146)	4 cm (2-6 cm)	1.0	8.7
Trigonella balansae	153 (122-202)	5 cm (2-10 cm)	0.5	14.7
SARDI Rose clover	152 (78-192)	4 cm (2-6 cm)	2.2	7.0

A mixture of Targa Bolt @ 150 ml/ha, Uptake @ 0.35 L/ha and Clethodim @ 450 ml/ha was applied on 27 August to eradicate grasses. Over 80% of plants were flowering in the medic, vetch and trigonella treatments on the 29 September, with the majority of clover flowering on 2 October and most of the wheat was flowering by the 9 October. Aphids were observed on all species apart from the wheat at the end of September and were sprayed on 2 October with 500 g/ha Pirimicarb. All plots were also sprayed with 250 ml/ha Alpha Scud Elite for native budworm on 10 October. These pests did somewhat supress plant growth, however plants recovered quickly after they were eradicated.

September rainfall was close to average with a total of 29 mm, conversely rainfall for October was well below average with only 7.2 mm received for the month (average 34.1 mm). Despite the low rainfall, all of the legume lines achieved satisfactory flowering and seed-set. The main October rainfall event during the middle of the month extended the growing season of some of the legumes and the wheat, however hot weather in the last week of October sped the anthesis process up rapidly. The natural medic began to senesce in early November with all other species growing until later into the month.

Table 3 presents the trial groundcover and peak legume biomass measurements undertaken in late October, and due to the substantial amount of both grass and broadleaved weeds growing within the treatments (many of which could not be controlled due to unavailability of information on the effect of typical chemicals on some of the legume species), the total weed biomass was sampled also. The percentage groundcover across the trial varied from 38-84%, with plots being reasonably patchy due to early season wind (creating sandy areas) and poor germination in some parts of the 2 ha plots.

Biomass for the wheat control varied quite substantially with some areas of the trial having poorer results, with the slightly better yields from replicate 2 (1.5 t/ha) where the plot was located further down a minor slope than the other replicates (1.28 t/ha in both rep 1 and rep 3).

Table 3 DLPS large grazing trial groundcover, peak legume biomass and grass/broadleaved weed biomass measurements in late October 2018

Species	Groundcover (%)	Peak biomass (t/ha)	Weed biomass (t/ha)
Scepter wheat	59 (42-75)	5.7 (4.2-7)	0
Harbinger medic	61 (38-76)	0.8 (0.5-1.1)	0.2 (0.1-0.4)
Volga vetch	70 (52-84)	1.3 (0.7-2.2)	0.2 (0.1-0.2)
PM250 strand medic	63 (46-78)	0.5 (0.1-0.9)	0.4 (0.1-1.6)
Trigonella balansae	59 (41-71)	0.8 (0-1.4)	0.3 (0.1-0.8)
SARDI Rose clover	63 (49-79)	0.5 (0.1-0.9)	0.4 (0.2-0.7)

The sown Harbinger medic biomass again was difficult to separate from the regenerated medic biomass (the same and similar species) and is therefore likely to be an overestimate. The PM250 medic was observed to have a longer growing season, up to a month longer than the Harbinger medic, therefore 'peak' biomass may have increased after sampling in this variety, which may provide some advantage compared to current medic varieties.

As expected, the vetch had the greatest measured biomass, averaging 1.3 t/ha, however was still quite patchy. The trigonella performed reasonably well in a poor season with 0.8 t/ha of biomass, which had the potential to average higher, however had patchy areas within some sampling points where it failed to germinate, most likely due to the windy conditions and being located near a sandhill outside of the trial (where the sand had blown and covered in many furrows after sowing). The SARDI Rose clover had a similar issue in one of the replicates, averaging 0.5 t/ha of biomass. Both the trigonella and clover had a similar growing season length to the PM250 medic.

What does this mean?

Patchy establishment and poor dry matter production of novel pasture legumes in the large grazing trial was predominantly caused by seasonal conditions in 2018, and meant that the potential benefits of these cultivars have not yet been measured or observed in this study. Successful establishment when renovating pastures with new varieties is essential to maximise seed-set and therefore regeneration in the following year(s). Improved pasture establishment methods have considerable potential to reduce costs and labour requirements, and aid farm logistics, which are not being assessed in this trial, but will be evaluated over the next four years through other research and demonstration components of the DLPS project. The project will address key constraints to the adoption of pasture legumes, including concerns over cost effective and efficient establishment methods, through trials examining establishment techniques (such as summer sowing and twin sowing), cultivars with suitable patterns of hard-seededness breakdown and resilience, mixed species feedbases, the ability of new cultivars to produce seed that can be farmer harvested and pasture technologies that are simple and cheap to implement and manage. These improvements may have assisted in a more successful establishment year of the large grazing trial.

It is likely that there are benefits to be had from some of the new legume varieties in terms of filling feed gaps in the low to medium rainfall zones of southern Australia. Improved nutrition and ruminant reproductive benefits are also possible. The later senescence of some of the novel legumes (e.g. PM250 medic and trigonella) may see them maintain higher nutritional value through senescence and reduce the need for supplementary feeding. Their nutritional value is presently being analysed. Farming systems benefits such as using livestock to remove weeds through selective grazing or nutrient cycling are difficult to quantify, and it is hoped that the DLPS project and this large-grazing trial may be able to provide some answers over the five-year period of study.

The priority for this trial in 2018 was to optimise seed set given the poor seasonal conditions, and therefore no grazing was undertaken on the large trial at Minnipa in 2018. Pastures will be allowed to regenerate in 2019 and livestock will be introduced once there is sufficient feed on offer to determine their performance on the different legume pastures. Wheat will be re-sown in the control plots with vetch planned to be re-sown on the same plots it was grown last season. The production of the legume treatments will be measured under grazing in 2019, with pasture regeneration, growth, composition, observed palatability and duty of care (ensuring that the plant type will not be problematic to livestock health, productivity or product quality) assessed in order to determine which legume species provide the best outcomes for livestock production and are able to persist in the farming system.

Acknowledgments

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 10 grower groups.

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Section Editor:
Fiona Tomney
SARDI, Minnipa Agricultural Centre

Section 7

Livestock

Importance of measuring livestock key performance indicators

Jessica Gunn (née Crettenden)
SARDI, Minnipa Agricultural Centre

INFO

Best practice

Key messages

- **Mixed farming businesses will benefit by using key performance traits to develop a flock of highly efficient sheep.**
- **Animals should be individually measured to determine their performance for the major profit drivers of meat, wool and progeny, and then selected to remain in the flock on this merit for optimum enterprise productivity, and therefore profitability.**

What is the issue?

Current record meat and wool prices are paving the way for substantial profitability growth in enterprises throughout the Australian sheep industry. However, in many mixed farming businesses across southern Australia, including the Eyre Peninsula, livestock are still considered to be an inferior enterprise when compared to the higher investment of time, money and effort into cropping. Progression in the cropping industry can be attributed to the advancement in plant genetics (genotypes) and technologies that enable the grower to measure their crop performance (phenotypes) and manage the cropping system responsively. Unfortunately, there has been poor uptake of this improvement process in the sheep industry, and as a result productivity and efficiency gains remain stagnant in flocks of many mixed enterprises.

To capture potential productivity and profitability gains with current markets, phenotypic traits or key performance indicators (KPI's) that optimise enterprise income should be measured. Businesses that are recording and selecting on animal phenotypes, and introducing new genotypes accordingly, are optimising their productivity and capitalising on the high prices. They have a significant advantage over those who don't measure flock production traits and tolerate substandard livestock to persist in their sheep flocks (referred to as 'passengers').

Why do the trial?

Mixed farming businesses need a system that can develop a highly efficient sheep flock using KPI's. Currently, standard KPI's in livestock enterprises include stocking rate, gross margin per area, cost of production per unit, quantity and quality of meat and wool produced, and profit from livestock trading, wool and meat sales. Generally, emphasis is placed on these measures according to area or whole flock, but the importance of production characteristics from individual animals is often not as valued as it ought to be. For example, profit drivers should be considered by determining the kg of wool produced per kg of animal in a Merino enterprise, or kg of lambs weaned by kg of ewes joined in a self-replacing enterprise, before determining how this fits into profitability per area or enterprise. Efficiencies are gained when you can improve the output per animal for the same cost of production.

Animals should be individually measured to determine their performance regarding phenotypic traits of reproduction, growth rates, wool and meat production, health status and lifetime performance in these areas, including their progeny. They can then be selected to remain in the flock on this production merit, and subsequent profitability.

Table 1 Minnipa Agricultural Centre individual sheep data records (2010-2018)

Year of measurement	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
Birth (0-24 hours)									
Sire pedigree	✓	✓	✓	✓	✓	✓	✓	✓	✓
Dam pedigree	✓		✓	✓	✓	✓	✓	✓	✓
Birth date			✓	✓	✓	✓	✓	✓	✓
Birth weight	✓		✓	✓	✓	✓	✓	✓	✓
Birth type	✓		✓	✓	✓	✓	✓	✓	✓
Lamb vigour			✓	✓	✓	✓	✓	✓	✓
Maternal temperament			✓	✓	✓	✓	✓	✓	✓
Rectal temperature			✓	✓	✓				
Birth mob/paddock		✓	✓	✓	✓	✓	✓	✓	✓
Death date			✓	✓	✓	✓	✓	✓	✓
Cause of death			✓	✓	✓	✓	✓	✓	✓
Marking (6-8 weeks)									
Marking date	✓	✓	✓	✓	✓	✓	✓	✓	✓
Breech & body wrinkle	✓	✓	✓	✓	✓	✓	✓	✓	✓
Weaning (12-14 weeks)									
Weaning date	✓	✓	✓	✓	✓	✓	✓	✓	✓
Weaning weight	✓	✓	✓	✓	✓	✓	✓	✓	✓
Yearling (10-13 months)									
Body weight	✓	✓	✓	✓	✓	✓	✓	✓	✓
Eye muscle depth	✓	✓	✓	✓	✓	✓	✓	✓	✓
Fat depth	✓	✓	✓	✓	✓	✓	✓	✓	✓
Sheep class		✓	✓	✓	✓	✓	✓	✓	✓
Breech & body wrinkle	✓	✓	✓	✓	✓	✓	✓	✓	✓
Fleece weight	✓	✓	✓	✓	✓	✓	✓	✓	✓
Wool quality*	✓	✓	✓	✓	✓	✓	✓	✓	✓
Hogget (13-18 months)									
Body weight	✓	✓	✓	✓	✓	✓	✓	✓	
Horn/Poll		✓	✓	✓		✓	✓	✓	
Sheep class	✓	✓	✓	✓	✓	✓	✓	✓	
Pedigree (DNA)		✓							
Adult (18 months or older) – annual measure									
Body weight	✓	✓	✓	✓	✓	✓	✓	✓	
Sheep class		✓	✓	✓	✓	✓	✓	✓	
Pregnancy scan	✓	✓	✓	✓	✓	✓	✓	✓	
Progeny number	✓	✓	✓	✓	✓	✓	✓	✓	
Rearing number	✓	✓	✓	✓	✓	✓	✓	✓	
Fleece weight	✓					✓	✓	✓	
Wool quality*	✓						✓	✓	

**Wool quality includes (µm, Mic' Dev, S.D., C.V, SpinF, Curv', C.F%, YLD%)*

How was it done?

Individual animal data for the Minnipa Agricultural Centre (MAC) research sheep flock have been captured annually since 2010. The data have been used to benchmark the livestock enterprise, and using KPI's, determine separate animal performance and efficiency within the flock. Measurements collected from the research flock are listed in Table 1.

Analysis has been undertaken on adult ewes born from 2010-2015 and hogget ewes born in 2016 which have recorded at least one pregnancy (therefore have a set of reproductive measures) to give dataset accuracy, i.e. avoids comparing cull or consistently dry animals against pregnant or lactating animals.

What happened?

Table 2 presents the average and range of a series of productive measures from the maiden (2016 drop) and adult (2010-2015) ewe flock at the MAC. The importance of reporting the range of data as well as the average is to show the large differences in production measurements across the flock, demonstrating that some animals are more productive than others, as determined by progeny, wool and meat records.

Using this information can make selection decisions easier within a flock, particularly if the purpose of culling animals is not always obvious. Understanding how individual ewes are performing based on KPI's of the entire flock can assist in choosing the most productive, therefore most profitable animals, which can increase the rate of flock improvement substantially.

Comparing how an animal is expressing traits such as number of progeny, kg of wool or kg of meat per annum against their dry weights (which relates to the amount of feed required by the animal to produce that amount), is one way to analyse the information collected as a KPI. This can be assessed in several different ways.

Table 3 shows a selection of ten ewes from the MAC flock with varying ages and dry weights to represent the range of the best (good) and the worst (poor) production measures. Drops from 2012-2016 have been chosen for the most comprehensive set of information and to compare maiden ewes.

Table 2 Minnipa Agricultural Centre weight, progeny, wool and meat production measures for maiden (2016 drop) and adult (2010-2015 drop) ewes

Measure	Maidens (2016)		Adult Ewes (2010-2015)	
	Average	Range	Average	Range
Weight (kg)				
Dry (joining)	46	37 - 55	68	41 - 100
Wet (scanning)	58	43 - 72	69	44 - 94
Wet (3rd trimester)	59	42 - 77	70	44 - 95
Wet (weaning)	68	50 - 88	75	48 - 111
Progeny				
Total number of lambs born	0.9	0 - 2	2.5	0 - 9
Total number of lambs weaned	0.8	0 - 2	1.9	0 - 9
No. progeny weaned per annum	0.8	0 - 2	0.8	0 - 3
Wool				
Total kg of GFW	10.6	6.2 - 15.3	18.6	2.4 - 38.6
Kg wool per annum	5.3	3.1 - 7.7	5.3	0.8 - 8.9
Meat				
Total kg of lambs weaned per ewe	27	0 - 78	57	0 - 281
Total kg of lambs weaned (-dries*)	39	24 - 78	85	17 - 281
Kg lambs weaned per annum	27	0 - 78	21	0 - 72
Kg lambs weaned per annum (-dries*)	39	24 - 78	31	6 - 72

**minus the ewes which were dry in that particular year*
***average number of years of data for maidens is 1 and adult ewes is 2.4, total average 2.2 years*
****number of animals in maiden group is 109 and adult ewes is 681, total number 790 animals*

Livestock

Table 3 'Good' versus 'poor' ewes in the Minnipa Agricultural Centre flock (2012-2016 drops) in relation to dry weights and KPI's

			Ewe weights (kg)			KPI's per annum		
Category	**Ewe**	**Drop year**	**Av. Dry joining**	**Av. Wet pre-lamb**	**Av. Lactating**	**kg lambs weaned**	**kg wool cut**	**no. progeny weaned**
Good	A	2016	49.0	54.0	65.0	66.0	6.5	2.0
	B	2015	56.6	77.0	69.0	59.0	6.2	2.0
	C	2014	64.6	69.5	64.8	57.0	6.9	2.0
	D	2012	83.4	94.8	91.1	70.3	7.1	2.0
	E	2014	76.1	77.0	68.4	64.5	7.7	2.0
Poor	F	2012	80.2	76.5	88.0	31.0	5.2	0.3
	G	2013	60.2	49.5	61.3	25.0	3.8	0.7
	H	2014	73.2	71.5	72.7	38.0	3.7	0.5
	I	2015	56.4	69.0	72.8	30.0	4.7	0.5
	J	2016	47.5	70.5	73.0	25.0	3.8	1.0

Table 4 'Low' versus 'high' ewe dry weight in the Minnipa Agricultural Centre flock (2012-2016 drops) in relation to dry weights and KPI's

			Ewe weights (kg)			KPI's per annum		
Category	**Ewe**	**Drop year**	**Av. Dry joining**	**Av. Wet pre-lamb**	**Av. Lactating**	**kg lambs weaned**	**kg wool cut**	**no. progeny weaned**
Low	K	2016	37.0	53.0	56.0	26.5	5.7	1.0
	L	2013	59.0	60.3	61.3	31.8	6.9	1.3
	M	2015	49.1	53.0	64.5	35.0	5.2	1.5
	N	2015	49.9	57.0	64.0	32.0	7.0	1.0
	O	2014	53.6	64.0	63.8	29.5	6.7	0.7
High	P*	2016	55.2	58.0	72.5	41.5	5.3	1.0
	Q	2015	71.1	78.0	87.5	38.3	7.5	1.5
	R	2013	84.9	83.3	88.4	21.6	6.2	0.8
	S	2011	87.1	85.0	87.0	23.0	5.2	1.0
	T	2014	85.4	80.0	85.0	30.5	4.2	0.5

******Ewe P is included in the 'high' weight category as it is the heaviest animal in the 2016 drop (maiden ewes)*

The KPI's in Table 3 show that high levels of meat, wool and reproductive production can be achieved with a range of weights, with the MAC flock recording the most productive animals having dry weights between 49 kg to 83.4 kg. These ewes have achieved over 57 kg of lamb weaned, 6.2 kg of greasy wool cut and reared two lambs per annum over the measured period. This is compared to the 'poor' animals that have weaned under 38 kg of lamb, cut under 5.2 kg of wool and weaned one lamb or less per annum, with dry weights ranging from 47.5 kg to 80.2 kg.

As an example, the contrast between ewe A (good) and ewe F (poor) shows that ewe F is almost an extra 30 kg heavier at dry weight, yet is weaning under half the kg of lambs, cutting over a kilogram less wool and weaning less than a quarter of the progeny per annum than ewe A. There are many other comparisons that could be made, but a key trait to observe in Table 3 is the amount of product (meat, wool or progeny) that has been produced per kg of dry ewe, considering the energy (food and water) inputs into that animal. This demonstrates the greater efficiency of some ewes over others, and highlights the importance of measured livestock data.

Another way to assess the information is by likening 'low' versus 'high' ewe dry weights directly with production data and KPI's. Table 4 presents the history of the ten ewes in their age groups with the lowest dry weights, compared to the highest dry weights and how their production measures differ.

Table 4 shows that the lowest dry weight ewes ranged from 37 kg to 59 kg and produced 27-35 kg of lambs weaned, 5-7 kg of wool cut and weaned between 0.7-1.5 lambs per annum. Ewes with the highest dry weight range of 55 kg to 87 kg produced 22-42 kg of lambs weaned, cut between 4.2-7.5 kg of wool and reared 0.5-1.5 lambs per annum.

Using an example from Table 4, the low versus high dry weights of ewes L and R, both dropped in 2013, can be compared by calculating the amount of product that they have produced per 10 kg of body weight. This equates to 5.39 and 2.54 for kg of lambs weaned, 1.17 and 0.73 for kg of wool cut and 0.22 and 0.09 of lambs weaned per annum for the 'low' weight ewe L and 'high' weight ewe R respectively, portraying that greater weight does not necessarily result in additional product.

What does this mean?

Understanding the KPI's in a sheep enterprise is important to ensure that your flock is continually progressing by culling out under-performing animals. Production data can go unnoticed if not measured over several years, which allows poor ewes to remain in the system and can subsequently lead to them breeding meagre progeny. The three KPI's presented in this article were chosen due to their significant impact on overall enterprise profitability. Meat, wool and progeny per head are the major profit drivers of self-replacing enterprises and therefore important traits to measure.

Being 'time-poor' is one of the main reasons for poor uptake of current technologies in the livestock system, however the adeptness at which these traits can be captured using innovative technologies is becoming considerably more efficient and cost-effective. Implementing sheep handling and measuring technologies provides sheep enterprises with the opportunity for optimum productivity, and therefore profitability, with reduced labour intensity.

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Useful resources

Nuffield Farming Scholarships Trust Report - Optimising ewe performance for a productive sheep enterprise and a high quality finished lamb. James Drummond, 2015. Available online at www.nuffield.com.au.

SARDI

SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE

Using standing crops to finish lambs and protect paddock health

Alison Frischke
Birchip Cropping Group

INFO

Key messages

- **Standing crops are a nutritious and profitable feed source to use later in the season for weaning and finishing lambs on.**
- **They provide excellent groundcover and reduce the risk of summer soil erosion, benefiting soil health.**

Why graze standing crops?

Want a good source of paddock feed to look after your lambs? A 'standing crop' can be used to wean and finish off lambs in spring and early summer, while providing benefits to ground cover and soil health.

Mixed farmers have grazed crops for a long time, however, crops are usually grazed when they're green and vegetative during the growing season, or remnant grain and stubble is grazed following harvest. It is not common to graze a crop during its reproductive phase and maturity unless it has failed.

Once pastures turn off in late spring, there can be a feed gap of a few weeks before harvest stubbles are available. For a system that is growing autumn/winter drop lambs with genetic potential for growth rates >300 g/day, the timing of this coincides with the stage that lambs should start to be finished, i.e. high growth rates should be maintained to achieve target sale weights for marketing.

If finishing is later and stubbles can be used, once sheep have grazed the unharvested heads or spilt grain the paddock feed value declines. Large paddocks also mean animals need to walk longer distances to search for grain. Nutrition can then fall short of requirements, and the growth potential of lambs may not be realised unless supplemented.

A 'standing crop' is a crop that has been held as a fodder bank for grazing later in the year, from head emergence and into grain fill. It can be used for high quality feed to wean lambs onto, and to finish lambs between three to six months of age. The standing crop can be a cereal, or a combination of a cereal with a legume or grain supplement which delivers higher protein for growing lambs.

The standing crop can be utilised any time, but care must be taken if introducing animals to the crop once grain has set. Introducing lambs to the crop during head emergence, flowering and early grain fill ensures they are grazing the crop as it matures, and grains develop, so the rumen microbes can gradually adjust to the change in nutrition. Once grain has set, lambs must first be carefully introduced to a full ration of grain before entering the crop to avoid animal health issues (except when grazing oats).

The practice is low cost and low risk. The standing crop is sown and grown as a crop would be for harvest, i.e. locally adapted varieties are sown on time with adequate fertiliser and weed management to maximise dry matter production, as opposed to just 'banging something in' with little or no management. The crop is then assessed in early spring for its best end-use opportunity; responsive decisions are made to graze, cut for hay or harvest the crop based on lamb and grain commodity prices, and seasonal conditions or events such as heat stress or frost that may cause a grain crop to fail.

Risk is also managed by growing the standing crop on winter rainfall, compared with summer crops which are opportunistic and have a greater risk of failure due to limited soil moisture and unreliable summer rainfall.

It's a solution that reduces grain handling and labour costs during spring and summer feedgaps, as the frequency and duration of feeding needed to meet target sale weights can be reduced.

Grazing of senesced pastures and stubble residues during dry months will eventually expose soil to the elements, increasing the chance of wind and water erosion from summer storm events. Because a full standing crop offers greater biomass and can meet the higher nutritional demands needed for lamb production, lambs will reach sale weights faster and can be removed from the property earlier. This relieves the stocking rate pressure over summer months, preserving groundcover levels, and ideally reduces the risk of overgrazing, erosion and soil nutrient loss.

Does it work?

South Australian livestock consultant, San Jolly, has been advocating for growers to use a standing crop for finishing lambs for over 15 years. San herself is a lamb producer and has worked with many growers in South Australia and Victoria to use standing crops to fine tune their lamb finishing systems. Along the way they have learnt which oat or barley varieties are better to graze and how animals should be introduced to make best use of the feed. This includes taking into account the biomass and height of the crop, the willingness of lambs to enter the crop, preference for certain varieties, starch contents of grain and feed introduction implications.

Alan Bennett and daughter Ellen farm in the west Wimmera and have been using standing crops to wean and finish lambs for the past five years. Using different combinations of barley, rye and oats with vetch, lucerne, clover and medic, they've achieved growth rates between 300 – 435 g/head/day with crossbred lambs weaned onto the standing crops. Alan describes it as a great pasture system because it makes management so much easier. Once he's done the planning and has the crop in, he knows that there will be abundant feed to wean lambs on to in August and October, and they can stay there comfortably for eight to 10 weeks.

The advantage of grazing a standing crop to finish lambs is that it is a low risk, proven practice. There is no need to learn new skills - you are already growing crops and have adapted varieties that perform well in your environment – you are just using the crop for a different and highly profitable purpose.

Acknowledgements

In 2019, with the support of the Australian Government's National Landcare Program, grower discussions, demonstrations and economic analysis will present how standing crops can benefit lamb finishing systems and paddock health. This project is funded by the Australian Government's National Landcare Program and delivered by BCG and Mackillop Farm Management Group.

Livestock

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Section Editor:
Amanda Cook
SARDI, Port Lincoln

Section 8

Nutrition

The effect of stubble on nitrogen tie-up and supply - the Mallee experience

Vadakattu Gupta[1], Therese McBeath[1], John Kirkegaard[2], Rick Llewellyn[1], Stasia Kroker[1], Steve Szarvas[2], Bill Davoren[1], Willie Shoobridge[1] and Alan Richardson[2]
[1]CSIRO Agriculture & Food, Waite campus; [2]CSIRO, Agriculture & Food, Canberra

RESEARCH

Key messages

- **Cereal stubble should be thought of as a source of C for microbes, not as a source of N for crops. In the Mallee under no-till systems, only 1-2% of the N requirement of wheat crops is derived from the previous wheat stubble.**
- **N tie-up in cropping soils is only a temporary constraint as the immobilised N will be released through microbial turnover, generally later in the crop season in spring.**
- **N tie-up by cereal residue is not just a problem following incorporation – it also occurs in surface-retained and standing-stubble systems.**
- **Management of tie-up is reasonably straightforward - supply more N (5 kg N for each t/ha of cereal residue) and supply it early to avoid impacts of N tie-up on crop yield and protein.**
- **Urea fertilizer N recovery by the wheat crop it is applied to is <50%, which needs to be considered in fertilizer recommendation programs.**

Background

Carbon availability along with soil moisture are the most limiting constraints of microbial functions in low organic matter Mallee soils. Previous research in the Mallee has shown that the management of biologically available C is the key to improving biological functions including those involved in N mineralisation and availability. Crop residues are one of the major sources of C for soil biota, therefore stubble retention can provide benefits through changes in soil physical, chemical and biological properties which influence carbon turnover, nutrient generation and subsequent availability of nutrients to crops (Gupta and Roget, 2008). Although stubble retention benefits are expected to be realised in all soil types, the magnitude and nature of change in biological functions can vary depending on type and timing of stubble management and is influenced by soil type and environmental factors (e.g. rainfall).

Most dryland farmers in the Mallee retain all, or most of their crop residues to protect the soil, retain soil moisture and maintain soil fertility in the long term. However, a proactive and flexible approach to stubble management that recognises and avoids situations in which stubble can reduce productivity or profitability makes sense, and has been promoted as part of the GRDC Stubble Initiative (Gupta *et al*. 2016; Swan *et al*. 2017). One such situation is where large amounts of retained stubble, especially high C:N ratio cereal stubble, "ties-up" soil N leading to N deficiency in the growing crop that may reduce yield. The timing, extent and consequences of N tie-up are all driven by variable weather events (rainfall and temperature) as well as soil and stubble type, so quite different outcomes may occur from season to season and in different paddocks (Gupta, 2016). In this article we review in simple terms the process of N tie-up (immobilisation) and mineralisation, to understand the factors driving it.

We then provide the results from a 3-year field experiment at Karoonda and other examples from experiments in the southern NSW (both long-term and short-term) that serve to illustrate the process, and the ways in which the negative consequences can be avoided while maintaining the benefits of stubble.

N cycling processes and controlling factors

Nitrogen mineralised from the soil organic matter and crop residues makes a substantial contribution (~50%) to crop N uptake (Angus and Grace, 2017; Gupta, 2016). The rate and timing of N mineralisation regulates plant available mineral N levels in soils and the release of mineral N in soil is regulated by the processes associated with microbial turnover (Figure 1). Microbial activities are also responsible for the conversion of fertilizer N into plant available forms.

The process of N tie-up and release (N-immobilisation and supply)

Farmers are always growing two crops – the above-ground crop (wheat, canola, lupins etc.) is obvious, but the below-ground crop (the microbial biomass, MB) are always growing as well; and like the above-ground crop they need water, warm temperatures and nutrients to grow (there's as much total nutrient in the microbes/ha as in the mature crop, and two thirds are in the top 10 cm of soil!). There are two main differences between these two "crops" – firstly the microbes can't get energy (carbon) from the sun like the above-ground plants, so they rely on crop residues as the source of energy (carbon). Secondly they don't live as long as crops – they can grow, die and decompose again ("turnover") much more quickly than the plants – maybe 2-3 cycles in one growing season of the plant. The microbes are thus immobilising and then mineralising N as the energy sources available to them come and go. In a growing season it is typical for the live microbial biomass to double by consuming carbon in residues and root exudates – but they need mineral nutrients as well. Over the longer-term the dead microbe bodies (containing C, N, P, S) become the stable organic matter (humus) that slowly releases fertility to the soil. In the long-term, crop stubble provides a primary C-source to maintain that long-term fertility, but in the short-term the low N content in the cereal stubble means microbes initially need to use the existing soil mineral N (including fertiliser N) to grow, and compete with the plant for the soil N.

Microbial biomass in soil

Soil microbial biomass (MB) is a storehouse for nutrients, changes in the amount of MB due to management and seasonal variation can exert a significant impact on microbial immobilisation and net N mineralisation. In Australian agricultural soils, MB-C accounts for 1.5 to 3.0% of soil organic C and MB-N 2-5% of total N. The amount of MB varies with soil type and agro-ecological region (Table 1), and is influenced by crop rotation, tillage and stubble management practices that influence microbial populations and the quantity and quality of residues. For example, MB is generally higher after legume and canola crops compared to cereal crops. MB-C:N ratio generally varies between 6.5 and 9 and a wide MB-C:N ratio is shown to be associated with cereal crop residues and rhizosphere soils. Due to the short turnover time of MB in Australian soils, it may only act as a short-term reservoir for nutrients and as a biocatalyst for soil organic matter cycling and N release, in particular in-crop N mineralisation.

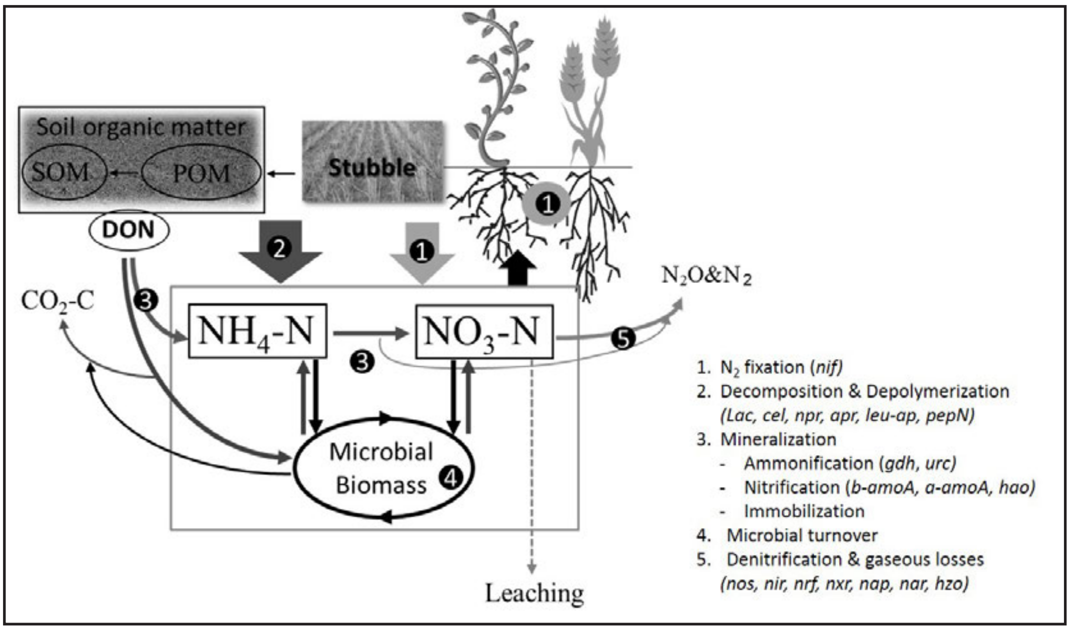

Figure 1. Biological processes involved in nitrogen cycling that influence plant available nitrogen levels in soil. SOM – soil organic matter, DON – dissolved organic nitrogen, POM – particulate organic matter (Gupta, 2016)

As microbial turnover and associated N mineralisation-immobilisation balance is influenced by seasonal conditions, estimation of N supply potential at the beginning of a crop season should include the amount of N in MB and the N that can be mineralised from SOM and crop residues (Gupta 2016, McBeath *et al*. 2015a). Additionally, management practices that increase the size of the MB pool and modulate its turnover could assist with the synchronisation of N mineralisation to crop demand. For example, higher N mineralisation after a legume crop is related to higher MB, whereas greater microbial turnover after canola also contributes to higher N mineralisation (Gupta, 2016).

In modern farming systems, where stubble is retained on the surface and often standing in no-till, controlled traffic systems, less is known about the potential for immobilisation. In GRDC-funded experiments as part of the Stubble Initiative (CSP187, CSP00174, MSF00003, BWD00024), we have been investigating the dynamics of N in stubble-retained systems.

Cereal stubble isn't a major source of N for crops - Tracing N from previous cereal crop stubble

Studies at three sites in southern Australia (Karoonda, Temora and Horsham) have tracked the fate of the N in wheat stubble to determine how valuable it is for successive wheat crops under Australian systems. Stubble labelled with ^{15}N (a stable isotope that can be tracked in the soil) was used to track where the stubble N went.

At the Karoonda experimental site (at Lowaldie, north east of Karoonda, SA), the 2-year continuous wheat experiment was conducted on the dune (sand) with different stubble management treatments using the ^{15}N wheat stubble grown at the site during 2014. The trials were generally sown at the end of May in each year using knife points with 50 kg/ha DAP and 24 kg/ha Urea placed below the seed (P10, N20). Results from the analysis of soils (sowing and harvest), crop residues and plant and grain samples (Figure 2) have indicated that, of the 12 kg/ha of N contained in 2.5 t/ha of retained wheat residue retained in 2014, only 0.75 kg/ha N (5%) was taken up by the first (following) wheat crop (representing 1.2 % of crop requirement); and 0.4 kg/ha N (3.5%) was taken up by the second wheat crop (1% of crop requirement).

The majority of the N after two years remained in the soil organic matter pool (5.5 kg N/ha or 45%) and some remained as undecomposed stubble (20% or 2.4 kg N/ha). Thus we can account for around 73% of the original stubble N in crop (8.5%), soil (45%) and stubble (20%) with 26.5% unaccounted (lost below 50 cm and/or denitrified). Similarly, N in cereal stubble represented only 6% and 1.1% of crop requirements over two years at Temora (7.6% Year 1; 4.4% Year 2) and at Horsham (3% Year 1; 2.5% Year 2), respectively. In similar work carried out in the UK which persisted for 4 years, crop uptake was 6.6%, 3.5%, 2.2% and 2.2% over the 4 years (total of 14.5%), 55% remained in the soil to 70 cm, and 29% was lost from the system (Hart *et al.* 1993).

The successive crops took up 5% (0.75 kg N/ha) and 3.5% (0.4 kg N/ha) of the N derived from the original stubble representing only 1.2% and 1% of the crops requirements. Most of the stubble N remained in the soil (45%) or was lost (27%).

Table 1 Amount of microbial biomass carbon and N supply and immobilisation potentials in the surface 0-10 cm of agricultural soils from the different cropping regions of Australia (Gupta 2016)

Location	**Soil type**	**MB-C**	**N immobilization potential[&]**	**N supply potential[$]**
		(kg C/ha)	**(kg N/ha)**	
Waikerie/Karoonda, SA	Sand and sandy loam	150 - 300	15 - 25	10 - 35
Streaky Bay, SA	Calcarosol - sandy loam	210 - 400	15 - 30	20 - 50
Minnipa, SA	Calcarosol - loam	560 - 710	40 - 51	42 - 56
Appila, SA	Loam	450 - 585	32 - 42	35 - 45
Kerrabee, NSW	Loam	420 - 525	30 - 40	35 - 50
Millewa, NSW	Sandy loam	150 - 310	11 - 22	14 - 31
Condobolin, NSW	Sandy loam	240 - 585	17 - 42	20 - 45
Horsham, Vic	Sandy loam	140 - 230	12 - 24	10 - 16
Horsham, Vic	Clay	546 - 819	39 - 59	52 - 72
Wongan hills, WA	Loamy sand	250 - 350	18 - 25	25 - 40

[&] *N immobilisation potential is estimated assuming an average 50% increase of MB during a growing season.*
[$] *N supply potential is calculated from N in MB plus N mineralization measured in a laboratory aerobic-incubation assay.*

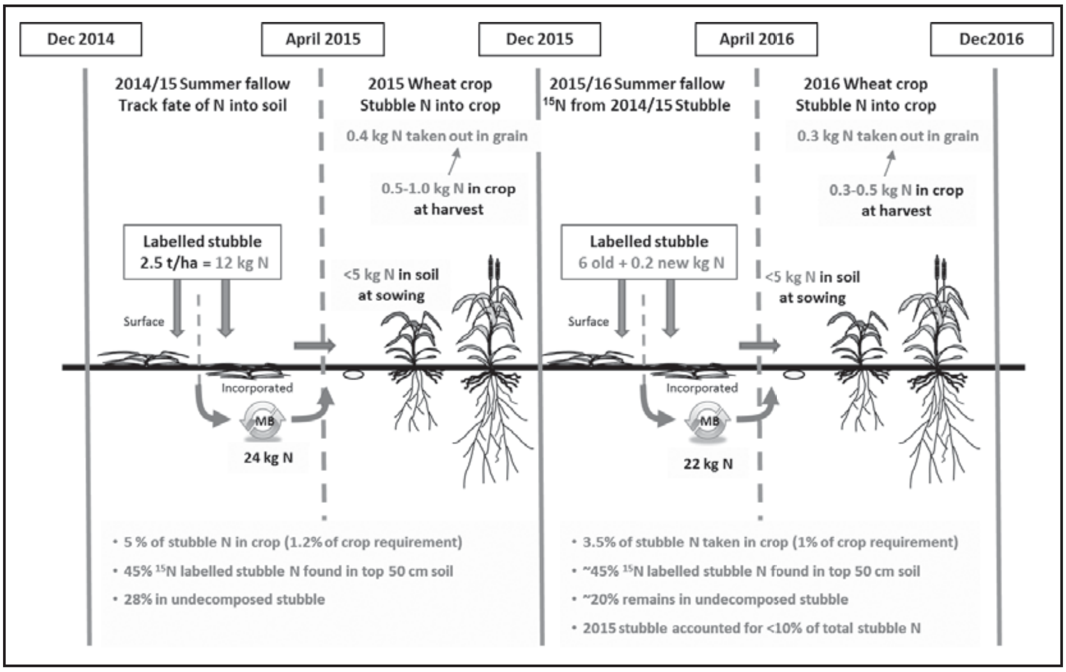

Figure 2 The fate of the N contained in retained wheat stubble over two years in successive wheat crops following the addition of 2.5 t/ha of wheat stubble containing 12 kg/ha N

The main point from the above evidence is that the N in cereal stubble represented only a small percentage of crop requirements over two years and takes some time to be released through the microbial biomass and organic pool into available forms and losses can occur during the process. Therefore, cereal stubble is not a major source of N, instead a source of C for biological activity. In the lower rainfall cropping regions, microbial turnover of C and N from residues is influenced by stubble retention practices and environmental conditions (rainfall; duration of wet and warm soil conditions). Results for soils at sowing indicated that stubble retention generally increased dissolved organic C (DOC) levels in the soil and Standing and Incorporated stubble treatments significantly increased MB C and MB N compared to *No-Stubble (cut low and removed)* and *Surface (cut low and retained)* stubble (Gupta *et al*. 2016).

Can stubble really reduce yield significantly in no-till systems - and is N-tie up a factor?

Five years of experiments across the Mallee environment (Karoonda, Loxton and Ouyen), have investigated the;

i. effect of amount and timing of N fertiliser application according to soil type,
ii. effect of sowing on previous season's crop row (on or near-row) vs. in between rows (inter-row) and
iii. the response to application of fertiliser with the seed or at depth on crop performance, N supply capacity and N uptake. Surface soils collected at sowing and in-crop were analysed for MB, mineral N, N supply potential (NSP) levels (see McBeath *et al*. 2015-17 Mallee Compendium articles for full details).

Sandy soils with low organic matter have lower N supply potential, hence any imbalance between mineralisation to immobilisation plays an important role in early season N nutrition of a cereal crop. The immobilisation (tie-up) potential in the surface (0-10 cm) soils at Karoonda range between 15 to 30 kg N/ha which would mean a considerable amount of N from the upfront fertiliser application would be tied-up, but would be released later in the season through microbial turnover. In the sandy soils, MB acts as a buffer or temporary storage pool for nitrate N protecting it against leaching, especially in the non-crop season and early crop season, conversely lower MB in the No-stubble treatment would result in greater loss of N in the soil profile. With the higher MB and activity levels, soils on the swale have greater N immobilisation potentials (25-40 kg N/ha) compared to soils on the dune (10-25 kg N/ha), especially in cereal stubble retention systems, but they also have higher NSP. While on-row soils have a higher N immobilisation potential (15-25 kg N/ha) compared to off-row soils (10-15 kg N/ha), benefits in terms of crop N uptake have been measured for on-row sown wheat.

Having N fertiliser placed with the seed and 8 cm below (50 kg DAP with seed and 35 kg Urea below) yielded better than all fertiliser 8 cm below the seed at Loxton but not Karoonda in 2017, despite the possibility of a fertiliser toxicity effect of 50 kg DAP/ha with the seed (McBeath *et al*. 2018). This result, combined with other measured responses to fertiliser placement (2016 and 2017) suggest that placement may be a tool to improve N supply in sands where there is immobilisation pressure.

Overall, the timing of N fertiliser has not had a big impact on yield and there was a notable absence of response to N inputs over the five years of experimentation on the swale soil (including a lack of difference between nil and plus N fertiliser, data not shown) (Table 3). However, there have been a few cases (3 of 10 sand site years) where all N at sowing on sands did generate more yield (in the order of 16-40% more yield). Immobilisation is likely to be proportionally more important on these sands and there are seasonal variables that enhance it's effects. However, the overall season type did not appear to drive the effectiveness of the in-season N application and in all cases the in-season N was applied with impending rainfall.

In the lower fertility Mallee soils, N tie-up and associated N deficiency could exacerbate effects of soilborne diseases (e.g. rhizoctonia disease), in turn reducing yields, hence fertilisation strategies should compensate for N tie-up effects, especially in cereal stubble retained systems. However, as stubble retention increases MB and overall N supply potential, long-term stubble management generally improves N supply potential and overall N availability.

Fertiliser N use recovery

Fertiliser N use efficiency is calculated as the amount of urea N applied which ends up in the wheat plant the year the fertiliser is applied. In the 2014 season it was 40% in the Mallee sand at Karoonda, 35% in the clay vertisol at Horsham and 45% in the red brown earth at Temora (Table 4). These results support previous observations from across different regions of Australia i.e. 44$\pm$14% (Angus and Grace, 2017). The fertilizer recovery at Cummins varied depending upon the time of application (Table 4). Fertiliser use efficiency is affected by seasonal conditions and soil properties influencing the conversion of fertiliser N into plant available nitrate and losses of N as gases and N leaching. Immobilisation (tie-up and/or opposite of mineralisation) of N fertiliser in microbial biomass would also affect its immediate availability to plants depending upon the quantity and quality of stubble, tillage and time of application.

Residual fertiliser N use efficiency refers to the amount of N applied to a previous crop which becomes available to the following crop. The residual recovery values varied between sites likely due to the differences in rainfall. For example, at Horsham, in 2015 it was 10% and in 2016 it was 13% (for example 10% of the total amount of N in the 2015 wheat crop was supplied through the residual fertilizer of the 2014 crop) which becomes available in the following year.

Post-sowing N tie-up by retained stubble

The evidence emerging from these studies suggests that even where cereal crop residues are retained on the soil surface (either standing or partially standing) and not incorporated, significant N immobilisation can be detected pre-sowing in some seasons. The extent to which differences emerge are related to seasonal conditions (wet, warm conditions) and to the time period between stubble treatment (burning or grazing) and soil sampling to allow differences to develop. However, even where soil N levels at sowing are similar between retained and burnt treatments (which may result from the fact that burning is done quite late) ongoing N immobilisation post-sowing by the microbes growing in-crop is likely to reduce the N available to crops in retained stubble as compared to those in burnt stubble, especially during the early crop growth period. At the Karoonda site, based on the amount of MB, a 3 t/ha stubble load could cause 19-24 kg N/ha of N tie-up depending upon the seasonal conditions.

Table 3 Wheat yield (t/ha) in response to time of fertilizer application and season (2010-2014) on different soil types in a dune-swale system in the Mallee region of SA (McBeath* et al. *2015)

Fertilizer treatment	2010	2011	2012	2013	2014	*Average*
	Swale					
High N upfront&	4.3	3.4	3.2	1.3	3.0	3.04 (4.1%*)
High N split$	4.0	3.3	2.9	1.4	3.0	2.8
	Mid-slope					
High N upfront	3.2	3.8	**2.4**	1.8	3.5	2.94 (7.3%)
High N split	3.1	3.6	**1.7**	1.8	3.5	2.74
	Dune					
High N upfront	2.0	**2.9**	1.5	1.6	**2.1**	2.02 (9.8%)
High N split	2.0	**2.5**	1.3	1.6	**1.8**	1.84

*Note: Within a season and soil, yield values in response to fertilizer strategies that are significantly different (P<0.05) are shown in bold. *Values in brackets indicate percentage higher than 'High N split' application. &40 kg N/ha with 10 kg P/ha applied at sowing, $N inputs split (9 kg N/ha at sowing and 31 kg N/ha first node with 10 kg P/ha at sowing). The N inputs split treatment received the second application of N at an earlier stage in 2013 and 2014, applied at early tillering.*

Table 4 Recovery of urea fertilizer nitrogen taken up by wheat crops

Location	Soil type	Year applied	1st wheat	2nd wheat	3rd wheat
			% urea fertilizer N applied		
Karoonda, SA	Mallee Sand	2014	40	4	2
Horsham, VIC	Vertisol	2014	35	10	13
Temora, NSW	Red brown earth	2014	45	7	2
Cummins, SA	Cummins Clay	10 April 2015	26	-	-
Cummins, SA	Cummins Clay	14 May 2015	51	-	-

Conclusions

In stubble retained systems in the Mallee, cereal stubble contributes only a small percentage (1-2%) of the N requirement for a following cereal crop, hence it should mainly be considered as a source of C for soil microorganisms. Our studies have confirmed a risk of N-tie up by surface-retained and standing cereal residues which may occur in-season, in addition to during the summer fallow, and so may not be picked up in pre-sowing soil mineral N measurements. Yield penalties from retained residues especially to successive cereal crops could be reduced by reducing the stubble load or by applying more N (~5 kg N per t/ha of cereal residue) and applying it earlier to the following crop. However, it is important to note that stubble provides the much needed C source to soil microorganisms in Australian agricultural soils. Deep placement of the N improved N capture by crops irrespective of stubble management, but was especially effective in stubble-retained situations. Although, N tie-up is a temporary issue, it could be potentially costly as early N supply is important for plant nutrition and health. In summary, N tie-up is an easily managed issue for growers with suitable attention to the management of stubble and N fertiliser.

Acknowledgements

We would especially like to thank Loller family (Karoonda), Darryl Moore (Horsham), O'Connor family (Harden) for the long-term use of their land for these experiments. We acknowledge the expert technical assistance provided by CSIRO staff (Mel Bullock, Tony Swan) and BCG staff (Claire Browne) and Farmlink Research (Paul Bruest, Tony Pratt, Colin Fritsch) who managed and measured the experiments. Funding was provided through GRDC Projects: CSP00174, CSP00186, MSF00003 and BWD00024.

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Nitrogen application at stem elongation, is it worth the investment?

Fabio Arsego[1] and Andrew Ware[2]

[1]SARDI, Minnipa Agricultural Centre/Port Lincoln, [2]formerly SARDI, Port Lincoln

Location
Cummins - Douglas Green, 2018
Rainfall
Av. Annual: 423 mm
Av. GSR: 314 mm
2018 Total: 361 mm
2018 GSR: 288 mm
Yield
Potential yield: 4.4 t/ha (W) (Hancock 2006)
Actual yield 2018: 3.3 t/ha
Paddock History
2017: Banker canola
2016: Buloke barley
2015: Wyalkatchem wheat
Soil Type
Clay loam
Plot Size
5 m x 1.6 m x 3 reps
Trial Design
Randomised complete block
Yield Limiting Factors
None

Location
Lock - Ian Burrows, 2018
Rainfall
Av. Annual: 390 mm
Av. GSR: 294 mm
2018 Total: 311 mm
2018 GSR: 231 mm
Yield
Potential yield 2018: 2.8 t/ha (W) (Hancock 2006)
Actual yield 2018: 3.3 t/ha
Paddock History
2017: Pasture-vetch-clover
2016: Scope barley
2015: Mace loam
Soil Type
Grey sandy loam
Plot Size
5 m x 1.6 m x 3 reps

Key messages

- **At Cummins, an increase of up to 100% grain yield in wheat to 5 t/ha over the control was reached by applying 120 kg N/ha (two split applications of 60 kg/ha each at emergence and before GS31) and extra irrigation (50 mm) at GS31.**
- **At Lock, up to a 19% higher grain yield to 5 t/ha was achieved compared to control by adding extra irrigation (50 mm) at GS31.**
- **At Minnipa, an increase of up to 31% grain yield to 3 t/ha over the control was achieved by adding extra irrigation (50 mm) at GS31 and applying 120 kg N/ha in two split applications of 60 kg/ha at emergence and by GS31.**
- **Water use efficiency (WUE) improved with N fertilisation by GS31 at Minnipa and Cummins.**
- **The split application of 120 kg N by GS31 may only be a good investment in paddocks where crops with N requirements (e.g. canola) were grown in the previous season or soil N at sowing was low (less than 44 kg/ha) and with average or above average seasonal soil moisture at GS31.**

Why do the trial?

This research aims to determine whether adding extra nitrogen (N) at GS31 will bring benefits above the current standard practice of only applying nitrogen at or near sowing in three different Eyre Peninsula (EP) environments.

Every season, growers need to make choices over limited resources in order to maximise their profitability. Nitrogen and water represent two of the key limiting resources which set the grain yield potential of a paddock. The unpredictability of growing season rainfall patterns restricts in-season N applications for EP growers, due to the associated high economic risks. Therefore, less than optimum N rates are applied in many instances, and maximum grain yield gains and optimum protein contents are not reached on occasions where opportunities have existed. Understanding soil water and N dynamics can be useful to determine if extra N application at GS31 is worth the investment in EP dryland farming systems.

How was it done?

Three trials were established at Cummins, Lock and Minnipa to cover a range of rainfalls for the EP region (Table 1). A complete randomised block design was used for the trials with three replicates. At sowing time, 20 mm of extra irrigation was added to the Minnipa and Lock trials to support crop emergence. Mineral N in control treatments were 74 kg/ha for Minnipa, 61 kg/ha for Lock and 44 kg/ha for Cummins. Rainfall from sowing up to harvest was 178 mm at Minnipa, 231 mm at Lock and 288 mm at Cummins.

Location
Minnipa Agricultural Centre, paddock N10, 2018
Rainfall
Av. Annual: 325 mm
Av. GSR: 241 mm
2018 Total: 269 mm
2018 GSR: 208 mm
Yield
Potential yield 2018: 1.6 t/ha (W) (Hancock 2006)
Actual yield 2018: 2.3 t/ha
Paddock History
2017: Scepter wheat
2016: Mace wheat
2015: No seeding
Soil Type
Red sandy clay loam
Plot Size
5 m x 1.6 m x 3 reps

Treatment applications were based on extra N (two applications of 60 kg/ha each of N as urea at emergence and GS31) and water (50 mm applied at the beginning of stem elongation). In this study, four wheat varieties were chosen to cover 50 years of South Australian breeding progress: Halberd (1969), Spear (1984), Mace (2007) and Scepter (2015). Weeds, pests and diseases were controlled following best practices used for National Variety of Trials (NVT).

Soil moisture was measured using the gravimetric method to 90 cm depth, with three replicates per block at sowing, and for each plot at maturity.

Statistical analyses were performed using the R software and the R package ASREML to estimate treatment variability and adjust for spatial trends in the trials. Tukey's test was applied to assess differences between treatments.

What happened?

Water and nitrogen levels up to GS31

As expected, Cummins had high water levels at sowing (214 mm, volumetric) with 165 mm of rainfall by stem elongation, however, N levels were the lowest (44 kg/ha) compared to Lock and Minnipa sites due to the canola rotation in the previous year (Table 2). The dry start at Minnipa and Lock (soil moisture at sowing: 145 and 176 mm, respectively, volumetric water) was supplemented by adding 20 mm of water at sowing (Table 2). Soil N at Minnipa was slightly higher than Lock, however, toxic boron levels were present from 60 cm onwards at the Minnipa site that may have affected N availability (data not shown).

Comparisons of estimated soil water at each site for an average season and for 2018 are important to understand the impact of the extra 50 mm irrigation at GS31 and split applications of N applied at emergence and GS31 across the different locations (Figure 1a-c). The extra water application at Cummins was quite small relative to average moisture conditions at that location (Figure 1a). However, at Lock it increased soil water from low to close to an average soil moisture scenario (Figure 1b, irrigation at GS31 represented by a blue arrow) and to an above-average soil moisture scenario at Minnipa (Figure 1c, irrigation at GS31 represented by the arrow).

Impact of nitrogen and irrigation at GS31 on grain yield

Soil moisture and N levels at sowing may have influenced the impact of extra N and irrigation by GS31 on grain yield (Figure 2a-c). At Cummins, the extra N application produced up to a 90% (Mace, 5.28 t/ha) increase in grain yield over non-fertilised plots (2.78 t/ha, Figure 2a). The high soil moisture and rainfall levels at Cummins may have saturated the soil, making the benefit of extra water at GS31 marginal (Fig. 1c-2a, Table 1).

At Lock, average soil moisture levels produced by 50 mm of extra irrigation at GS31 and 61 kg/ha of N levels at sowing were responsible for the highest grain yield in the trial (Figure 1b-2b). Scepter had a 21% increase in grain yield (4.43 t/ha) by adding extra water at stem elongation over the combination of extra water and N applications (Figure 2b). Similar trends were also observed for the other cultivars (Figure 2b). The negative impact of extra N applied at GS31 on grain yield may have been due to over fertilisation, given the previous rotation consisted of pasture and a lodging effect was observed at harvest.

At Minnipa, the combination of above average soil moisture at GS31 produced by extra irrigation (50 mm) and the extra N in split application by GS31, resulted in the highest grain yield compared to the other treatments and varieties (3.22 t/ha, Figure 2c). Particularly, Mace and Scepter had a 31% and 16% grain yield increase over the control (Figure 2c). N levels at sowing and extra irrigation at GS31 were still beneficial for Scepter and Spear (2.8 t/ha, Figure 2c). These results may indicate that, in specific scenarios (above average soil moisture and extra N at GS31), N and water levels at GS31 may have a synergistic effect on grain yield.

Table 1 Trial details for the three EP environments in 2018

Trial Details	Lock	Minnipa	Cummins
Varieties	Scepter, Mace, Halberd and Spear		
Sowing date	22 May 2018		15 May 2018
Fertiliser	120 kg/ha Triple Super Phosphate		86 kg/ha Triple Super Phosphate
Herbicide	Boxer gold 1.5 L/ha, Avadex® 1.5 L/ha, Treflan 1.7 L/ha, Round up 2 L/ha, Hammer 100 ml/ha, Sulphate Ammonia 800 g/ha		
Harvest date	28 November	13 November	16 November

Table 2 Nitrogen and water details at sowing and rainfall up to stem elongation

Trials	Mineral nitrogen at sowing (kg/ha to 90 cm)	Soil moisture at sowing (mm to 90 cm)	Rainfall up to stem elongation (mm)
Cummins	44	214	165
Lock	61	176 (extra 20 mm irrigation due to the dry start)	56
Minnipa	74	145 (extra 20 mm irrigation due to the dry start)	45

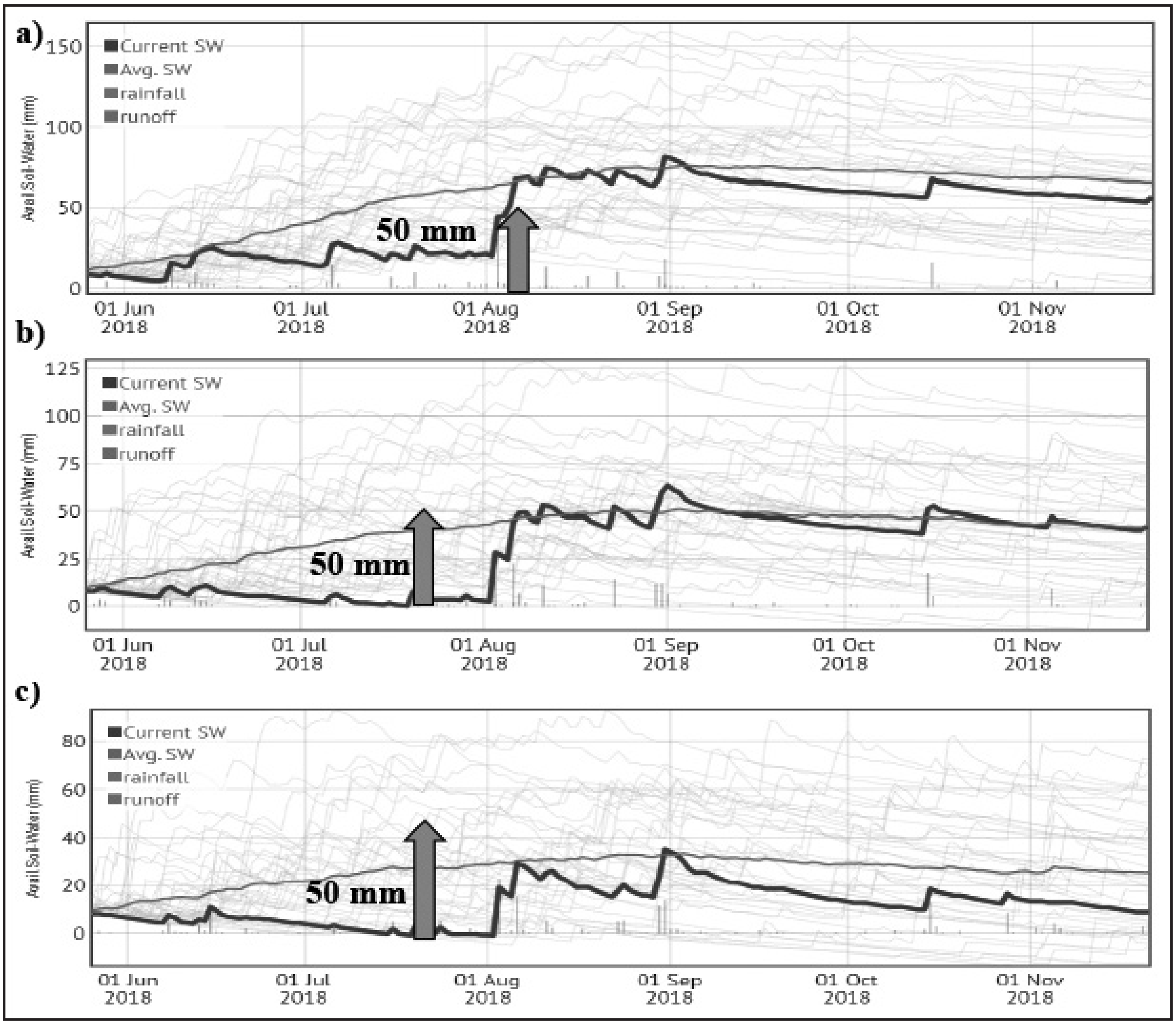

Figure 1 Projections of average historic and actual soil moisture, rainfall and runoff across season 2018 at Cummins (a), Lock (b) and Minnipa (c). The arrow highlights the extra 50 mm irrigation application at stem elongation compared to actual and average historic soil moisture data. Data sourced from: https://climateapp.net.au/A04_HowWetN

Water use efficiency

Across the three trials (Figure 3a-c), N fertilisation had a different impact on water use efficiency (WUE). At Cummins, an increase in WUE was recorded, especially by the newer cultivars. At Lock, the over fertilisation may have affected the WUE response, a higher WUE was found for unfertilised Spear and Scepter (Figure 3b). As previously observed for grain yield (Figure 2c), a higher WUE was assessed from the interaction of the newer cultivars with N and water application at GS31 at Minnipa (Figure 3c). Older varieties had either an opposite water by N interaction (Halberd, Figure 3c) or an increased WUE only due to irrigation at GS31 (Spear, Figure 3c).

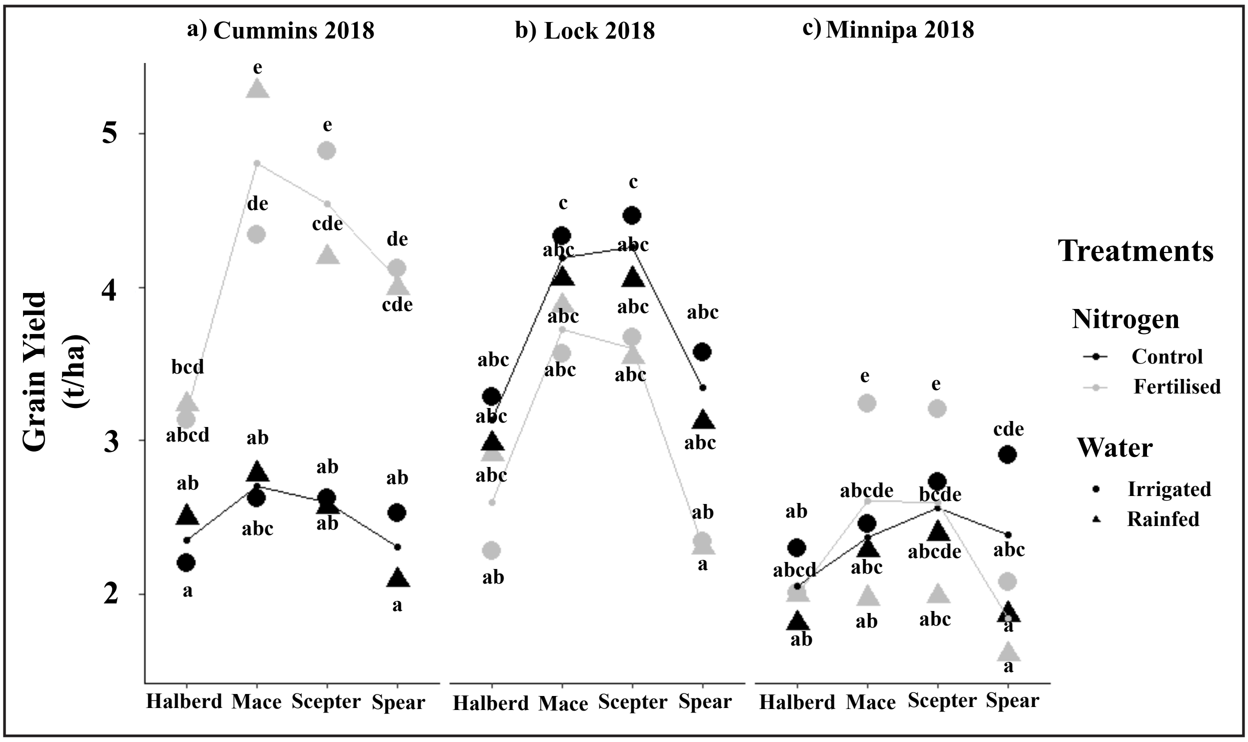

Figure 2 Grain yield (t/ha) of Halberd, Spear, Scepter and Mace at Cummins (a), Lock (b) and Minnipa 2018 (c) in 2018

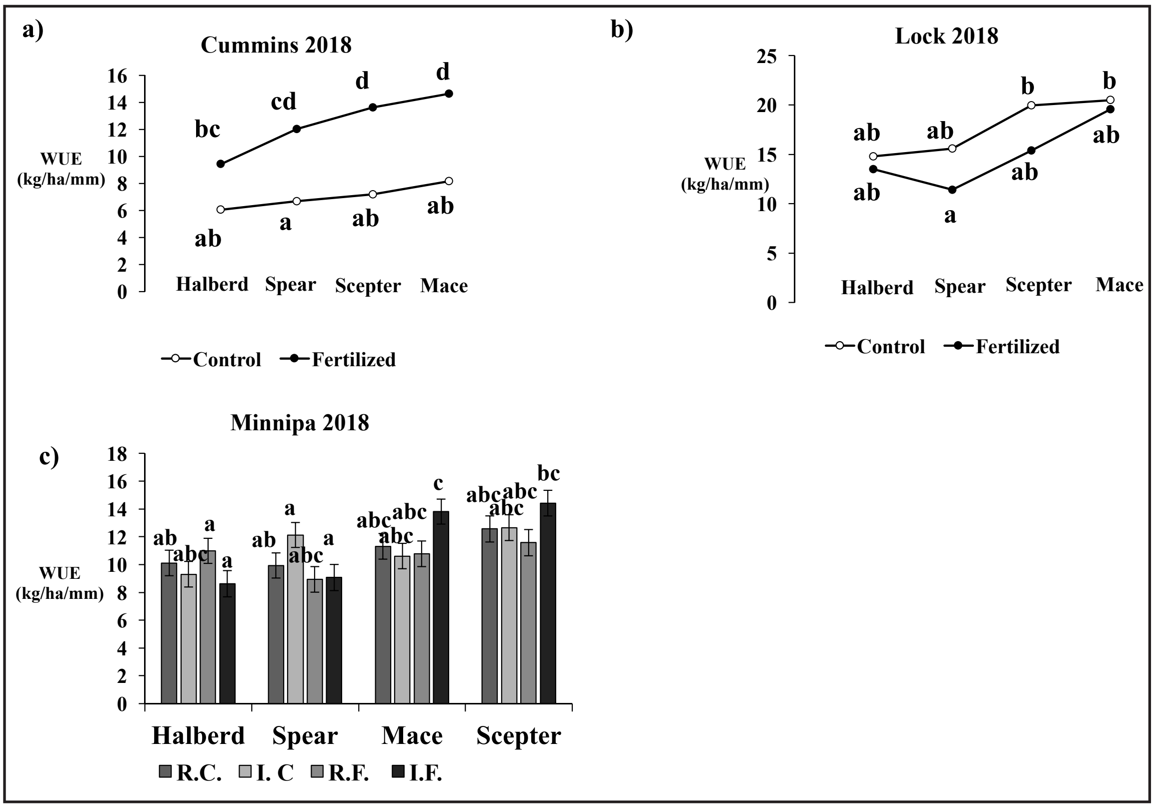

Figure 3 Water use efficiency (WUE) kg/ha/mm across Cummins (a), Lock (b) and Minnipa (c) in 2018

R.C. = Rainfed and no extra N at stem elongation, R.F. = Rainfed and extra N at stem elongation, I.C. = Irrigated and no extra N at stem elongation, I.F. = Irrigated and extra N at stem elongation.

What does this mean?

In this study, three common EP scenarios were considered: high (Cummins), middle (Lock) and low (Minnipa) yielding locations (Fig. 2a-c) to evaluate the possibility of applying extra N at GS31. At Cummins, paddocks with canola as the previous crop and average seasonal soil moisture, an extra 120 kg/ha of N in split application by GS31 achieved up to a 90% increase grain yield over an unfertilised control up to 5 t/ha. At Lock paddocks with close to average seasonal soil moisture at GS31 and pasture as the previous crop, extra N application at GS31 may have caused over fertilisation and reduced grain yield. At Minnipa paddocks under an intensive cropping regime (third cereal), an extra N application provided a 31% increase of grain yield over an unfertilised control (up to 3 t/ha) when seasonal soil moisture at GS31 was average or above average. As previously reported in Cossani *et al*. 2012 and Sadras *et al*. 2006, nitrogen use efficiency (NUE) decreased with extra fertilisation at GS31, while WUE had a positive relationship with N application at Cummins and Minnipa.

In conclusion, when below average growing season soil moisture at GS31 and approximately 60 kg/ha or above N levels at sowing, 120 kg/ha extra N in split application by GS31 was not beneficial at Minnipa. At Cummins, an extra application of 120 kg/ha of N in split application by GS31 brought 90% higher grain yield over unfertilised plots when growing wheat after canola. Further study would be needed to increase the number of different water by N scenarios trialled to develop a predictive model that could support growers' fertiliser decisions at GS31.

Acknowledgements

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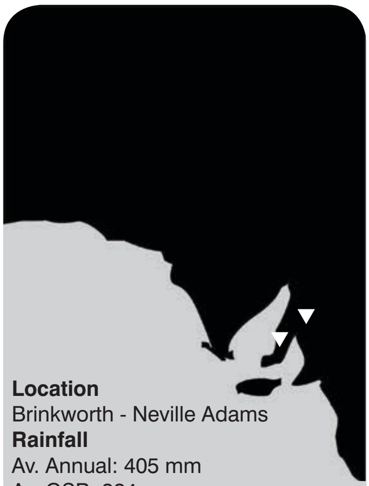
Pulse phosphorus requirements and resulting nitrogen fixation

Sean Mason[1], Liz Farquharson[2] and Lynette Schubert[2]

[1]Agronomy Solutions; [2]SARDI, Waite

RESEARCH



Location
Brinkworth - Neville Adams
Rainfall
Av. Annual: 405 mm
Av. GSR: 324 mm
2018 Total: 289 mm
2018 GSR: 251 mm
Yield
Potential yield: Not measured
Actual: 2.55 t/ha Mace wheat from adjacent trial
Soil Type
Red calcareous loam
Soil Test
See table 2
Plot Size
12 m x 1.41 m x 3 reps
Trial Design
Experimental: randomised complete block
Yield Limiting Factors
Frost - Slight, main part of the paddock affected was in a valley > 50m away.
Dry finish - Moderate, 34 mm for September and October meant early season potential was not fulfilled.
Wind - Moderate, significant late season wind events meant pulse crops had lodged and meant harvesting was extremely difficult.

Location
Urania - Ashley Wakefield
Rainfall
Av. Annual: 506 mm
Av. GSR: 421 mm
2018 Total: 334 mm
2018 GSR: 296 mm
Yield
Potential yield: Not measured
Actual: 5.15 t/ha Mace wheat from adjacent trial
Soil Type
Grey calcareous
Soil Test
See table 2

Key messages

- **Pulse phosphorus requirements for biomass growth is equal to or greater than cereals.**
- **Poor P nutrition will hinder pulse N fixation and soil N reserves.**
- **On P responsive soil types, pulse crop dry matter increases may occur with increasing P rates above district practice.**
- **Further research is needed to determine what the most efficient fertiliser type is to deliver adequate P inputs, but not hinder pulse N fixation through extra N applied via DAP/MAP.**

Why do the trial?

The aim of the trials was to determine optimal P rates for two pulse crops (lentil and chickpea) compared to wheat and assess the flow on effects of extra pulse biomass on nitrogen (N) fixation and yield. Growers are potentially missing out on returns due to inadequate phosphorus nutrition on pulse crops. Early data has shown that P requirements for important pulse crops grown in SA (e.g. lentil, chickpea) can be as high, if not higher, than that for cereals. Recent work (SAGIT funded projects AS216, UA115) has also shown that gross margins can be significantly lifted by increasing P rates on applicable soil types that have a moderate to high ability to fix P. Many of these soil types are in regions (Eyre Peninsula (EP), Yorke Peninsula (YP), mid-North) where pulse crops are often an important component of crop rotations.

How was it done?

Measurements:

- Starting soil P and N levels (Colwell P, PBI, DGT P and mineral N)
- Early biomass response - NDVI (GS30 for wheat)
- Nodulation counts (12 weeks after sowing)
- N fixation using 15N natural abundance technique
- Grain yields and quality
- Mineral N (0-10 cm) after harvest

What happened?

Pre-sowing phosphorus and nitrogen status

Both sites were low in P as measured by both DGT P and Colwell P. Background N levels were moderate at both sites (Table 2).

In-season measurements

NDVI biomass: Early biomass assessment was performed using a greenseeker when wheat was at the end of tillering (GS30). Responses to applied P were clear at both sites and similar trends were found between the three different crop types. Chickpeas and wheat had similar P response characteristics, but linear responses were found for lentils indicating P rates greater than 50 kg P/ha were required to maximise biomass at this growth stage (Table 3).

Nutrition

Plot Size
5 m x 1.6 m x 3 reps
Trial Design
Experimental: randomised complete block
Yield Limiting Factors
Wind - Moderate, significant late season wind events meant pulse crops had lodged and meant harvesting was extremely difficult.

Table 1 Trial details at Brinkworth and Urania in 2018

Trial details	Trial 1 Brinkworth (mid-North)	Trial 2 Urania (YP)
Crop (Variety)	Wheat (Mace), Chickpea (Genesis 090s), Lentil (Hurricane)	
Sowing date	25 May 2018	26 May 2018
Treatments	5 P rates (as Pasture King, no N), 0, 5, 10, 20, 50 kg P/ha N requirements for wheat met with Urea	
Harvest	5 December 2018	10 December 2018

Table 2 Starting soil P and N levels as measured by various soil tests at both trial sites. Critical values (wheat): DGT=48-60 ug/L, Colwell P=27 mg/kg and 30 mg/kg for Brinkworth and Urania respectively.

Site	DGT P (ug/L)	Colwell P (mg/kg)	PBI	Nitrate N (mg/kg)	Critical Colwell P (mg/kg)	Total N (kg/ha)
Brinkworth	13	18	90	19	27	50 (0-60 cm)
Urania	9	19	123	22	30	30

Table 3 Comparative early biomass responses of chickpea, lentil and wheat to applied P at both sites and the corresponding optimal P required to reach maximum yields. *Linear responses meant that higher rates of P addition would be needed to maximise plant growth.

Site	Crop	NDVI control @ 0 kg P/ha	NDVI max	Relative yield (%)	Optimal P (kg/ha)
Brinkworth	Chickpea	0.27	0.32	86	40
	Lentil	0.30	0.37*	72*	>50
	Wheat	0.33	0.44	75	26
Urania	Chickpea	0.32	0.38	85	50
	Lentil	0.38	0.45*	84*	>50
	Wheat	0.54	0.70	77	47

Nodulation counts

Twelve weeks after sowing (before flowering) nodulation counts were performed on three P treatments (0, 10 and 50 kg P/ha) at both sites. Significant ($p<0.05$) increases in both nodulation numbers (data not shown) and nodulation dry weight per gram of root were found in select cases by applying 10 kg P/ha compared to the control (0P). A further increase in most cases was found by increasing rates up to 50 kg P/ha (Figure 1).

Grain yields

Yield responses for both chickpea and lentil at both sites were erratic mainly due to the poor finish to the season and significant wind events which meant crops were flattened, reducing harvestability. Pulse yields at Brinkworth were very low and in combination with site variability responses to P were hard to interpret (Table 4). Pulse yields at Urania were also poor compared to the yields obtained for wheat. The significant delay between desiccation and harvest due to rainfall events may have contributed to the low pulse yields (Table 4).

Nitrogen fixation

Prior to harvest, shoot samples were collected at peak biomass to estimate the proportion of N that came from biological fixation. There was a significant difference in the total amount of N fixed between standard P rates (10 kg P/ha) and higher P rates for lentils at Urania, with approximately 40 kg/ha more fixed in the latter (data not shown). Trends showed that N fixation generally increased with P rate for Urania but less so for Brinkworth, where there were no significant treatment effects, possibly due to the poor finish.

There was a highly significant relationship between nodule number per plant early in the season (12 weeks) and the amount of N fixed at peak biomass. This highlights the importance of maximizing nodulation, in this case by optimising P nutrition particularly for the Urania site which had the higher nodule counts (Figure 2 - lentil only).

Soil mineral N post-harvest

All pulse plots from both sites were sampled (0-10 cm) and analysed for mineral N values post-harvest (Brinkworth – mid December, Urania – mid January). No significant differences ($p> 0.05$) were obtained between treatments at both sites due to sample variability but significant correlations ($p<0.05$) between soil nitrate values and P rate were observed for chickpea and lentil at Urania (Figure 3). This sampling time would only have captured a fraction of the full mineralization potential of the pulse crops which can occur over several years and will be most prevalent in autumn and spring.

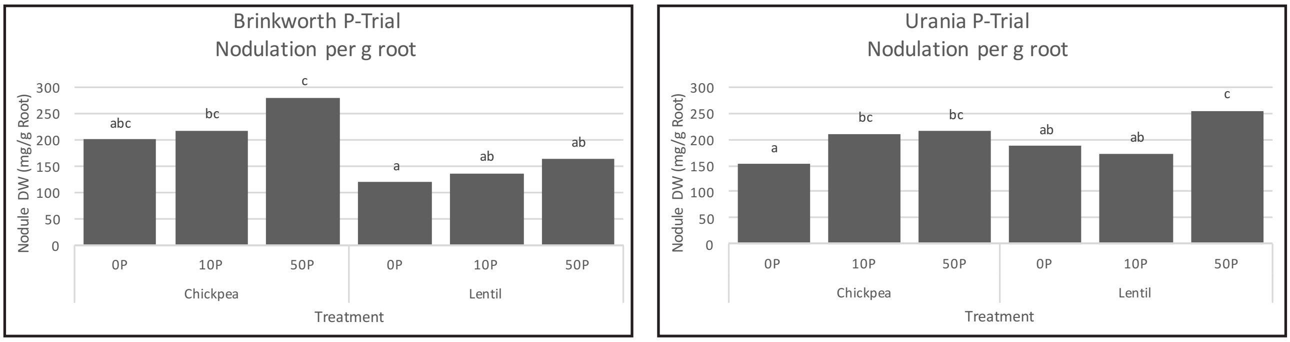


Figure 1 Effect of P nutrition (0P, 10P and 50P) on nodulation (dry weight per gram of root) of chickpea and lentils at Brinkworth and Urania in 2018. Different letters denote values are significantly different (p<0.05).

Table 4 Comparative grain responses of chickpea, lentil and wheat to applied P at both sites and the corresponding optimal P required to reach maximum yields. NR denotes not responsive.

Site	Crop	Grain yield control (t/ha)	Grain yield maximum (t/ha)	Relative yield (%)	Optimal P (kg/ha)
Brinkworth	Chickpea	0.339	0.498	68	5
	Lentil	0.088	0.121	72	5
	Wheat	1.570	1.770	89	NR
Urania	Chickpea	1.180	1.220	97	NR
	Lentil	0.809	0.927	87	5
	Wheat	4.264	5.147	83	16

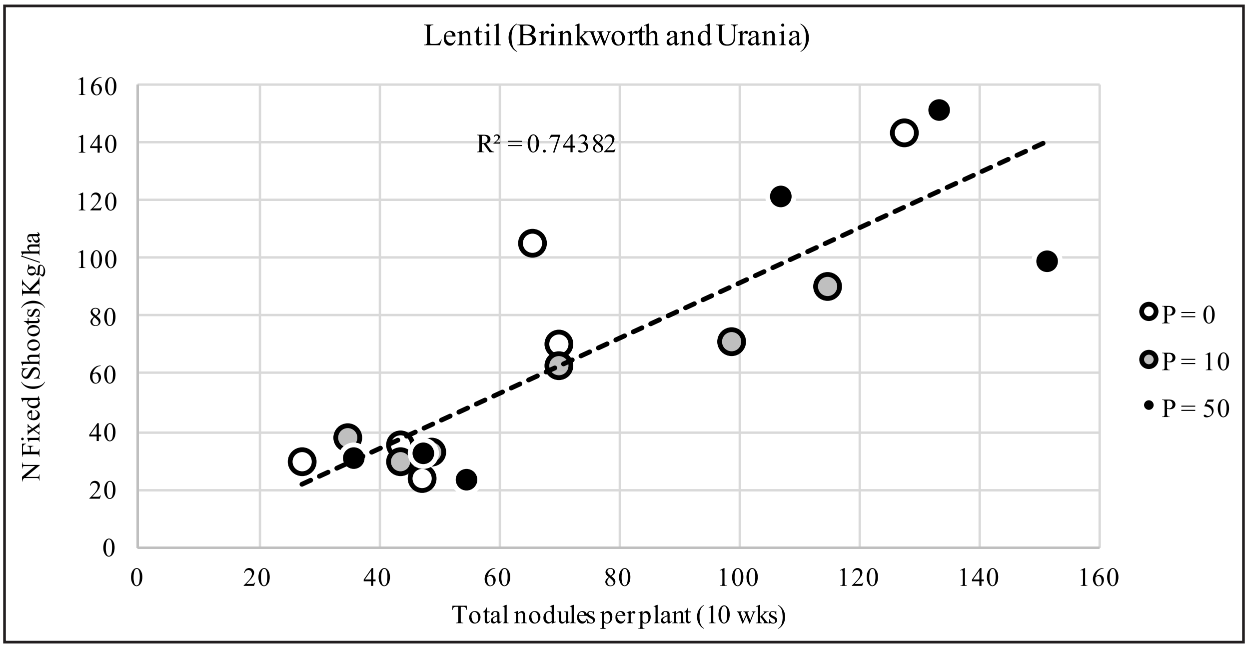


Figure 2 Relationship between nodule number per plant and the nitrogen fixed (shoot – kg/ha) for lentil grown at Brinkworth and Urania at three P rates (0P, 10P, 50P).

Soil mineral N post-harvest

All pulse plots from both sites were sampled (0-10 cm) and analysed for mineral N values post-harvest (Brinkworth - mid December, Urania - mid January). No significant differences ($p>0.05$) were obtained between treatments at both sites due to sample variability but significant correlations ($p<0.05$) between soil nitrate values and P rate were observed for chickpea and lentil at Urania (Figure 3). This sampling time would only have captured a fraction of the full mineralization potential of the pulse crops which can occur over several years and will be most prevalent in autumn and spring.

Form of phosphorus

There has been limited research into the best form of P and P+N combinations for optimal pulse production. High background N (from soil of fertilizer) can suppress nodulation and N fixation, and additional work is required to quantify this relationship with respect to starter fertilizer application on P responsive soils.

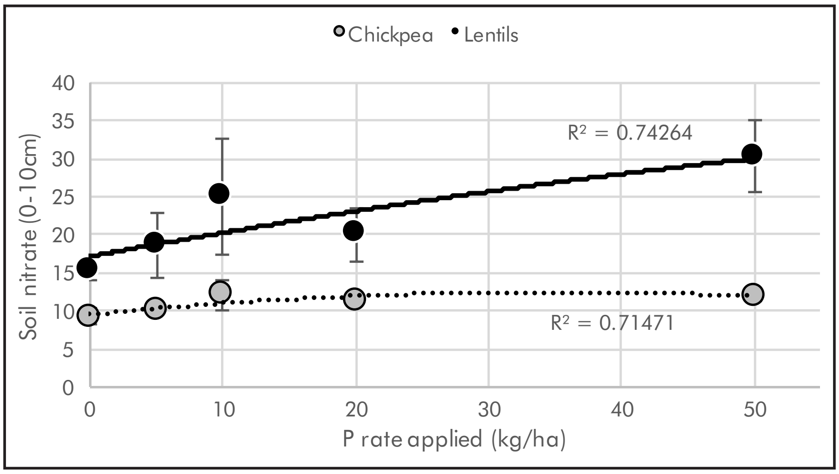


Figure 3 Soil nitrate levels (0-10 cm) with applied P sampled after harvest for both chickpea and lentils at Urania. Error bars represent standard errors from 3 replicates.

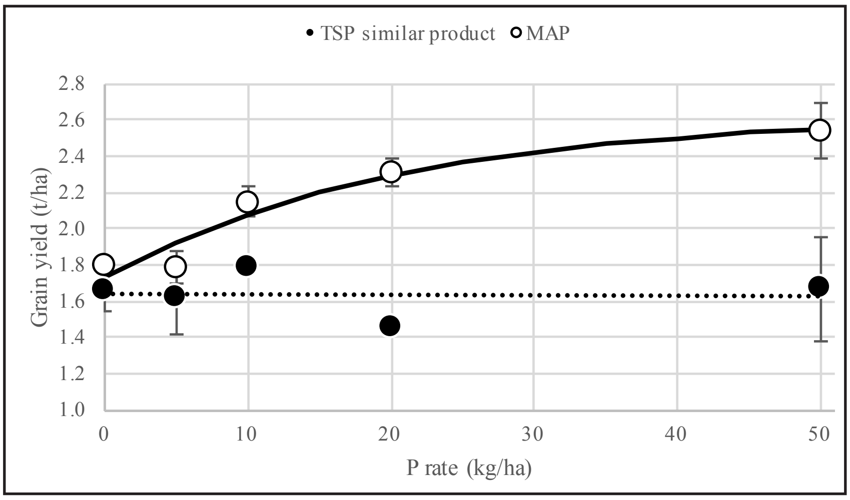


Figure 4 Comparison of wheat responses to P applied as MAP (TOS P trial) and Pasture King (Pulse trial) at Brinkworth. Error bars represent standard errors from 3 replicates.

Observations of an adjacent trial at Brinkworth show positive responses in wheat to MAP compared to a TSP (triple superphosphate equivalent) (Figure 4). It is known that TSP has an inferior performance at delivering P in highly calcareous soils, but it also appears to be limited in performance on moderate calcareous soils ($CaCO_3$ = 10%, PBI 90). This limits the choice of optimal P products available for growers as P deficiency coincides with moderate to high fixing soils driven by $CaCO_3$ soil levels.

Economics

Simple economic analyses for both pulse crops at both sites (2018) which include the cost of applied P treatments, income from corresponding grain yields, conversion of the amount of N fixed into a urea equivalent revealed that low P rates (5-10P) produced the highest gross margins for both crops at Brinkworth (data not shown). This was mainly due to the poor returns from low grain yields. At Urania, 10P produced the highest gross margin for chickpea but 20P was the highest gross margin treatment for lentil. It is important to consider that this economic analysis uses an initial estimate of the amount of N fixation and no consideration of the economics resulting from the performance of the next crop in rotation.

What does this mean?

- In season assessments showed higher P requirements for both pulse crops (particularly lentil) compared to wheat.
- The increase in pulse biomass with increasing P rates coincided with increases in both nodule number but also nodule weight per gram of root.
- Benefits from optimising pulse production occurred at P rates higher than what is considered district practice for these crops.
- Later season assessments (due to seasonal conditions) meant that the early season increases in biomass didn't translate to grain in 2018.
- Nitrogen fixation estimates were highly related to early season nodule nodulation, particularly for lentil.

Acknowledgements

The authors would like to acknowledge funding from SAGIT which allowed us to fulfil these trials (AS118: Economics of high P rates on Pulses). Both trials were sown and managed by AgXtra. Article was reviewed by Andy Bates and Ross Ballard.

SARDI

SAGIT 25 YEARS 1991-2016

SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE

AGRONOMY SOLUTIONS

RESEARCH • EDUCATION • ADVICE

Calibrations of soil tests for N, P, K or S

Sjaan Davey[1], Nigel Wilhelm[2], Ian Richter[3] and Amanda Cook[3]

[1]SARDI, Struan; [2]SARDI, Waite Campus; [3]SARDI, Minnipa Agricultural Centre

RESEARCH

Location
Minnipa - Gareth Scholz
Minnipa Ag Bureau
Rainfall
Av. Annual: 325 mm
Av. GSR: 241 mm
2018 Total: 208 mm
2018 GSR: 155 mm
Yield
Potential yield: 2.0 t/ha (W)
Actual: 1.0 t/ha
Paddock History
2017: Pasture
2016: Pasture
2015: Pasture
Soil Type
Red sandy clay loam
Soil Test
$pH_{(water)}$ 8.4, PBI 79, K 523 mg/kg
Plot Size
20 m x 2 m x 4 reps
Trial Design
Completely randomised design, 2 bays x 44 plots x crop type (wheat or canola)
Yield Limiting Factors
Dry conditions at start of the season - moderate impact

Key messages

- **With low rainfall and poor growth at many sites, crops required little P to maximise grain yield, even though P fertiliser was quite inefficient early in the season due to soils often being dry.**
- **On a Minnipa red sandy clay loam, poorly performing wheat only needed a Colwell P value of 10 mg/kg to achieve maximum grain yield.**

Why do the trial?

Soil testing for N, P, K and S is a key strategy for monitoring soil fertility of cropping soils as well as for refining fertiliser application strategies for future crops. For this to be successful, the relationship between the soil test and likely response to applied nutrients needs to be well calibrated. Many of these calibrations were developed from fertiliser trials conducted over 20 years ago and have provided robust guidelines on many soil types, but mostly for cereals. Since these trials were conducted cropping systems have changed significantly and altered the face of soil fertility in the Australian grains industry. A detailed re-examination of those existing guidelines is needed to ensure they are still relevant in current farming systems.

As part of the GRDC funded MPCN2 (More Profit from Crop Nutrition) program, a review of data in the Better Fertilizer Decisions for Cropping (BFDC) database showed gaps exist for key crops, soils and regions. Most of these gaps relate to crops that are (i) new to cropping regions or are a low proportion of cropped area, i.e. break crops, (ii) emerging nutrient constraints that had previously been adequate in specific soil types and (iii) issues associated with changing nutrient profile distribution. This project (UQ00082) is closing gaps in the BFDC database using replicated trials. Trials are being established on sites selected for nutrient responses and run over multiple years to develop soil test-crop response relationships. By using wheat as a benchmark alongside a break crop, we should be able to extend the relevance of the guidelines beyond the conditions at the trial site.

How was it done?

A P deficient site on a red sandy clay loam was selected near Pildappa on upper Eyre Peninsula. Soil P status was very low at < 6 ppm Colwell P. On 7 May 2018, P fertiliser treatments were applied at 11 rates from 0-200 kg P/ha to create a range of soil P reserves. Every plot was sampled from 0-10 cm for Colwell P immediately prior to seeding.

Two identical trials were sown at the site on 21 June 2018, one with Mace wheat @ 60 kg/ha as the benchmarking crop and Stingray canola @ 5 kg/ha. The canola failed to establish with the initial seeding so the trial was re-seeded in August. However, this crop failed in spring and no data was captured for canola.

What happened?

Adding P fertiliser successfully created a range of soil P values in both the wheat and canola trials (Figure 1) despite the generally dry conditions from application to sampling 6 weeks later.

The best yields of wheat were just under 1 t/ha with the late seeding and if no P had been applied, yields were less than 0.6 t/ha. Rates of P fertiliser had to be at least 20 kg P/ha (equivalent to 100 kg/ha of MAP or DAP) to achieve maximum yields, but rates higher than 20 kg P/ha had little or no benefit on wheat yields. This relatively high rate of P to overcome P deficiency was common last year and was probably due to the very dry conditions last season. P fertiliser is very poorly available in soils which are often dry.

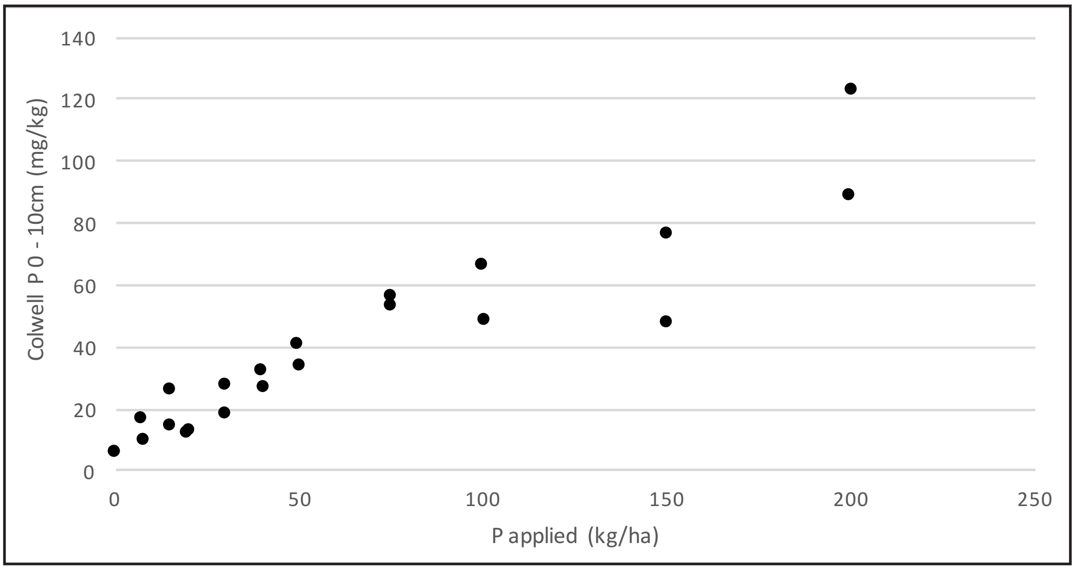


Figure 1 Soil phosphorus measured as Colwell P (mg/kg) for soil samples taken at 0-10cm in every plot of the wheat trial after treatment application at Pildappa, SA in 2018

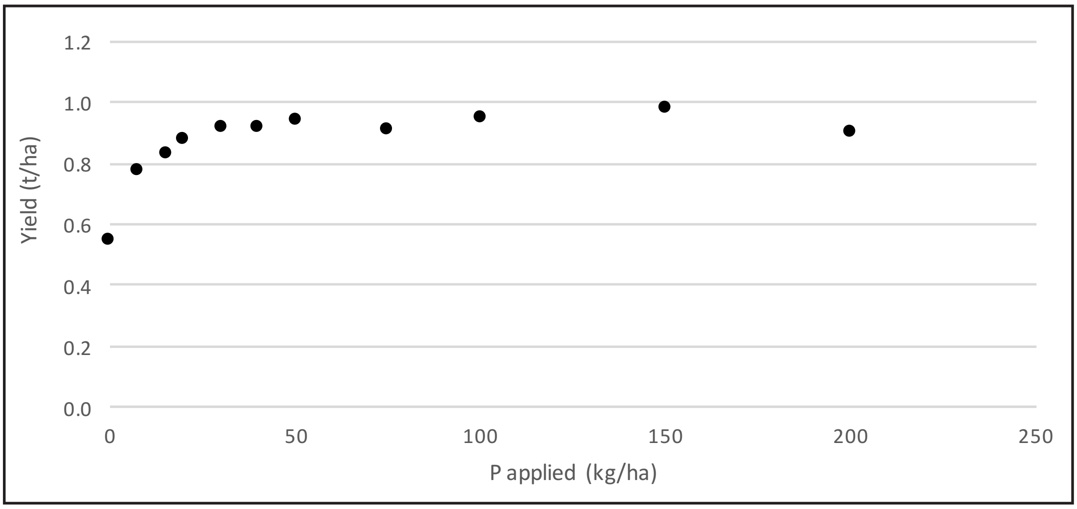


Figure 2 Yield (t/ha) for treatments with a range of applied phosphorus (kg P/ha) at Pildappa, SA in 2018

What does this mean?

Preliminary calibration of the Colwell P soil test for wheat suggest that levels above 10 mg/kg were sufficient to maximise grain yields in 2018 (without the addition of P fertiliser) (Figure 2). This critical level is substantially lower than the current standard of 20-25 mg/kg for mallee-type soils. The value from 2018 is probably low due to the very low production levels experienced in the 2018 season. Under these conditions, the crop requires very little P to maximise growth. These are very much provisional conclusions because we are concerned that in the setup years for these trials, soil test values may be confounded by lots of fresh fertiliser (whole granules) also being in the soil.

The trials will be re-seeded in 2019 to check calibrations in a different season and to evaluate canola requirements relative to wheat under identical conditions.

Acknowledgements

Mike Bell (The University of Queensland) who leads the UQ00082 project. GRDC for funding, and Minnipa Agricultural Centre staff for organising the trials. Thanks to Gareth Scholz for having the trial on his property.

Does soil and plant testing pay for itself?

Rachael Oxborrow[1], Harm van Rees[2] and Sean Mason[2]

[1]AgCommunicators, [2]Agronomy Solutions

RESEARCH

Key messages

- **2016 GRDC grower surveys indicate there is a low adoption of soil and plant test data to underpin nutrient regimes.**
- **Growers are missing out on the economic benefits of making informed nutrient management decisions.**
- **Soil testing rates are influenced by advisers and agribusiness, as well as individual grower attitude towards the practice.**
- **Improving fertiliser returns will assist in improving the profit margin for southern region growers.**

Why do the trial?

Grower surveys conducted by GRDC in 2016 indicate low adoption of soil and plant testing data being used to inform nutrient decisions, highlighting an opportunity to assist growers to improve their nutrient decisions and create better crop outcomes. (https://grdc.com.au/FarmPracticesSurveyReport)

The wider industry often promotes the benefits of using testing to guide nutrient decisions both pre and in-season, however soil testing rates appear to remain quite low. This GRDC investment runs from 2018-2021 and aims to increase soil and plant testing rates. It incorporates a range of extension and communication activities to gauge the barriers to adoption and provide education opportunities. An intensive, high-impact soil and plant testing demonstration program will also be conducted with growers interested in improving fertiliser returns. The economic value of nutrient management practices in terms of increased nutrient use efficiency, including savings where soil nutrient levels are high, will be widely promoted throughout the duration of the project and beyond its completion.

How will it be done?

The project involves a number of outputs to ultimately give growers and advisers a good understanding of nutrient management decision making processes and the benefits to their operation.

- An economic framework analysing the value of soil and plant testing will involve survey and workshop analysis, farm-scale assessment via fertiliser test strips and existing literature. The framework is designed to be used together with large scale on-farm paddock trials to demonstrate how fertiliser decisions informed by test results can lead to increased profitability. Results from this trial program will be included in the on-going development of the economic framework.
- A precision agriculture and farm management platform will be used for data management, trial paddock setup and will detail procedures for soil and tissue testing. This will ensure consistent results are gathered from 100 growers in SA and Victoria with six paddocks each to be sown to wheat in 2019. Of these trial paddocks, half will have a fertiliser strip trial included. Three years of historical production data will be collected and pre-sowing samples for nitrogen (N) and phosphorous (P) conducted to give a paddock baseline. Throughout the growing season there will be N and P nutrient strip trials and tissue sampling and grain yields will be collected to assess nutrient responses.
- Promotion of nutrient management best practices using key influencers of practice change in varying communication and extension activities. Initial focus group workshops for growers and advisers participating in the trials will seek feedback around soil testing. This series of workshops will also outline the economic framework established and protocols for soil sampling, demonstration trials and data collection. A survey of more than 200 growers will be conducted with the goal of providing insight into the current attitudes of growers and advisers towards soil and plant testing. This will assist in guiding communication and extension activities which are expected to include promotion and messaging to growers via participating farming systems groups including Eyre Peninsula Agricultural Research Foundation, Hart Field-Site Group, Mallee Sustainable Farming and Southern Farming Systems.

What happened?

The project is in its early stages with grower surveys and workshops underway in early 2019. As 2019 progresses, paddock trial sites will be set up across the southern region to test for pre-sowing soil N and P before fertiliser strips are tested and monitored by NDVI and harvest yield map data. The impact on nutrient use efficiency, profit for each grower (costs, input savings and/or increased income) and soil data will be compiled and trends across the region summarised each year. Soil and plant testing data will provide a useful snapshot of nutrient status and soil fertility in the southern region and will help highlight emerging issues such as soil acidity and declining organic matter.

Ultimately, the investment aims to improve nutrient management best practice through the increased use of soil testing and provide grain growers in the southern cropping region (Victoria, South Australia and Tasmania) with the confidence, knowledge and ability to make more effective and profitable nutrient management decisions.

Acknowledgements

GRDC Project 9176604 - Using soil and plant testing data to better inform nutrient management and optimise fertiliser investments for grain growers in the southern region. Australian Precision Ag Laboratory (APAL) - Ryan Walker. Landmark - Sam Bald, Daniel Bell. CSIRO - Rick Llewellyn, Therese McBeath, Marta Monjardino. AgCommunicators - Belinda Cay, Bridget Penna, Tina Brock. Farming systems groups - Hart Field-Site Group (Sarah Noack), Eyre Peninsula Agricultural Research Foundation (Amanda Cook, SARDI), Mallee Sustainable Farming (Tanja Morgan), Southern Farming Systems (Jon Midwood). Independent reviewers - Rob Norton, Jeff Kraak.

Effect of rate and placement of phosphorus on vetch performance

Brian Dzoma[1], Nigel Wilhelm[2] and Kym Zeppel[1]
[1]SARDI Loxton Research Centre, [2]SARDI Waite

RESEARCH

Location
Loxton - Robin Schaefer & Family
Rainfall
Av. Annual: 263 mm
Av. GSR: 171 mm
2018 Total: 177 mm
2018 GSR: 105 mm
Paddock History
2018: Volga vetch
2017: Canola
2016: Wheat
Soil Type
Red sand
Soil Test
$pH_{(water)}$: 8.45
Plot Size
15 m x 2 m x 3 reps
Trial Design
Factorial RCBD with 3 replicates
Yield Limiting Factors
Moisture

Location
Peebinga - George Gum & Family
Rainfall
Av. Annual: 319 mm
Av. GSR: 210 mm
2018 Total: 190 mm
2018 GSR: 116 mm
Soil Type
Grey sand
Soil Test
$pH_{(water)}$: 7.27
Plot Size
15 m x 2 m x 3 reps
Trial Design
Factorial RCBD with 3 replicates
Yield Limiting Factors
Moisture

Key messages

- **Our trial showed an increase in nodule numbers, root and shoot dry matter and leaf tissue P with increasing P rates.**
- **Placing P shallow (banded) is key to getting early good nodulation, however deep banding will result in higher biomass production.**

Why do the trial?

Phosphorus (P) is a nutrient which is essential for normal plant growth. Inadequate P restricts root and shoot growth and other functions which reduce N fixation by legumes. Vetch (*Vicia sativa*), a versatile pasture legume that can be used for grain, pasture, hay/silage or green manure, is being grown on naturally infertile Mallee soils which are often quite deficient in P. It struggles to achieve optimum productivity on low P soils and hence less fixed nitrogen is returned to the system. The trials reported here evaluated the impact of P rate and placement at sowing on vetch productivity and nodulation. By addressing the optimum rate and right depth to place the P at sowing, productivity gains in the form of improved dry matter production, grain yield, nodulation and N-fixation can result in multiple benefits, particularly in low rainfall mixed farming systems.

How was it done?

Two replicated field trials were established in 2018 on sites representative of neutral to alkaline sandy soils in the northern Mallee of South Australia (SA), a grey sand over clay at Peebinga and a red loamy sand at Loxton. Both trial sites had low background Colwell P in the top 10 cm (5 mg P/kg soil at Peebinga and 8 mg P/kg soil at Loxton). Trials were sown to Volga vetch @ 35 kg/ha on 13 June (Loxton) and 14 June (Peebinga). Different rates of P were applied as triple superphosphate (TSP), at different depths below the seed (Table 1). Plot length was 15 m and all treatments were replicated three times.

All treatments received a trace element package (Table 1) at sowing to make sure the responses to applied P were not restricted by trace element deficiencies. Emergence counts were undertaken on 10 July 2018 to determine plant population, and on 28 August, Clethodim @ 250 ml/ha + 1L/ha wetter was applied at both trial sites to control grass weeds. Sampling for nodulation, leaf tissue P, and early shoot and root dry matter (DM) was done on 5 September. Late flowering/early podding cuts were done on 22 October to determine maximum biomass. Soil sampling will be done in autumn 2019 in the 0-10 cm zone to determine residual P.

What happened?

With total growing season rainfall of 116 mm (Peebinga) and 106 mm (Loxton), plant productivity was low at both sites. Visual responses to the different rates of P applied at different depths were more evident at the Loxton site than at Peebinga.

Response to P rate

There was a general increase in leaf tissue P, nodulation, root dry matter production and shoot dry matter (DM) production with increased soil P at both sites (Table 2). Average early shoot DM was higher at Loxton (382 kg DM/ha) than at Peebinga (317 kg DM/ha), which can be attributed to the better background soil nutrition at the Loxton site.

Table 1 Treatment details at Loxton and Peebinga trial sites, 2018

Crop	Volga vetch
Main plot factor (P placement)	With seed
	Banded (4 cm below seed)
	Deep banded (8 cm below seed)
Sub-plot factor (kg P/ha)	0, 4, 8, 16, 32
Experimental design	Factorial RCBD x 3 replicates
Trace element package @ sowing (kg/ha)	10 S, 1 Zn, 2 Mn and 1 Cu

Table 2 Effect of different P rates on leaf tissue P, nodulation, early shoot and root DM at Loxton and Peebinga

Site	P rate (kg/ha)	Leaf tissue P (%)	Nodulation (# nodules/ root)	Early shoot DM (kg/ha)	Root DM (mg/root)
Loxton	0	0.27	6.0	168	95
	4	0.28	11.3	312	251
	8	0.27	11.3	342	431
	16	0.31	15.0	446	315
	32	0.33	27.8	641	456
	LSD (5%)	*0.03*	*4.8*	*123*	*190*
	p value	*<0.001*	*<0.001*	*<0.001*	*0.004*
Peebinga	0	0.23	8.4	241	96
	4	0.25	11.9	320	12
	8	0.27	12.6	278	138
	16	0.28	16.3	352	127
	32	0.36	19.9	396	139
	LSD (5%)	*0.03*	*6.4*	*102*	*23*
	p value	*<0.001*	*0.01*	*0.03*	*0.005*

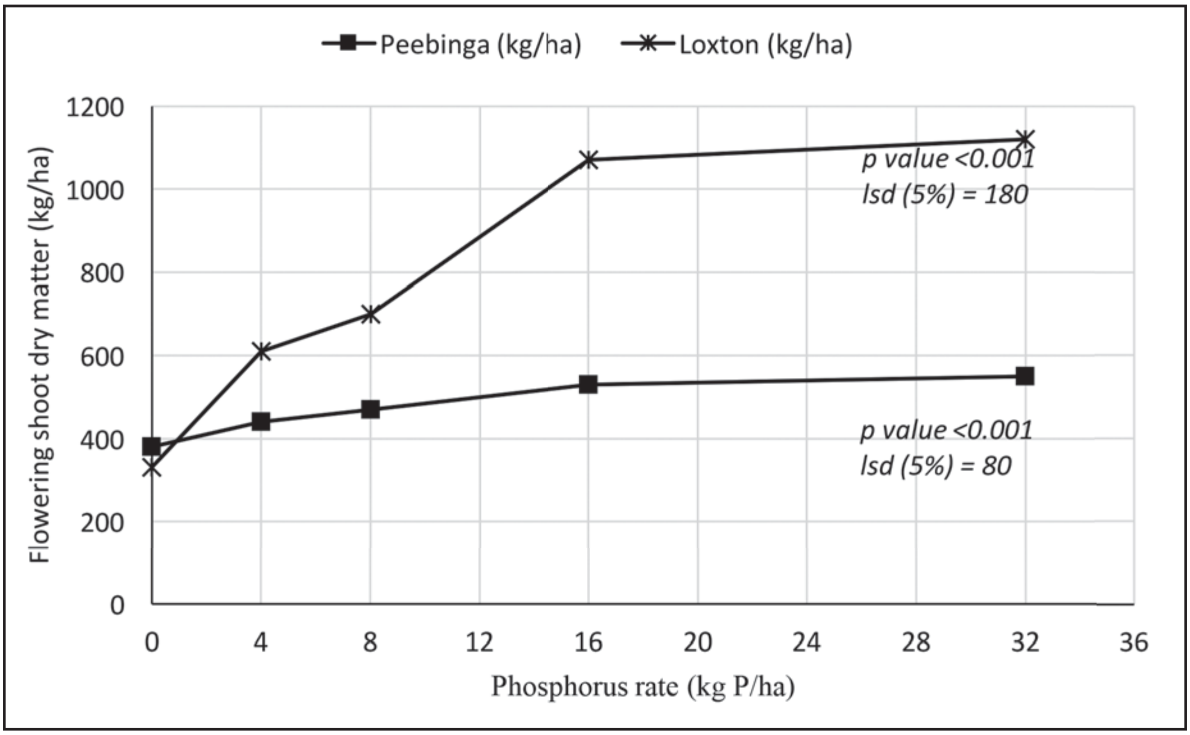


Figure 1 Effect of phosphorus of flowering shoot DM at Loxton and Peebinga in 2018

Increasing rates of P also progressively increased flowering shoot DM at both sites (Figure 1). At both sites, the biggest response to applied P was from the nil treatment to 4 kgP/ha. The response was greater at Loxton (85%) and less at Peebinga (16%).

Responses to P placement

There was no response in leaf tissue P at the Loxton site, however early shoot DM increased with increasing depth of P placement. Deep banding P resulted in better early biomass production but resulted in the least amount of nodules per root. At the Peebinga site there was no response to leaf tissue P, nodulation and shoot DM when P was placed at different depths away from the seed (Table 3). However, placing P with the seed at sowing showed the greatest increase in root DM. This was in contrast to the Loxton site where the response to banded placement of P was statistically insignificant.

Phosphorus agronomic efficiency (PAE) is calculated in units of yield increase per unit of nutrient applied. It more closely reflects the direct production impact of an applied fertilizer and relates directly to economic return (Fixen P *et al*. 2014). Mean PAE was higher at Loxton (47 kg DM/kg P) than at Peebinga (10 kg DM/kg P), meaning that the impact of applied P was greater on shoot biomass at Loxton. Deep placement of P had the largest PAE response at Loxton (55 kg DM/kg P), while placing P with the seed at sowing had the lowest response (34 kg DM/kg P). At Peebinga, banding P gave the largest PAE response (24 kg DM/kg P) with deep banding giving the lowest response (1 kg DM/kg P).

Fitted exponential curves (Figure 2) were used to derive estimates of the rate of change of PAE with changes in P applied. At both sites, there was a similar trend of decreasing PAE with increasing rate of P applied. The rate of PAE decrease was higher however at Peebinga, decreasing by 2.68 kg DM/kg of P added. Comparatively, at Loxton the extrapolated decrease in PAE was 0.97 kg DM/kg P added.

Table 3 Effect of P placement on leaf tissue P, nodulation, early shoot and root DM at Loxton and Peebinga in 2018

Site	Placement	Leaf tissue P (%)	Nodulation (# nodules/ root)	Early shoot DM (kg/ha)	Root DM (mg/root)
Loxton	Deep banded	0.29	10.9	461	240
	Banded	0.30	17.0	385	350
	With seed	0.29	14.9	298	339
	LSD (5%)		*3.7*	*96*	
	p value	*ns*	*0.008*	*0.006*	*ns*
Peebinga	Deep banded	0.28	13.6	352	115
	Banded	0.28	12.6	309	119
	With seed	0.28	15.2	292	139
	LSD (5%)				*18*
	p value	*ns*	*ns*	*ns*	*0.02*

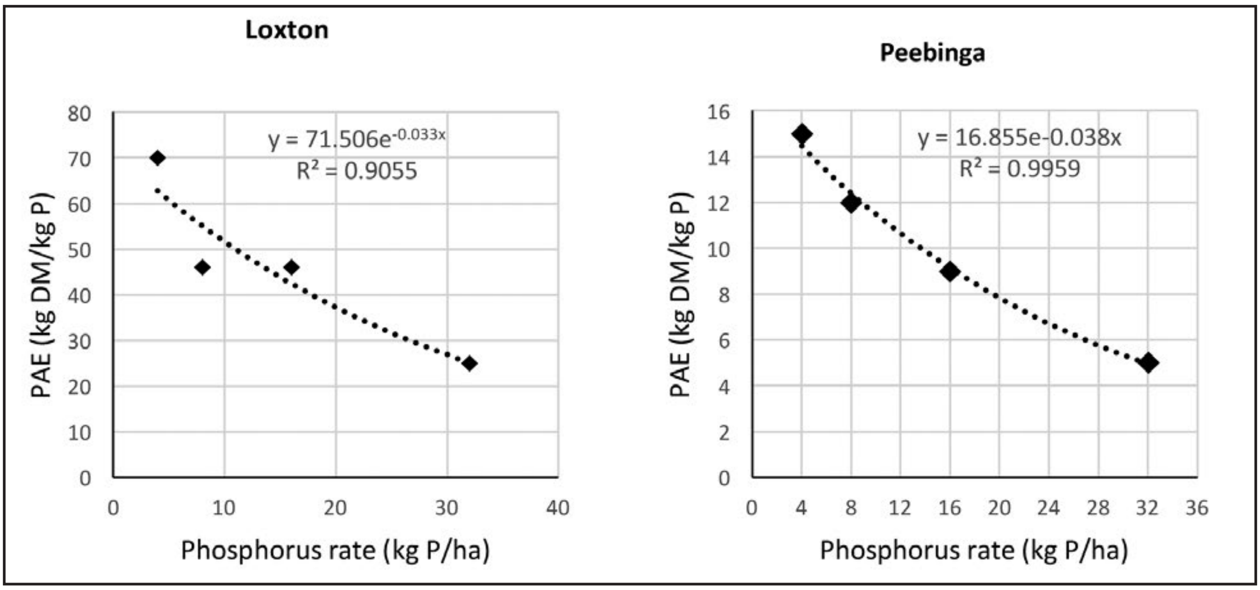


Figure 2 Phosphorus agronomic efficiency (kg DM/kg P) at Loxton and Peebinga

Table 4 Gross margin ($/ha) analysis for Peebinga and Loxton trials

	P rate (kg P/ha)	0	4	8	16	32
	Fert cost ($/ha)	0	12	24	48	96
Loxton	Yield (kg/ha)	380	440	470	530	550
	Fert cost c/kg DM	0.00	2.73	5.11	9.06	17.45
	Gross income @ 44 c/kg hay	167.2	193.6	206.8	233.2	242.0
	Gross margin $/ha	**167.2**	**181.6**	**182.8**	**185.2**	**146.0**
Peebinga	Yield (kg/ha)	330	610	700	1070	1120
	Fert cost/kg DM	0.00	1.97	3.43	4.49	8.57
	Gross income @ 44c/kg hay	145.2	268.4	308.0	470.8	492.8
	Gross margin $/ha	**145.2**	**256.4**	**284.0**	**422.8**	**396.8**

What does this mean?

Vetch is now a significant legume rotation in cereal cropping systems in Australia's low and medium rainfall zones. There is limited recognition of the impacts of phosphorus on vetch productivity in low rainfall Mallee environments, and estimates of the impact of soil P levels on nodulation and N-fixation in alkaline coarse-textured soils is also poorly understood.

Our results show that there are productivity gains from applying P fertilisers when sowing vetch on soils with low P reserves. Application of 32 units of P resulted in shoot DM increases of 239% and 45% at Loxton and Peebinga respectively. P applications, however, need to be matched against expected productivity gains for different soil types and rainfall regions to make sure that the fertiliser applications are economically justifiable.

The calculation of the gross margin (GM) analysis (Table 4) only considered gross income from vetch hay (flowering DM) and the main variable cost i.e. cost of TSP/ha. The assumption was TSP at a cost of $600/tonne and vetch hay at $440/tonne (Agtrader.com, 2019). The GM analysis consistently shows an increase in GM ($/ha) with increasing rate of P, up to 16 kg P/ha only. Increasing P rate from 16 to 32 kg P/ha resulted in a decrease of GM of $39/ha and $26/ha at Peebinga and Loxton respectively.

The total number of nodules per plant also increased by 363% at Loxton and 137% at Peebinga when 32 units of P were added. The results also show that deep placement of P is beneficial to early and late DM production, but can set back nodulation as the plants need the P upfront. P plays a key role in the symbiotic N fixation process by increasing shoot and root growth. This decreases the time needed for developing nodules to become active and to benefit the host legume, both; increasing the number and size of nodules and the amount of N assimilated per unit weight of nodules, and increasing the percent and total amount of N in the harvested portion of the host legume (Armstrong, 1999).

Improved nodulation and dry matter production can result in significant amounts of nitrogen returned back into the soil and also improved levels of soil organic matter and microbial activity. Cereal yields following vetch are usually at least 30 to 50% higher than in continuous cropping cereals (Unkovich *et al*. 1997). This is highly beneficial to low rainfall mixed farming systems where cropping and livestock production complement each other to result in resilient sustainable farming enterprises.

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Proximal sensing technologies on soils and plants on Eyre Peninsula

RESEARCH

Fabio Arsego[1], Andrew Ware[2] and Helena Oakey[3]

[1]SARDI, Minnipa Agricultural Centre/Port Lincoln; [2]formerly SARDI, Port Lincoln; [3]Biometry Hub University of Adelaide

Location
Minnipa Agriculture Centre, paddock N10, 2017 & 2018
Rainfall
Av. Annual: 325 mm
Av. GSR: 241 mm
2018 Total: 269 mm
2018 GSR: 208 mm
2017 Total: 262 mm
2017 GSR: 141 mm
Yield
Potential yield 2018: 1.6 t/ha (Hancock 2006)
Actual yield 2018: 2.3 t/ha
Potential yield 2017: 1.6 t/ha (Hancock 2006)
Actual yield 2017: 2.3 t/ha
Paddock History
2017: Scepter wheat
2016: Mace wheat
2015: No seeding
Soil Type
Red sandy clay loam
Plot Size
5 m x 1.6 m x 3 reps

Location
Lock - Ian Burrows 2017 & 2018
Rainfall
Av. Annual: 390 mm
Av. GSR: 294 mm
2018 Total: 311 mm
2018 GSR: 231 mm
2017 Annual: 357 mm
2017 GSR: 241 mm
Yield
Potential yield 2017: 2.0 t/ha (W) (Hancock 2006)
Actual yield 2017: 2.4 t/ha
Paddock History
2017: Pasture-vetch-clover
2016: Peas/self regenerating medic pasture
2015: Barley
2014: Wheat
Soil Type
Grey sandy loam
Plot Size
5 m x 1.6 m x 3 reps

Key messages

- **Proximal sensing reflectance data predicts soil moisture with reasonable accuracy at depths (0-10, 10-30, 30-90 cm) on upper Eyre Peninsula in 2018.**
- **Reflectance data may also be useful for predicting the amount of soil nitrogen and crop macronutrients, including but not limited to nitrogen, phosphorus, potassium and sulphur.**
- **Further experimental data is required to use soil and crop reflectance as a means to predict nutrient content because environmental parameters can confound results.**

Why do the trial?

This research has developed predictive formulas that can be used by growers to estimate in-season soil moisture at different depths and crop nutrient content from proximal sensing (PS) data.

The upper Eyre Peninsula (UEP) is a challenging environment for growers, due to the Mediterranean-type of climate, where irregular and infrequent winter rainfall patterns are coupled with low soil fertility. Additionally, poor soil structure, low water holding capacity and limited nutrient availability provide challenging conditions for plant growth, as growers currently use granular fertilisers which require good soil moisture conditions to enable the uptake of nutrients. Topsoils from calcareous soils may dry quickly after rain events, which may explain poor water use and nutrient extraction efficiency.

Proximal sensing technologies have the potential to support grower's nutrient management decisions by monitoring in-season soil and crop water and nutrient content (Allen *et al*. 2017, Arsego *et al*. 2017). Compared to the Green Seeker/normalised difference in vegetation index (NDVI) device, newer PS technology can use a wider range of wavelengths to predict soil and crop nutritional status in a non-destructive, quick and inexpensive way. Until recently, PS technology was limited to laboratory use given the size and robustness of the machinery necessary to perform the analysis. The development of small, portable PS devices has now allowed the use of this technology in the field, allowing for the potential for PS to be utilised by growers in their paddocks in the near future. In this research, two years of UEP trials have been combined to calibrate PS for crop nutrient content, and one year of data has been examined for soil moisture and nutrient content.

How was it done?

A total of eight trials (season 2018) were established, three in Cummins, Lock, and Minnipa, two in Piednippie, and three in Nunjikompita (Table 1). A randomised complete block design with three replicates was used for all trials.

Data from biomass cuts sampled at GS31 (stem elongation) include all eight trials and Lock Cummins and Minnipa replicated trials of 2017. At Lock, Cummins and Minnipa 2017-18, a second biomass cut was performed at GS65 (anthesis). A third biomass sampling was conducted at maturity for grain yield and quality testing at Lock 2017-18, Minnipa 2017-18 and Cummins 2017.

Location
Cummins - Stuart Modra 2017
Rainfall
2017 Av. Annual: 396 mm
2017 Av. GSR: 306 mm
2017 Total: 401 mm
2017 GSR: 278 mm
Yield
Potential yield 2017: 3.3 t/ha (W) (Hancock 2006)
Actual yield 2017: 2.3 t/ha
Paddock History
2016: 44Y89CL canola
2015: Mace wheat
2014: No seeding
Soil Type
Clay loam
Plot Size
5 m x 1.6 m x 3 reps

Location
Cummins - Douglas Green 2018
Rainfall
Av. Annual: 423 mm
Av. GSR: 314 mm
2018 Total: 361 mm
2018 GSR: 288 mm
Yield
Potential: 4.4 t/ha (W)(Hancock 2006)
Actual: 3.3 t/ha
Paddock History
2017: Banker canola
2016: Buloke barley
2015: Wyalkatchem wheat
Soil Type
Clay loam
Plot Size
5 m x 1.6 m x 3 reps
Trial Design
Randomised complete block
Yield Limiting Factors
None

Location
Piednippie - John Montgomerie 2018
Rainfall
Av. Annual: 378 mm
Av. GSR: 225 mm
2018 Total: 233 mm
2018 GSR: 181 mm
Yield
Potential: 3.0 t/ha (W)(Kirkegaard and Hunt 2012)
Actual: 2.0 t/ha
Paddock History
2017: Pasture
2016: Canola
2015: Pasture
Soil Type
Clay calcareous
Plot Size
10 m x 1.6 m x 3 reps
Trial Design
Randomised complete block
Yield Limiting Factors
1% grain loss at each plot, late harvest

Table 1 Trial details for the five EP environments tested in 2018

Trial Details	Lock	Minnipa	Cummins
Varieties	Scepter, Mace, Halberd and Spear wheat		
Sowing date	22 May 2018		15 May 2018
Fertiliser	120 kg/ha Triple Super Phosphate		86 kg/ha Triple Super Phosphate
Herbicide	Boxer gold® 1.5 L/ha, Avadex® 1.5 L/ha, Treflan® 1.7 L/ha, Round up® 2 L/ha, Hammer® 100 ml/ha, Sulphate Ammonia 800 g/ha		
Harvest date	28 November	13 November	16 November

Trial Details	Nunjikompita	Piednippie
Variety	Scepter wheat	
Sowing rate	60 kg/ha (Normal seeding rate) and 80 kg/ha (High seeding rate)	
Sowing date	8 May 2018	6 June 2018
Fertiliser	Different treatments on the trials 50 kg/ha DAP; 50 kg/ha MAP; 50 kg/ha Urea; 100 kg/ha Triple Super (TSP); 200 kg/ha Single Super; 200 kg/ha Complete Nutrient Mix	
Herbicide	Boxer gold @ 1.5 L/ha, Avadex @ 1.5 L/ha, Roundup @ 2 L/ha, Hammer @ 1.6 L/ha, Broadstrike @ 800 ml/ha	
Harvest date	5 December 2018	7 December 2018

The GS31 biomass cuts were dried at 35°C in the oven until a constant weight. Then, dry biomass and grain samples were ground and sent to the laboratory for nitrogen content testing. The ground tissue samples of GS31 biomass cuts from Nunjikompita and Piednippie were also tested for macro and micronutrients (nitrogen, phosphorous, potassium, copper, magnesium, iron, manganese, sodium, boron, sulphur and zinc) content at the laboratory.

A gravimetric method was applied to estimate soil moisture of the samples, which were collected with three samples per replicates at sowing, and one sample per plot at maturity. At Cummins, Lock and Minnipa, soil samples were collected up to 90 cm depth. At Piednippie, the soil sampling depth was limited by limestone at a depth of 30 cm onwards, while a maximum depth of 60 cm was reached at Nunjikompita. Additional soil samples were collected using the same methods described above. However, these soil samples were dried in an oven (35°C until constant weight), sieved and sent to the laboratory for nitrogen content.

Water use was calculated with the following formula: (Soil moisture at sowing + growing season rainfall) - Soil moisture at maturity.

Nitrogen nutrition index (NNI) was calculated by dividing the crop critical N concentration (N% at GS31, 4.7) by the actual N% from the laboratory.

Spectral data was collected for biomass and soil samples using a proximal sensing technology (i.e. a SR-3500 spectroradiometer from Spectral Evolution). When the sky was clear, four biomass spectral readings per plot were collected using a 25° (field of view) bare fibre optic in the field at noon time (10 am - 3 pm). On cloudy days, a leaf clip probe was used to measure four random main leaves per plot.

Location
Nunjikompita - Tim Howard 2018
Rainfall
Av. Annual: 299 mm
Av. GSR: 225 mm
2018 Total: 168 mm
2018 GSR: 128 mm
Yield
Potential: 1.9 t/ha (W)(Kirkegaard and Hunt 2012)
Actual: 1.1 t/ha
Paddock History
2017: Medic pasture
2016: Mace wheat
2015: Medic pasture
Soil Type
Red calcareous
Plot Size
10 m x 1.6 m x 3 reps
Trial Design
Randomised complete block
Yield Limiting Factors
Poor germination

Soil spectral data was recorded using a contact probe, measuring four readings per soil sample, for both gravimetric and oven dried soil. Spectral data were pre-treated using standard methodology (Esbensen and Swarbrick, 2018) and analysed using partial least square (PLS) regression in the Unscrambler X (CAMO version 10.5) to calculate (i) the relationship between spectral data and nutrient data and (ii) the relationship between spectral data and soil moisture data. Linear mixed models were fitted using ASReml R version 3. Package software was then used to develop local spectral indices and formulas to predict nutrient content from spectral data (Figure 1).

What happened?

Soil moisture

As a first step, a multi-site PLS of soil moisture versus spectral data analysis was undertaken considering the five locations. The output revealed a strong correlation (R^2=0.86, Figure 2a) between the soil moisture and spectral data.

Six new spectral indices were combined with four reference indices to test a linear relationship with soil moisture for both sowing and maturity sampling dates at each location (Table 2). Cummins showed a completely different trend from all other locations (possibly due to differences in soil texture), therefore was excluded from the analysis. Within each location, most trials exhibited similar results, hence results were reported by location. All indices were significant in the linear analysis for Minnipa and Lock, while Nunjikompita and Piednippie had different indices of significance. Only three spectral indices were significant across all sites (ninson, wisoil and wat3; Table 2), each of these indices represents water vapour peaks of absorbance. The differences in significance within the linear relationship of spectral indices and soil moisture may be related to differences in soil structure across locations.

In order to validate the predictive model (Table 2), a linear model of spectral vs soil moisture was calculated by combining trials sharing similarities in reflectance data (data not shown). As a result, Minnipa and Lock had the highest R^2 for predicting soil moisture, followed by Nunjikompita and Piednippie trials (Figure 3a-c). At Piednippie and Nunjikompita, there was a distinct separation of soil moisture versus spectral predictions according to depth (Figure 3b-c). The greater separation at Piednippie over Nunjikompita may be due to the lower number of soil depths used in comparison with the other trials (Minnipa and Lock 0-90 cm, Nunjikompita 0-60 cm and Piednippie 0-30 cm).

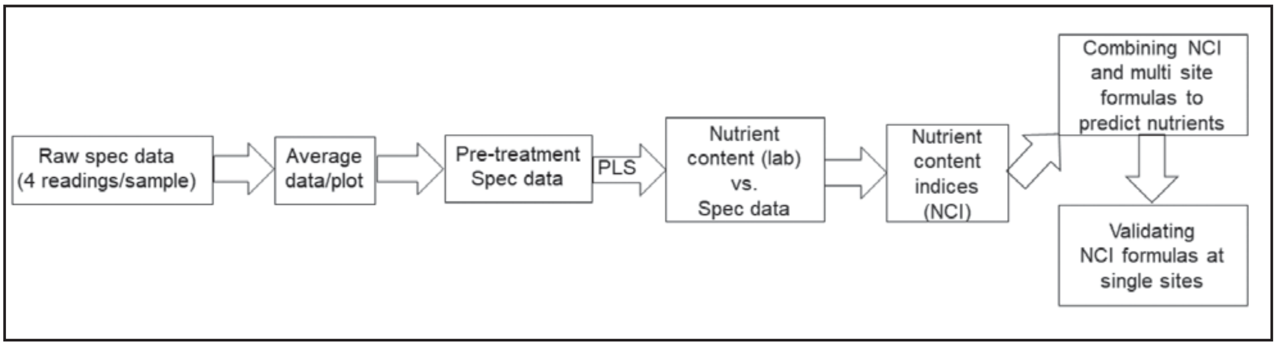

Figure 1 Example flowchart of the spectral (spec) data processing for nutrient data, from collection to the development of spectral equations. PLS=partial least square analysis.

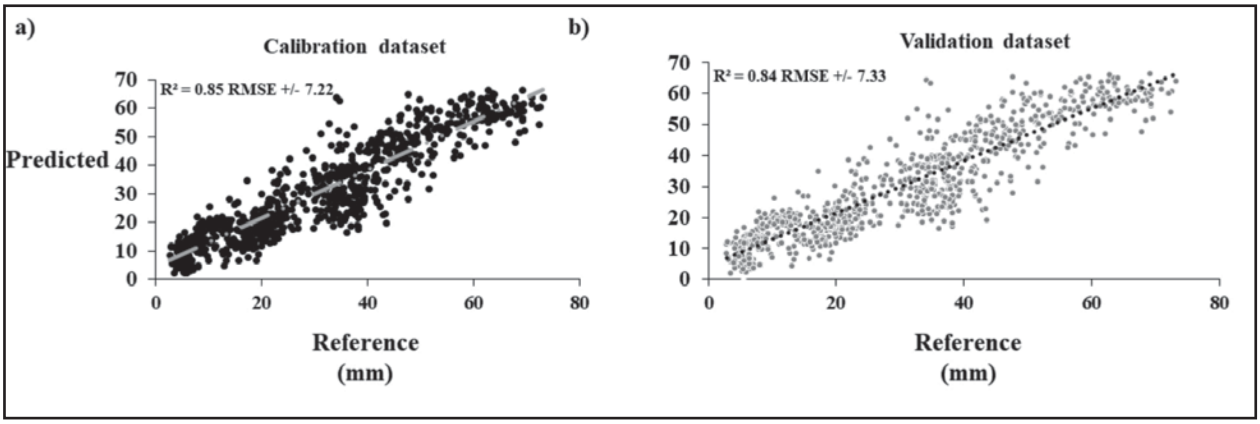

Figure 2a-b Relationship between soil moisture (reference, mm) and the spectral (predicted) data from the five locations on Eyre Peninsula in 2018. RMSE=root mean square error.

Table 2 List of new (wat3-wat9) and published (ninsol, ninson, nmsi, wisoil) spectral indices. The + sign indicates the spectral indices that were significant in the analyses for each location.

Name of spectral indices	Wavelength intervals	Minnipa /Lock	Nunjikompita	Piednippie
ninsol	(2076-2260)	+		
ninson	(2122-2230)	+	+	+
nsmi	(1800-2119)	+	+	
wisoil	(1300-1450)	+	+	+
wat3	(1666-1807)	+	+	+
wat4	(565-606)	+		+
wat5	(1948-2042)	+		
wat6	(350-523)	+		
wat8	(856-1102)	+	+	
wat9	(1290-1500)	+	+	

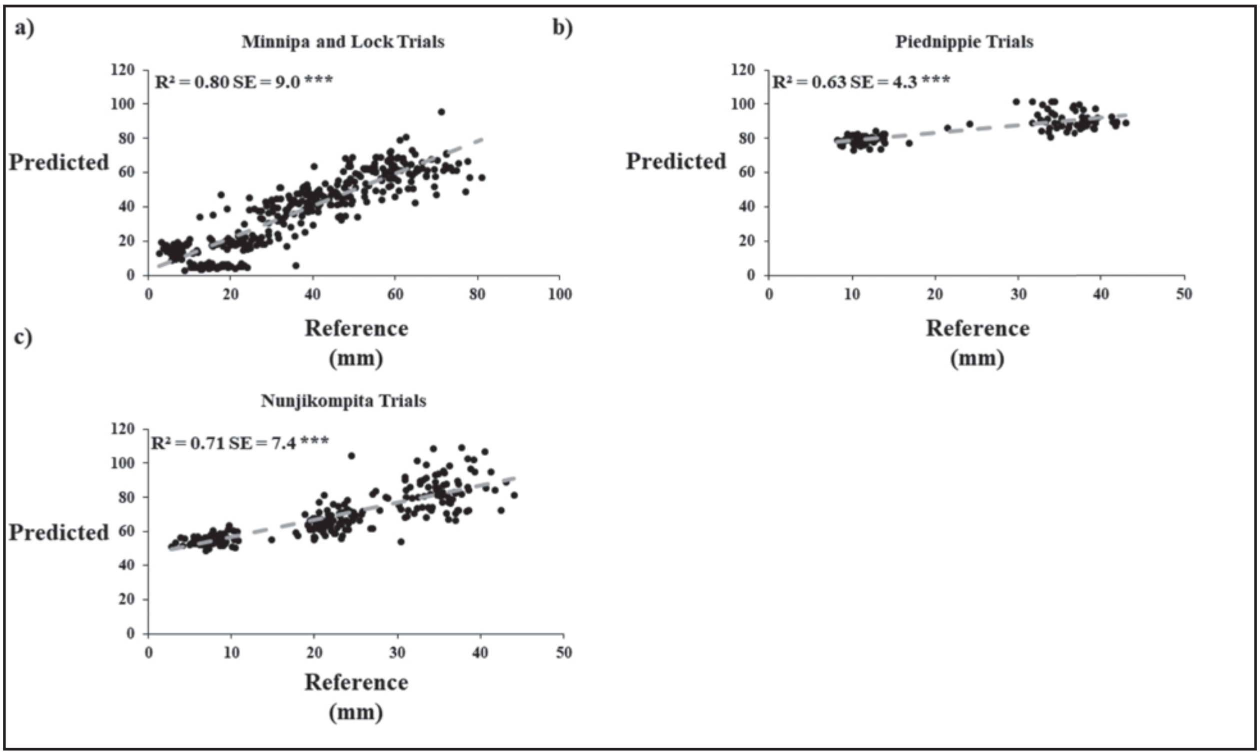

*Figure 3a-c Validation linear models using reference and predicted soil moisture at Minnipa and Lock (a), Piednippie (b) and (c) Nunjikompita trials. SE=Standard error, *** = P<0.001.*

Soil nitrogen

A multi-site analysis considering Lock, Cummins and Minnipa data for 2018 was performed to test the relationship between soil nitrogen and soil spectral data (Figure 4). From the analysis, multiple peaks of regression coefficients were detected with a moderate relationship to soil nitrogen (R^2=0.56-0.54, RMSE, Figure 4a-b). Although seven new spectral indices were generated following the same process as in the soil moisture dataset, the variability explained by the data was not sufficient to be used by growers (data not shown). Further studies should examine the potential environmental factors that may affect the relationship between spectral data and soil nitrogen.

Crop nutrient content (nitrogen)

A multi environment partial least square analysis was performed considering 2017-18 trial data from Cummins, Lock, Minnipa and Nunjikompita, and the Piednippie 2018 trial to establish a strong relationship between nitrogen (nitrogen nutrition index) and spectral data (Figure 5a-b).

Crop nutrient content - phosphorus, potassium, sulphur and copper

In the Unscrambler X software, Piednippie and Nunjikompita trials were combined to determine the relationship between GS31 biomass nutrient content measured in the laboratory and biomass nutrient content measured by using spectral data (Figure 6a-c). All micronutrients showed a non-significant relationship between the spectral data and laboratory reference (data not shown). Potassium and phosphorous showed the highest relationship between the laboratory and field reference, followed by sulphur and copper. Particularly, sulphur showed a moderate relationship at the Nunjikompita trial (R^2=0.6), while a low relationship (R^2=0.2) was detected at Piednippie. Relationships between macronutrients and spectral results would require further testing across multiple seasons and locations in order develop reliable predictive models.

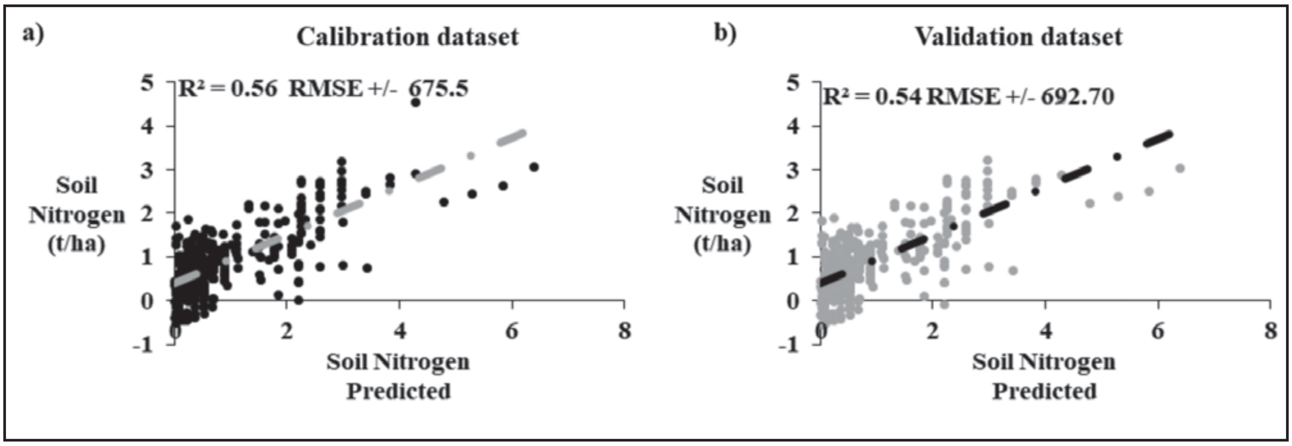

Figure 4a-b Output of the partial least square regression analysis in the Unscrambler software X between the soil nitrogen (kg/ha, reference) and the spectral (predicted) data from Cummins, Minnipa and Lock trials. In (a) linear relationship between reference and prediction, in (b) weighted regression coefficients across the 350-2500 nm spectra. RMSE=root mean square error

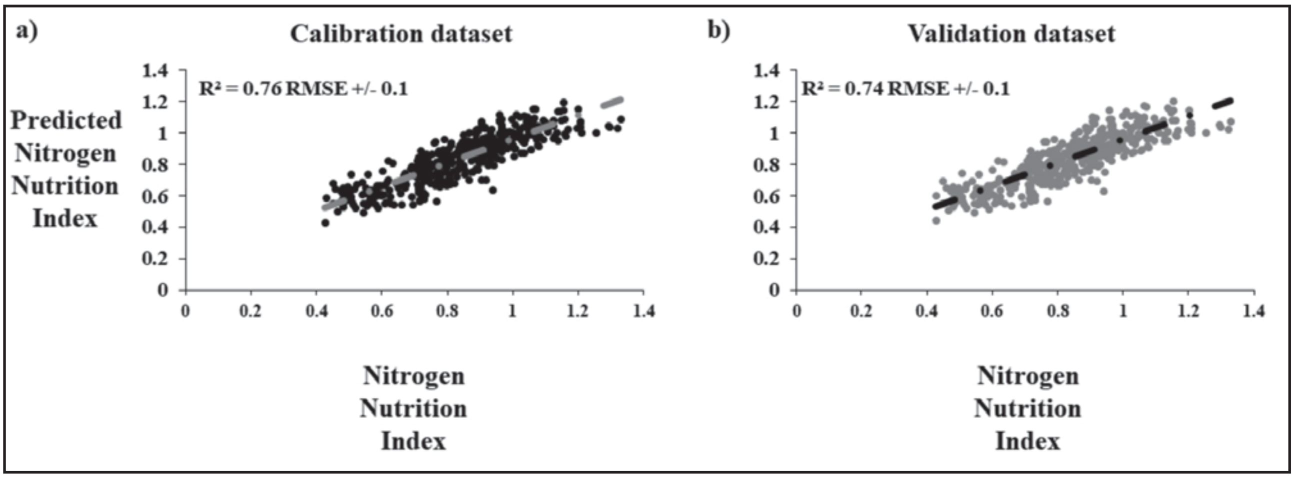

Figure 5a-b The relationship of crop nitrogen (reference) and the spectral (predicted) data from Cummins, Minnipa, Lock 2017-18 and Nunjikompita, Piednippie 2018 trials. RMSE=root mean square error.

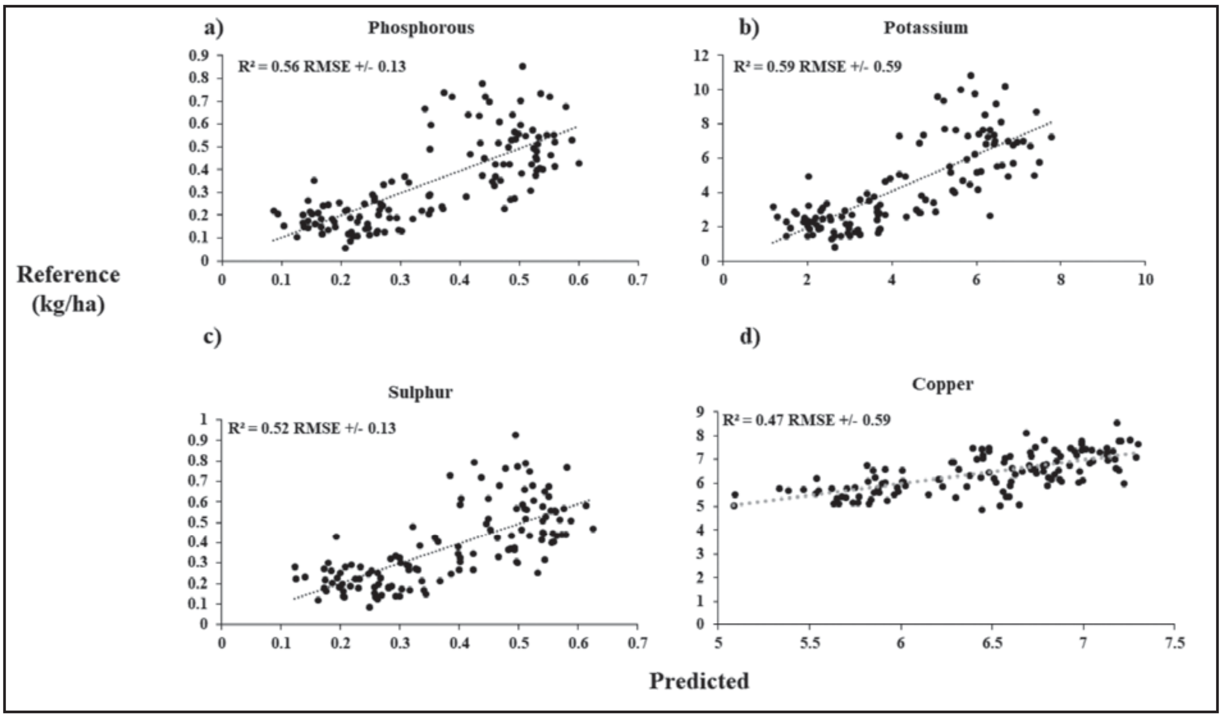

Figure 6a-d The relationship between crop nutrients (kg/ha, lab reference) and spectral data (predicted) data from Nunjikompita and Piednippie in 2018 trials. RMSE=root mean square error.

What does this mean?

PS technology could provide a useful method for estimating soil and crop nutrient content as it is a quicker and cheaper method than traditional laboratory results. Spectral predictions of soil moisture and depths appear to be reliable and stable across different soil types and depths. Spectral predictions of crop nitrogen have shown a strong relationship across six EP locations. In calcareous soils, a moderately stable relationship was also found between spectral indices and nutrients other than nitrogen, especially sulphur. However, in order for growers to use PS technology on soil and crop nutrient content in the field, further research and studies are needed to determine the environmental conditions that allow specific arrays of spectral indices to have a significant relationship with nutrients.

Acknowledgements

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Section Editor:
Jessica Gunn
SARDI, Minnipa Agricultural Centre

Section
9

Weeds

Swathing cereals for barley grass weed seed collection

RESEARCH

Amanda Cook[1], Ian Richter[1] and Bruce Heddle[2]
[1]SARDI, Minnipa Agricultural Centre; [2]Minnipa farmer

Location
Minnipa
Rainfall
Av. Annual: 325 mm
Av. GSR: 241 mm

Key messages

- **In 2016 only 40% of the barley grass was greater than 17 cm tall and had the potential to be collected by early swathing, or 60% of the barley grass seed had already shed or was below harvest weed seed collection height.**
- **Sampling of the swathed paddock area showed slightly better barley grass weed seed collection using swathing than from the rest of the paddock which was harvested normally.**
- **Seed capture at both swathing and harvest is higher with annual ryegrass than with barley grass.**

Why do the demonstration?

Barley grass continues to be a major grass weed in cereal cropping regions on upper Eyre Peninsula. An integrated approach to weed management (IWM) is required to slow the development of herbicide resistance and aims to lower the weed seed bank with the use of non-chemical techniques such as harvest weed seed management including burning stubble, narrow windrows and chaff cart dumps. Swathing early then harvesting for weed seed collection may be another tool for IWM which needs further evaluation, especially for barley grass.

Just prior to harvest in 2016, Bruce Heddle swathed a cereal crop with grass weed issues early (between 20 and 40% grain moisture) for grass weed seed capture into windrows, which he followed with harvesting using a chaff cart. This SAGIT funded project has provided resources to assess barley grass weed seed capture by swathing and weed seed capture in chaff dumps after harvest, to determine how effective these practices can be in contributing towards an IWM program for barley grass on upper Eyre Peninsula.

How was it done?

At harvest in 2016, swathing was undertaken by Bruce Heddle in a Mace wheat crop sown at 50 kg/ha which was grazed early then allowed to recover for harvest. Samples were collected pre-harvest for weed assessment on 21 September 2016, and post-harvest soil and chaff samples were taken on 15 December 2016, to be assessed in weed seed trays. Due to the poor season and limited seed germination in 2017, the weed seed trays were also left during the 2018 season to further assess grass weed germination.

In-crop paddock monitoring for grass weed populations was undertaken and grass weeds were assessed at 10 GPS points along two transects for weed density, with six counts taken at each sample point.

Early harvest barley grass weed seed capture (at swathing)
Crop and weeds were cut at 15-17 cm height (header cutting height) from four quadrats at six GPS-located sampling points before swathing. Crop and grass weeds were separated to measure weight and weed seed head length and calculate weed seed capture/m^2.

Weeds

The surface soil was also collected, and barley grass weed seeds were cleaned from the soil sample and weighed to calculate the weed seeds that had dropped before swathing.

Assessing weed seed capture in chaff dumps after harvesting

Chaff was collected from 14 chaff dumps (6 swathed, 6 with normal harvest and 2 in selected grass weed areas) with 10 samples per dump, taken approximately 40 cm into the dump (which were approximately 1 m high), to determine the weed seed species being collected at harvest. Fifty grams of chaff were added to each germination tray with three replications. Soil samples for weed seed bank were collected on 20 December 2016 near the chaff dumps sampled, taking ten soil cores at each location, which was evenly distributed into three soil trays to be germinated. The trays were assessed for weed germination approximately every four weeks. The counted weeds were removed from the trays.

What happened?

Transects conducted pre-harvest at 20 locations in the paddock, with four counts at each location, resulted in an average 115 Mace wheat plants/m^2, 7.9 barley grass plants/m^2 (but up to 47 barley grass plants/m^2 in weedier areas) and 2.8 ryegrass plants/m^2 (Table 1).

The pre-harvest weed counts showed that over 60% of the weed seed had already dropped by mid-September in 2016. Therefore less than 40% of the total barley grass seed was still in a position to be harvested using swathing (Table 2). In all of the chaff dumps ryegrass numbers are higher than barley grass indicating ryegrass retains its seed better and is able to be collected using harvest weed seed collection methods.

Table 1 Plant counts pre-harvest 2016 from Bruce Heddle's Hardy Hill paddock, Minnipa

	Wheat (plants/m^2)	Barley grass (plants/m^2)	Rye grass (plants/m^2)
Transect 1 (along fence line)	126	5	3
Transect 2 (through paddock)	105	11 (47 in weedy area)	3

Table 2 Weed seed counts from pre-harvest 2016 cuts from Bruce Heddle's Hardy Hill paddock, Minnipa

Average of four samples	Wheat (plants/m^2)	Wheat dry matter (t/ha)	Barley grass seed to be potentially captured above 17 cm (seeds/m^2)	Ryegrass seed to be potentially captured above 17 cm (seeds/m^2)	Barley grass seed already dropped, in soil sample (seeds/m^2)	Barley grass seed dropped or below 17 cm (%)
Point 7	107.3	5.6	767	419	1331	63
Point 8	94.5	5.1	801	659	1372	63
Point 9	105.3	6.4	287	391	619	68

Table 3 Weed seed counts in 2017 weed seed trays from chaff dumps and soil collected at harvest 2016 from Bruce Heddle's Hardy Hill paddock, Minnipa

	Barley grass (plants/50 g chaff or soil)	Rye grass (plants/50 g chaff or soil)	Self-sown cereal (plants/50 g chaff or soil)
Chaff dumps			
Normal harvest dumps	0.4	20.8	1.5
Swathed dumps	4.4	77.5	52.7
Fence line transect dumps	2.4	3.0	0
Weedy area dumps (2)	1.1	46.8	0.9
Soil			
Soil normal harvest area of paddock	22.5	0.4	0
Soil swathed area of paddock	7.2	1.8	0
Soil fence line transect	2.4	3.0	0

The weed seed germination tray data collected in 2017 (Table 3) shows the greatest number of seeds for both weeds and cereal was collected in the swathed dumps compared to harvesting at normal time. The weedy area dumps showed lower barley grass weed seed collection than the swathed area despite having greater barley grass weeds present in this area.

The soil collected near the dumps after harvest also shows the swathed area had lower barley grass weeds than the normal harvested area. The fence line transect had lower initial grass weed numbers than the paddock transect, which is reflected in the weed seed data (Table 3). The cereal seed numbers were higher in the chaff dump in the swathed crop than at normal harvest timing.

What does this mean?

In weed counts pre-harvest 2016, only 40% of the barley grass seed was greater than 17 cm height or hadn't already shed so had the potential to be collected by early swathing. Swathing the wheat has resulted in greater numbers of barley grass in the swathed dumps and lower numbers in the soil compared to leaving the crop until normal harvest timing. The results reflect that annual ryegrass is easier to collect using harvest weed seed collection methods both at normal harvest, and using swathing. Cereal losses in the chaff dumps were higher in the swathed crop than normal harvest timing but was still a very low overall loss of less than 2% in a 3 t/ha crop. Further evaluation of swathing for grass weed seed collection and cereal grain losses need to be undertaken. Swathing will not become a commonly used practice but if barley grass resistance to herbicides becomes a bigger issue in the future it may be an additive tool to potentially increase the amount of seed contained to within the chaff dumps and chaff rows.

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Monitoring barley grass in broad acre paddocks

RESEARCH

Amanda Cook[1], Ian Richter[1], Scott Gillet[2], Terry Traeger[3] and Jake Hull[1]

[1]SARDI, Minnipa Agricultural Centre; [2]Wisdom Data and Mapping, Loxton; [3]Drone View Photography, Cleve

Location
Minnipa and Heddle's
Rainfall
Av. Annual: 325 mm
Av. GSR: 241 mm
2018 Total: 268 mm
2018 GSR: 208 mm
Soil Type
Red loam
Plot Size
Paddock monitoring
Location
Yaninee
2018 Total: 181 mm
2018 GSR: 156 mm
Soil Type
Red loam
Plot Size
Paddock monitoring

Key messages

- **UAV imagery with skilled specialist analysis and programs has the potential to identify and map weed issues in paddocks.**
- **Grass weed patches are easier to identify in legume and pasture crops than cereal crops.**
- **Variability in germination and crop growth makes it harder to identify grass weed areas.**
- **Data capture and analysis for analytical purposes such as grass weed mapping in individual paddocks will be beyond the skills of most farm businesses unless farmers have a special interest in this area.**
- **Group A resistant barley grass has once again been detected at the Minnipa Agricultural Centre. Barley grass resistance to Group A herbicides has been detected three times in three years, so be aware it is present in current farming systems.**

Why do the trial?

Barley grass continues to be a major grass weed in cereal cropping regions on upper Eyre Peninsula (EP). The use of unmanned aerial vehicle (UAV) technology to identify and assess barley grass populations in paddocks and monitor potential resistant populations may be a useful tool for farmers. Barley grass weed density was monitored in three paddocks on upper EP (Minnipa Agricultural Centre (MAC), Heddle's at Minnipa and Wilkins' at Yaninee using an UAV during the 2017 (EPFS Summary 2017, p 83) and 2018 growing seasons at three different timings, with paddock transects conducted to verify grass weed density in paddocks.

How was it done?

In-crop paddock monitoring for grass weed populations

Grass weeds were assessed in crop or pasture at eight paddock-marked GPS points, and in 2018 also marked in the paddock with a large corflute sign visible in the imagery, with six or more counts taken at each sample point and each timing during the season. This was used to verify the UAV data captured at three times during the cropping season. Extra sampling points in the paddock were targeted if more information was needed to verify the imagery. The paddock photos were captured on an iPad with 'Avenza Maps' linked to the location in the paddock.

In 2018, grass weed assessments were undertaken on:

- Heddle's (sown early with barley and wheat) 13 July, 21 August, 14 September.
- MAC (vetch) 9 August, 14 September, 18 October.
- Yaninee (late sown wheat to allow grass control) 9 August, 17 September, 18 October.

UAV imagery

UAV data were captured three times in each paddock during the 2018 cropping season. The UAVs used were either a DJI Matrice 100 with both NIR and RGB sensors or a Mavic Pro with RGB sensors. In 2018 the UAVs were flown at a height of 120 metres and a smaller 10 ha area at 50 metres to increase the detail of the information captured.

Training features were created which highlighted areas of high weed infestation within the image. These areas are identified by matching photos from the ground with the aerial imagery. Originally, training features also aimed to identify other features such as clean crop areas, but the training process was found to be more accurate when a single type of weed pixel was the focus of analysis. This currently needs to be done separately for each image flown, which is a labour intensive process.

Data analysis of UAV imagery

To analyse weed locations at a whole paddock level using the UAV imagery, geospatial analysis tools were used to automate the selection of likely weed infestation areas. A map of the paddock with the UAV coverage was generated from ArcGIS Desktop as a geo-pdf to enable collection and analysis of field data.

This is a map file which can be used in a range of devices. With this file loaded to the 'Avenza Maps' app on a tablet, photos and comments with GPS locations were collected. This data was then added to ArcGIS and used to interpret the UAV mapping.

The Spatial Analyst extension within ESRI's ArcGIS Desktop software was used to carry out a 'Maximum Likelihood' spatial classification. This classification uses small parts of the image selected by the user as 'training features' for deciding which category each pixel of the image most likely fits into. This classification method is based entirely on the spectral (colours through different bands of light) characteristics of the imagery. Training features were created which highlighted areas of high weeds, low weeds/crop features and bare ground.

What happened?

In 2018 the paddocks monitored were two cereal crops and one vetch. Heddle's at Minnipa Hill was sown on 7 May with Scope barley at 50 kg/ha with 60 kg/ha of 18:20:0:0 (DAP) on the outside with six seeder widths to increase grass weed competition with weeds captured in the chaff dumps, which are dropped in the outer areas of the paddock. The remainder of the paddock, and the larger area, was sown with Mace wheat at 60 kg/ha with 60 kg/ha of 18:20:0:0.

Wilkins' paddock at Yaninee was sown on 16 June after a cultivation and grass weed germination with Mace wheat and 18:20:0:0, both at 60 kg/ha, and pre-emergent herbicides of 1 L/ha Treflan and 800 ml/ha Ultramax. Post emergent herbicides Ester 680 @ 400 ml/ha and ZMC @ 3 L/ha were applied on 18 August.

MAC paddock S4 was sown with Volga vetch @ 40 kg/ha on 4 May with 40 kg/ha Granulock Z and Metribuzin @ 100 g/ha and Diuron @ 400 g/ha. The paddock was sprayed with 150 ml/ha of Targa Bolt and Uptake @ 500 ml/ha on 10 August for grass weeds. Circular barley grass patches were still present in the paddock so the western corner of the paddock was cut for hay on 27 September. The vetch averaged 81 plants/m^2, with 132 barley grass weeds/m^2 and 11 ryegrass weeds/m^2 on 9 August, before grass weed control. In the general paddock there were 21 barley grass weeds/m^2 on 14 September after spraying, with visual circular patches of barley grass with an average of 212 barley grass weeds/m^2.

At Minnipa the 2018 growing season rainfall was 208 mm, decile 3 (below average), with small rain events in April and May, 30 mm in June and July, with August finally having good rains totalling 89 mm. There was variable germination in early sown paddocks and minimal growth and dry matter in paddocks until mid-August. Very little rainfall occurred in September, but 33 mm in October and mild grain filling conditions were followed by rain events during harvest.

UAV flights were conducted on the dates shown in Table 1. Wilkins' paddock was sown and established late and had very few grass weeds to monitor, so only two flights were undertaken in this paddock, three flights at MAC and four flights at Heddle's during the 2018 season.

Early season growth in paddocks was low, especially in later sown crops and dry matter (DM) only increased in mid-August. In Heddle's paddock (Images 1, 2 and 3), differences in early moisture stress and plant establishment resulted in large differences in dry matter by 21 August (average of 0.24 t/ha DM, with a maximum of 1.06 t/ha DM). Differences in crop growth may be an important factor in the changing of crop coloration (Image 3).

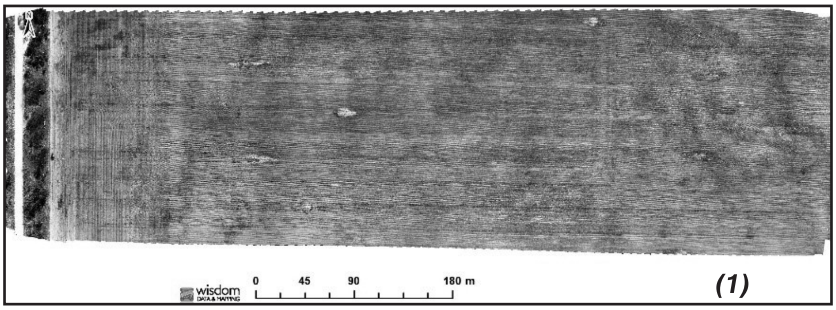
In 2018 higher and lower UAV flights were trialled so a smaller area at higher resolution with more detail was captured to use as a training data source for the image flown at higher altitude. The training data created from the lower flight didn't seem to detect grass weeds any better when used in an analysis process run against the larger image. It is possible the camera slightly changed the exposure due to different light levels, even though they were flown on the same day. The image is also at lower resolution so the pixels would be different. Flying at different heights to add more detail to the analysis will be tested again in 2019. Satellite imagery may be another way to extend the area of the analysis, however no satellite imagery with a resolution below 10 m could be cost effectively sourced and this option was not pursued in 2018.

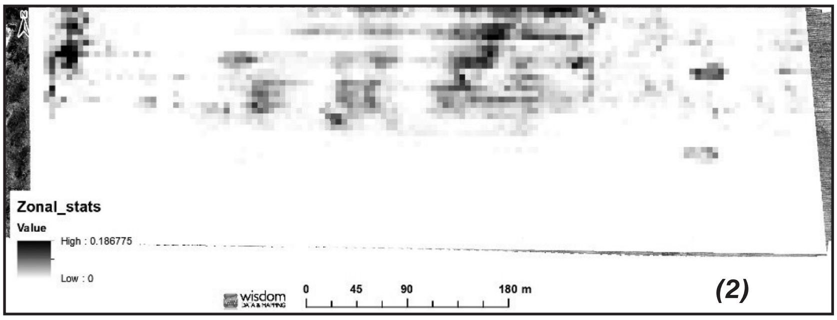
The MAC S4 paddock in vetch, which has previously shown resistance to Group A herbicides, had large areas of barley grass weed patches survive chemical applications, and some smaller circular patches in the southern end (Image 6). This paddock is again being tested for herbicide resistance to confirm Group A resistance in barley grass.

A comparison of the 2017 and 2018 weed map area in MAC S4 for the western half of the paddock was made (Image 4 and 5). Some similarities in occurrence patterns were observed, but differences in crops sown (barley in 2017 and vetch in 2018) may also have had an impact. The vetch crop in 2018 may have been less competitive with weeds, or it is much easier to detect grass weeds in legume and pasture crops than cereal crops. The area of heaviest weed growth in the 2017 imagery was cut for vetch hay in the 2018 image, indicating the area is likely to have been higher in weeds in both seasons.

Table 1 UAV image capture flights conducted in 2018

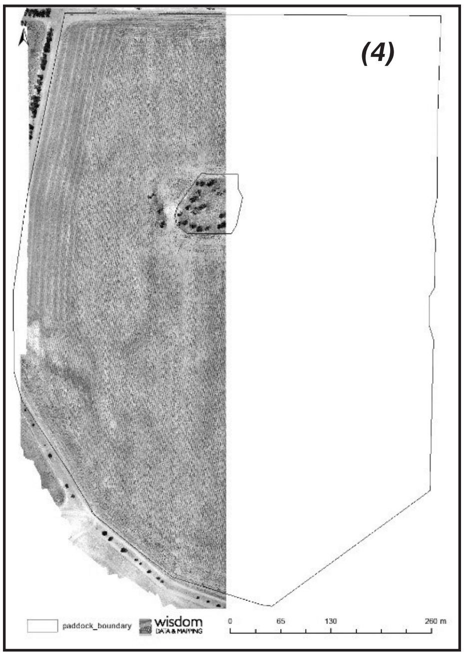
Heddle's	20 July	21 August	12 September	18 October
MAC S4		13 August	12 September	18 October
Wilkins			12 September	18 October






(3)

Image 1 and 2 Heddle's crop image flown on 12 July 2018 and weed areas detected from the analysis. Image 3 Photo of differences in crop growth at Heddle's in July 2018 due to germination and moisture stress.



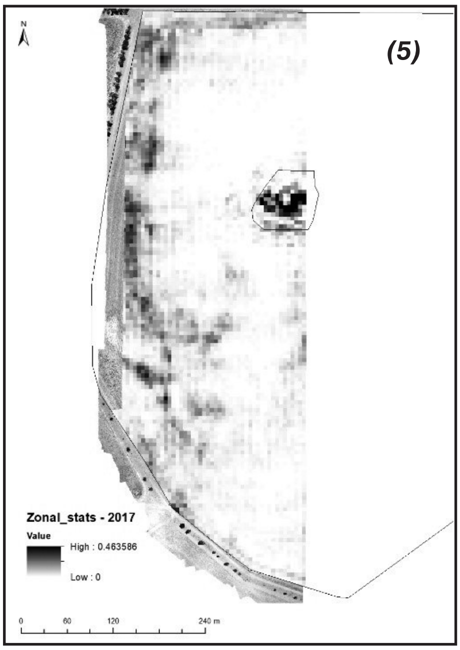


Image 4 and 5 MAC S4 paddock in 2018 and the barley grass weed density map. Image 6 Photo of Group A resistant barley grass patches, September 2018

Wilkins' paddock was sown late to enable effective grass weed control with cultivation prior to sowing, and the flight analysis found this to be a 'clean' (almost grass free) paddock, which was reflected by in-paddock grass weed counts. At this site the changing light conditions (cloud cover) as the flight was in progress in September resulted in variability in exposure on the image which made the analysis less accurate.

What does this mean?

UAV imagery may provide an opportunity to assist in targeted grass weed management. Current UAV technology is cheap to purchase and has high resolution. However the time and effort of collecting data over large paddock areas, and the expertise required for analysing the data, and variable image quality, may limit the adoption by farmers unless they personally have the time or the interest to acquire these skills, are willing to pay to acquire the data capture and analysis (approximately $6,000 per paddock), or if a cheap and easy to use analysis method or program becomes available.

In 2018 the UAV flights captured data over a smaller area at half the usual height to provide a higher resolution strip, which was used for more accurate analysis within this smaller area of the paddock. Higher resolution imagery allows 'cleaner' weed pixels (those which include less dirt, stubble or crop) to be selected when training the image classification process. With a higher resolution image the classification process will also encounter a higher percentage of 'cleaner' weed pixels, which improves the classification output. It is also possible to check the analysis results and see what is being identified because the inter-row areas can be selected from the crop. This process of analysis is looking to identify weed infestation trends to guide variable rate application and identify areas of the paddock needing ongoing grass weed monitoring.

Acquiring a full paddock analysis but using the information from the smaller area to predict the whole paddock and other paddocks on the same farm is required before the technology will be adopted by farmers on a broad scale. This research is ongoing for the 2019 season so more information and knowledge will be generated about the use of imagery and data collection for weed management in current farming systems.

Acknowledgements

This research was funded by SAGIT S117. Sincere thanks to SAGIT and their extremely valuable input into regional South Australian research and researchers. Thank you to Bruce Heddle and Wilkins families for having the research and monitoring on their property.

SARDI

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SAGIT

Harvest weed seed collection in broad acre paddocks

Amanda Cook and Ian Richter
SARDI, Minnipa Agricultural Centre

Location
Minnipa
Rainfall
Av. Annual: 325 mm
Av. GSR: 241 mm

Location
Mudamuckla
Rainfall
Av. Annual: 291 mm
Av. GSR: 219 mm

Key messages

- **Harvest weed seed collection showed barley grass is harder to capture using harvest weed seed collection techniques due to its habit of shedding seed early.**
- **Burning windrows decreased the number of weed seeds present in the soil seedbank at Minnipa in 2017.**
- **Harvest weed seed collection allows for the capture of ryegrass weed seed and cereal screenings, potentially increasing feed utilisation for stock when placed in chaff dumps or rows.**

Why do the demonstration?

Barley grass and ryegrass are the major grass weeds in cereal cropping regions on upper Eyre Peninsula. An integrated approach to weed management (IWM) is required to slow the development of herbicide resistance and aims to lower the weed seed bank with the use of non-chemical techniques such as harvest weed seed management, including narrow windrows, chaff cart dumps and burning stubble. This is a summary of paddock surveys of harvest weed seed collection samples taken in 2016, 2017 and 2018 as a part of the GRDC Stubble Initiative project ‘Maintaining profitability in retained stubbles on upper Eyre Peninsula’ (EPF00001).

How was it done?

Samples were collected post-harvest each season, with both soil and chaff samples taken to be assessed in weed seed trays during the following growing season. In-crop paddock monitoring for grass weed populations was undertaken and grass weeds were assessed at 10 GPS points along transects for weed density with six counts taken at each sample point.

Assessing weed seed capture and burning in narrow windrows

Soil samples for weed seed banks were collected in February 2017 along a transect across the paddocks comprising of 10 GPS-located sampling points. The core soil sampling method was described by Kleemann *et al*. (2014). Prior to narrow windrows being burnt, a 5 m section of chaff was removed (non-burnt area) within each paddock (see EPFS Summary 2015, p150-151 for further details) and weed seeds in soil or chaff were germinated in 2017. Germinating trays, 35 cm x 29 cm, were partially filled with sterilised soil mix and the collected weed seed bank soil or chaff was then spread over the top to 1-2 cm depth, with another light coating of the sterilised soil mix spread over the soil or chaff. The trays were placed in a rabbit proof open area and watered if required during the season. Trays were assessed for weed germination approximately every four weeks. Counted weeds were removed from the trays. Control plots with barley grass seed collected from Minnipa Agricultural Centre (MAC) oil mallee area (sprinkled into trays) were located across the germination area to assess timing of barley grass germination relative to a non-cropped population.

Assessing weed seed capture in chaff dumps after harvesting

Chaff was collected from chaff dumps with 10 samples per dump, taken approximately 40 cm into the dump (which were approximately 1 m high), to determine the weed seed species being collected at harvest. Fifty grams of chaff were added to each germination tray with three replications.

What happened?

The weed populations were generally lower in the paddocks sampled (Table 1), except Paddock 33 at Mudamuckla which had higher levels of ryegrass present (33 plants/m^2) and the Tcharkuldu paddock in 2017 had high levels of barley grass (259 plants/m^2). MAC generally had low levels of ryegrass and some barley grass present.

Table 1 Plant counts at Mudamuckla and Minnipa before harvest 2016, and at Tcharkuldu in 2017

Location	Barley grass (plants/m²)	Rye grass (plants/m²)	Cereal crop (plants/m²)
Paddock 33	5.3	33	93
Paddock 95	0.4	12	99
MAC S4	6.9	0.3	110
MAC S1	7.4	0.1	110
MAC S7	4.3	1.3	87
MAC Airport	2.3	1.7	115
Tcharkuldu	259	0.6	190

Table 2 Mean weed seed counts in 2017 weed seed trays from chaff dumps and soil collected from Mudamuckla at harvest 2016

Location	Barley grass (plants/50 g chaff or soil)	Rye grass (plants/50 g chaff or soil)	Self-sown cereal (plants/50 g chaff or soil)	Brome grass (plants/50 g chaff or soil)
Paddock 33 chaff dumps	0.3	12.2	14.6	0.04
Paddock 95 chaff dumps	1.4	3.8	18.3	0.6
Paddock 33 soil	7.0	12.3	0	0
Paddock 95 soil	0.7	1.2	0	0.07

Table 3 Weed seed counts in 2017 weed seed trays from chaff dumps and soil collected at harvest 2016 from Minnipa Agricultural Centre windrows (burnt in autumn 2017)

Paddock	2016 Crop	Sample	Barley grass (plants/50 g soil)	Rye grass (plants/50 g soil)	Self-sown cereal (plants/50 g soil)
MAC S4	Trojan Wheat	Inter row (before burning)	2.6	0.2	0.5
		In row before burning (soil collected before burning)	0.6	0.2	0.1
		In row burnt (soil collected after burning)	0.8	0.2	0.5
MAC S1	Mace Wheat	Inter row (before burning)	2.6	0.2	0.5
		In row before burning (soil collected before burning)	0.6	0.2	0.1
		In row burnt (soil collected after burning)	0.5	0	0.3
MAC S7	Mace Wheat	Inter row (before burning)	5.1	0.1	0.1
		In row before burning (soil collected before burning)	0.5	0.3	0.8
		In row burnt (soil collected after burning)	0	0	0
MAC Airport	Wheat	Inter row (before burning)	1.6	6.5	0.1
		In row before burning (soil collected before burning)	0.8	0.4	0.5
		In row burnt (soil collected after burning)	0	0.2	0.1
Oil Mallee	Uncropped	Barley grass check plots	144	0	0

Table 4 Weed seed counts in 2018 weed seed trays from chaff dumps and soil collected from Tcharkuldu at harvest 2017

	Barley grass (plants/50 g chaff or soil)	Rye grass (plants/50 g chaff or soil)	Self-sown cereal (plants/50 g chaff or soil)
Chaff dumps	30	1.7	13.5
Soil near chaff dump	40	0.3	0.2
Soil off header row (paddock)	27	1.5	0
In header row soil and chaff	34	1.2	2.2

The weed seed tray results from Mudamuckla (Table 2) show there were greater barley grass numbers in the paddock than collected in the chaff dump, indicating seed had dropped before harvest or shattered at harvest time and did not enter the header to be captured. The ryegrass weed seed numbers in the soil were similar to those in the chaff dump indicating mature plants had either dropped seed heads which avoided harvest or small plants were lower than the harvest height. The self-sown cereal was greater within the chaff dumps than in the paddock soil, indicating the screenings were collected into the chaff fraction of the harvest system.

The weed seed trays from the MAC paddocks (Table 3) show the inter row or general paddock area has greater barley grass weed seed numbers than in-row with the chaff fraction. Burning the chaff rows decreased the weed seed numbers, except in MAC S4.

In the paddock at Tcharkuldu (Table 4) with a high barley grass population there was little difference in the barley grass numbers in the chaff dumps or in the header chaff row than in the nearby paddock soil, indicating the barley grass had shed seed before harvest or was too low (less than 15-17 cm) to be collected at harvest. There were more cereal screenings within the chaff dump.

What does this mean?

The harvest weed seed collection results have showed that barley grass, due to its habit of dropping seed early, is harder to capture using harvest weed seed collection techniques. The ability to detect barley grass within the chaff dumps as easily as other seed may also be a factor as barley grass has a burrowing habit, which may result in seed being potentially located lower in the chaff dump/closer to the soil than other seed. More research on the distribution of weed seeds species in chaff dumps could be undertaken in the future. Burning windrows decreased the number of weed seeds present in the soil seedbank at Minnipa in 2017.

Harvest weed seed collection allows for the capture of ryegrass and cereal screenings, and placing the plant material into rows potentially allows for greater feed utilisation for stock rather than grain and straw being distributed randomly across the paddock. Again further research into farming systems efficiencies of harvest windrows, chaff dumps and livestock needs to be undertaken to effectively reduce weeds in low rainfall farming systems.

Acknowledgements

This research was funded by GRDC as a small component of the Stubble Initiative. Thank you to Steve Jeffs, Katrina Brands, Fiona Tomney, Rochelle Wheaton and Brett Hay for helping with the data collection from the weed seed trays. Thanks to the farmers involved for having the research and monitoring on their properties.

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Effect of sowing time x seed rate x herbicides on ryegrass management in wheat

RESEARCH

Gurjeet Gill[1], Ben Fleet[1], Amanda Cook[2] and Ian Richter[2]

[1]University of Adelaide; [2]SARDI Minnipa Agricultural Centre

Location
Minnipa - Bruce Heddle
Rainfall
Av. Annual: 283 mm
Av. GSR: 202 mm
2018 Total: 244 mm
2018 GSR: 186 mm
Paddock History
2018: Medic pasture surrounding, wheat trial
2017: Wheat
2016: Canola
2015: Medic
2014: Wheat
Yield
Potential: 2.6 t/ha (top yielding plot across both trials
Soil Type
Grey calcareous loam
Plot Size
1.5 m x 10 m x 3 reps
Trial Design
Experimental, split, split plot
Yield Limiting Factors
Anuual ryegrass and dry start to season

Key messages

- **Annual ryegrass (ARG) plant density and wheat grain yield at Minnipa was influenced by time of sowing, herbicide treatment and the interaction between time of sowing and herbicide.**
- **There was a significant impact of delayed seeding to late June, with a reduction in ARG plant density and higher efficacy of pre-emergence herbicides measured.**
- **There were large benefits of delayed sowing on weed control. However, these benefits came at a significant cost in wheat grain yield.**

Why do the trial?

Change in sowing time can have multiple effects on crop-weed competition. Delayed sowing can provide opportunities to kill a greater proportion of the weed seedbank before seeding the crop, but weeds that establish in late sown crops can be more competitive on a per plant basis. This is one of the reasons why farmers who have adopted early seeding have reported excellent results in crop yield and weed suppression. Therefore, it is important to investigate sowing time in combination with other practices across different rainfall zones. The review of Widderick *et al*. (2015) has recommended research on sowing time in many crops. Delayed sowing can also reduce crop yield so the gains made in weed control may be completely nullified by the yield penalty.

There has been some research already on crop seed rate on weed suppression but none of these studies have investigated the benefits of higher crop density in factorial combinations with sowing time and herbicide treatments. Crop seed rate is an easy tactic for the growers to adopt provided they are convinced of its benefits to weed management and profitability. Furthermore, growers in the low rainfall areas tend to be reluctant to increase their seed rate due to concerns about the negative impact of high seed rate on grain screenings.

This field trial at Minnipa was undertaken to investigate factorial combinations of sowing time, seed rate and herbicides on the management of annual ryegrass in wheat.

How was it done?

Measurements taken were pre-sowing weed seedbank, crop density, weed density, ARG spike density, ARG seed production, wheat grain yield.

All data collected during the growing season was analysed using the Analysis of Variance function in GenStat version 15.0.

What happened?

In 2018, annual rainfall received at Minnipa was 14% below the long-term average of 283 mm and the disparity for the growing season rainfall from the long-term average of 202 mm was only 8%. The 86 mm of rainfall received in August was more than double the long-term average and rainfall in October (29 mm) and November (30 mm) was also greater than the long-term average.

Wheat plant density

There was a significant interaction between sowing time and wheat seed rate (Figure 1). At the low seed rate, both sowing times produced an identical plant density (64-68 plants/m^2), which was 32-36% below the target density. However, the gap from the target seed rate increased to 37% at the highest seed rate in TOS 1 and 47% in TOS 2. Lower than expected crop establishment in this trial appeared to be related to below average rainfall at the site in May and June.

Table 1 Key trial treatments and management operations undertaken at Minnipa in 2018

Operation	Details
Location	Minnipa, SA
Seedbank soil cores	8 April 2018
Plot size	1.5 m x 10 m
Trial design	Split plot x 3 replicates
Seeding date	TOS 1: 11 May 2018 TOS 2: 25 June 2018
Fertiliser	Applied at sowing, DAP (18:20) @ 60 kg/ha
Variety	Scepter wheat
Seeding rate x 3	100 seeds/m^2 150 seeds/m^2 200 seeds/m^2
Herbicides x 3	11 May and 25 June, 2018 (applied just before seeding) Sakura 118 g/ha + Avadex 1.6 L/ha IBS Control (knockdown treatment only)

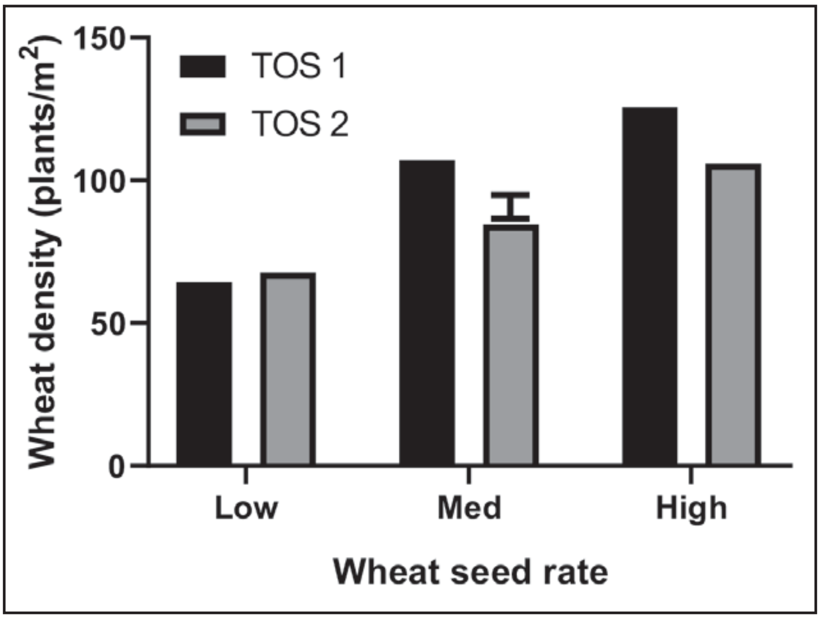

Figure 1 The effect of seed rate on wheat plant density in time of sowing 1 (TOS 1) and time of sowing 2 (TOS 2). The vertical bar represents the LSD (P=0.05).

Annual ryegrass plant density and seedbank

The average seedbank of annual ryegrass (ARG) at the site was 716 ± 38 seeds/m^2. ARG plant density was significantly influenced by the time of sowing ($P<0.001$), herbicide treatment ($P<0.001$) and the interaction between the time of sowing and herbicide ($P<0.001$).

There was a large impact of the six week delay in seeding on ARG plant density (Figure 2). This was particularly evident in the untreated control in which ARG density decreased from 262 plants/m^2 in TOS 1 to 139 plants/m^2 in TOS 2. This large response of ARG density to delayed sowing is most likely related to many small rainfall events in June, which would have caused weed emergence. The reduction in ARG plant density due to delayed seeding was also apparent in the herbicide treatments (Figure 2) with both herbicide treatments providing greater efficacy in TOS 2.

The recruitment index (RI) of ryegrass (the ratio between ARG seedbank and plant density) was also significantly affected by the interaction between the time of sowing and herbicide treatments ($P<0.001$). In the untreated control, RI for ARG was 0.46 (i.e. 46% recruitment) which declined to 0.22 (22% recruitment) in TOS 2. This large difference in ARG establishment in two sowing dates again points to high pre-sowing weed establishment, which was effectively controlled by the knockdown treatment of glyphosate.

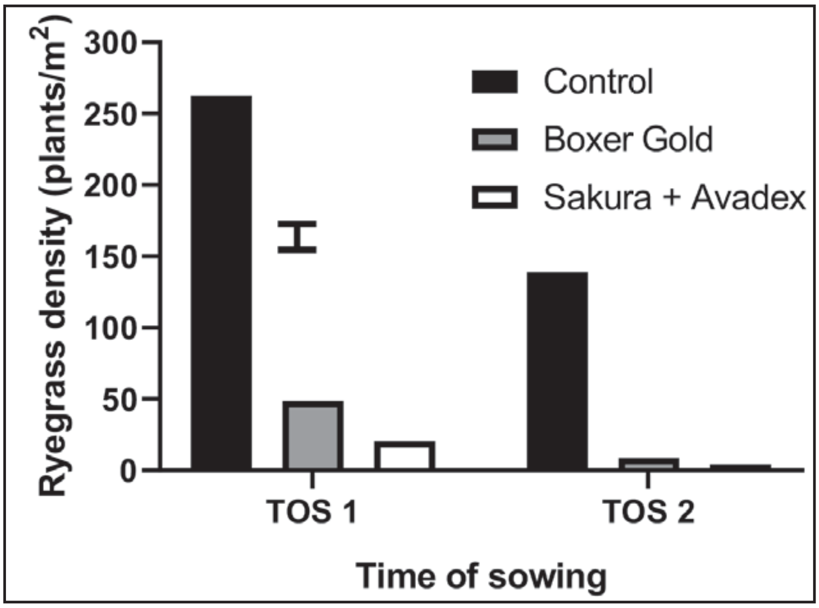

Figure 2 The interaction between the time of sowing and herbicide treatments (P<0.001). The vertical bar represents the LSD (P=0.05).

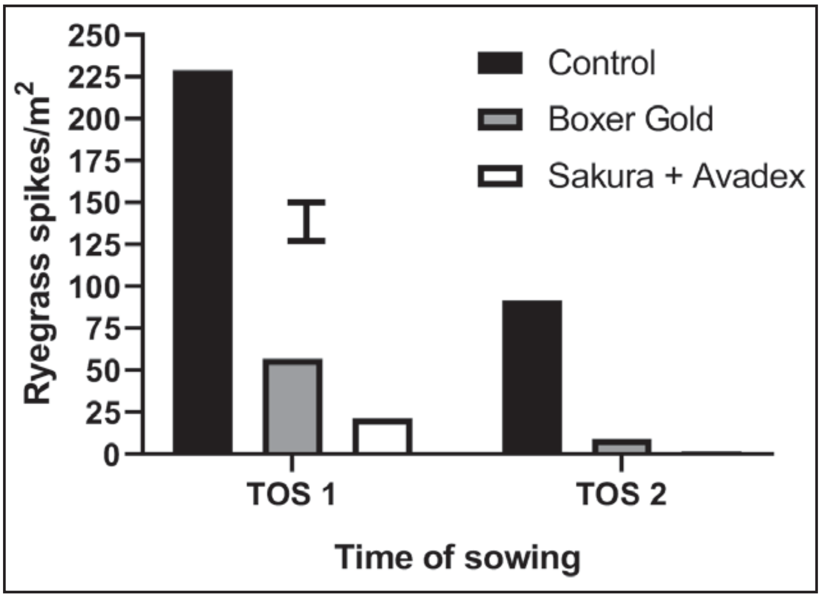

Figure 3 The effect of interaction between the time of sowing and herbicide treatments (P<0.001) on ARG spike density. The vertical bar represents the LSD (P=0.05).

Annual ryegrass spike density and seed production

ARG spike density was significantly influenced by the time of sowing (P=0.012), herbicide treatment (P<0.001) as well as the interaction between the TOS and herbicide treatment (P<0.001). However, there was no effect of wheat seed rate on ARG spike density (P=0.212). When averaged across the seed rates and herbicide treatments, the six week delay in seeding at Minnipa reduced ARG spike density from 102 spikes/m^2 to 34 spikes/m^2 (67% reduction).

Herbicide treatments were also more effective in TOS 2, with the Sakura + Avadex treatment resulting in the production of only two ARG spikes/m^2 (Figure 3). These results clearly highlight the ability of Boxer Gold and Sakura to effectively manage moderate levels of ARG seedbank under adequate soil moisture conditions.

Consistent with the trends observed for ARG spike density, ARG seed production was also significantly influenced by the time of sowing (P=0.047), herbicide treatments (P=0.001) and the interaction between the TOS and the herbicide treatments (P=0.023). Pre-emergence herbicides performed much better in TOS 2 where the density of ARG plants had been reduced by the delay in seeding (Figure 4). In the treatment of Sakura + Avadex, ARG only produced 53 seeds/m^2 in TOS 2, compared to 830 seeds/m^2 in TOS 1.

Wheat grain yield

Wheat grain yield at Minnipa was significantly influenced by the time of sowing (P=0.002), seed rate (P<0.001), herbicide treatment (P<0.001) and the interaction between the time of sowing and herbicide treatments (P<0.001). Averaged across the seed rates and herbicide treatments, wheat produced grain yield of 1.67 t/ha in TOS 1, compared to 1.06 t/ha in TOS 2 (Figure 5). Even though the amount of rainfall received in May and June was well below the long-term average, the six week delay in sowing reduced wheat yield by 36%. Wheat yield increased as seed rate increased from low (1.25 t/ha), to medium (1.41 t/ha) and high (1.44 t/ha). Even though this increase was only 13%, it was statistically significant.

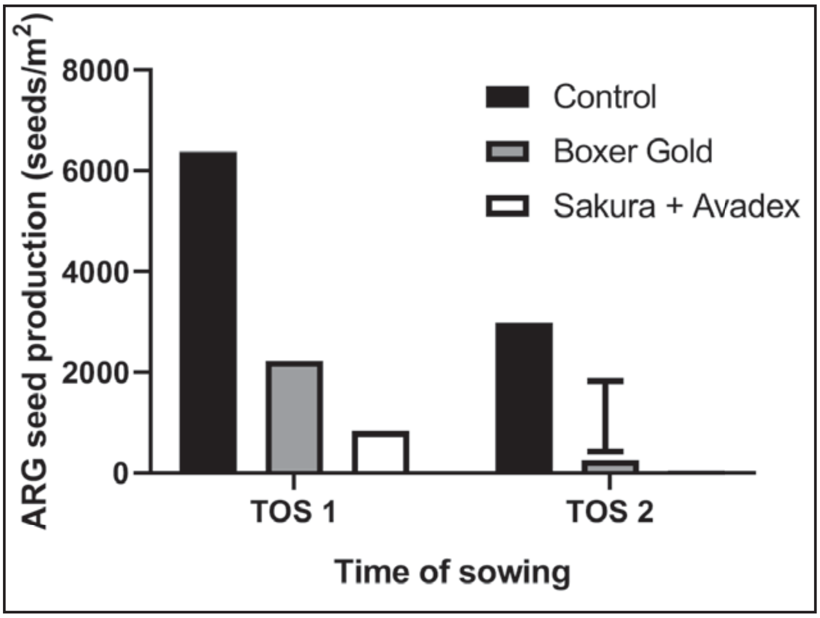

Figure 4 The effect of interaction between the time of sowing and herbicide treatments (P<0.001) on ARG seed production. The vertical bar represents the LSD (P=0.05).

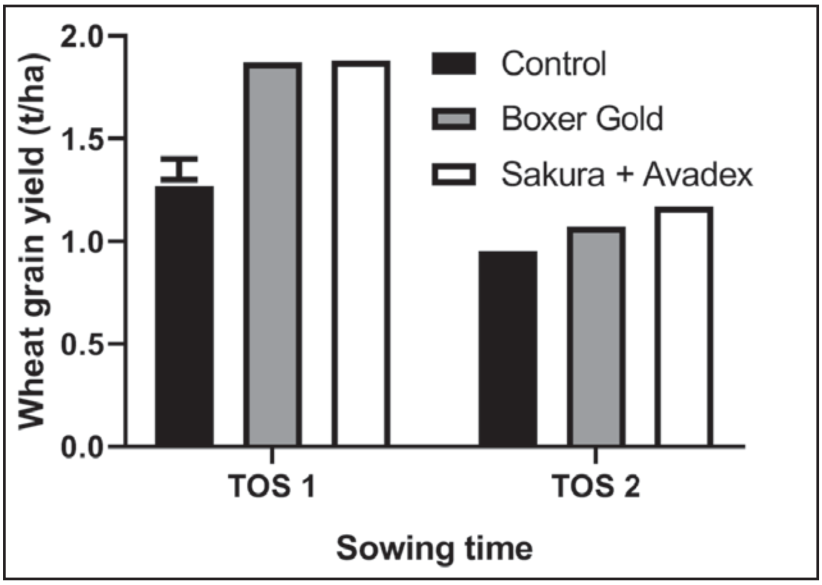

Figure 5 The effect of interaction between the time of sowing and herbicide treatments (P<0.001) on wheat grain yield. The vertical bar represents the LSD (P=0.05).

What does this mean?

As stated earlier, there were large benefits of delayed sowing on weed control by herbicides in terms of ARG plant density, spike density and seed production. However, these benefits came at a significant cost in wheat grain yield. All herbicide treatments showed a significant reduction in yield due to the six week delay in sowing. Sakura + Avadex provided superior control of ARG than Boxer Gold, but there were no differences in wheat yield between these treatments.

Even though the untreated control plots had a greater ARG plant density in TOS 1 (262 plants/m^2) than TOS 2 (139 plants/m^2), still wheat produced 0.32 t/ha more grain yield in TOS 1 than TOS 2.

These results clearly highlight the superior competitive ability of wheat against ARG at earlier sowing. It could also be argued that yield loss of wheat due to delayed sowing was greater than the yield loss due to ARG competition. Therefore, it would not be advisable to delay sowing wheat to manage ARG unless weed seedbanks are excessively large. It would be preferable to target the optimum sowing date for wheat in the region and use the most effective herbicide options available to control ARG.

Based on grain yields achieved and APW prices for last year, TOS 1 treated with Boxer Gold provided $291/ha greater gross margin than TOS 2 treated with the same herbicide.

Acknowledgement

The authors thank Bruce and Kathryn Heddle for hosting the site. Malinee Thongmee and Hue Thi Dang (University of Adelaide), Fiona Tomney, Steve Jeffs and Katrina Brands (SARDI) for their technical input to the trial. We also acknowledge the investment from GRDC for the research into ‘Cultural management for weed control and maintenance of crop yield’ (9175134).

Effect of row spacing x seedbed utilisation x pre-emergence herbicides on ryegrass management in wheat

RESEARCH

Ben Fleet[1], Gurjeet Gill[1], Amanda Cook[2] and Ian Richter[2]

[1]University of Adelaide, School of Agriculture, Food and Wine; [2]SARDI, Minnipa Agricultural Centre

Location
Minnipa - Bruce Heddle
Rainfall
Av. Annual: 283 mm
Av. GSR: 202 mm
2018 Total: 244 mm
2018 GSR: 186 mm
Paddock History
2018: Medic pasture surrounding, wheat trial
2017: Wheat
2016: Canola
2015: Medic
2014: Wheat
Yield
Potential: 2.6 t/ha (top yielding plot across both trials
Soil Type
Grey calcareous loam
Plot Size
1.5 m x 10 m x 3 reps
Trial Design
Experimental, split, plot design
Yield Limiting Factors
Anuual ryegrass and dry start to season

Key messages

- **Favourable rain events in June were highly suitable for the activity of both pre-emergent herbicides investigated in this trial.**
- **The density of ARG spikes and ARG seed production were significantly influenced by the herbicide treatment.**
- **It is profitable to control ARG with effective herbicide treatments. Based on the cash grain price of Australian Premium Wheat (APW) of $400/t in 2018, Boxer Gold would be expected to increase the gross margin by $68/ha as compared to a $12/ha increase for Sakura + Avadex.**

Why do the trial?

As a general principle, availability of large inter-row space tends to encourage weed invasion in field crops. At the start of the trend towards no-till, many growers adopted wider row spacing of crops as a way of achieving stubble retention. There is large variation in the row spacing used by growers for seeding wheat crops across the southern region. In wider row configurations the crop's ability to close the canopy and compete with weeds between rows reduces significantly. This delays inter-row weed suppression and the wider the rows, the longer the delay. In a review of research gaps by Widderick *et al*. (2015), crop row spacing was identified as a priority area of research for the southern region.

Seedbed utilisation (SBU) as a concept has been used by Australian agronomists to achieve safer use of fertilisers at crop sowing. Greater SBU reduces the concentration of fertiliser close to crop seed, which improves safety. The same concept appears to have relevance for increasing the inter-row space occupied by crop plants, which has the potential to improve crop's competitive ability with weeds. Greater SBU by crops can be achieved by altering seed boots to provide a greater lateral spread of crop seed. Some growers have been using 'Ribbon seeders' such as Concord to increase SBU and resource utilisation by their crops.

How was it done?

Trial details are presented in Table 1. This field trial investigated combinations of the following management tactics: Row spacing x splitter boots (4): 25 cm (10") and 37.5 cm (13") – with and without splitter boots. These seeding treatments were overlayed with three different herbicide treatments: Control (knockdown treatment only), Boxer Gold 2.5 L/ha incorporated by sowing (IBS) and Sakura 118 g/ha plus Avadex 1.6 L/ha IBS.

Measurements taken in 2018 included: pre-sowing weed seedbank, crop density, weed density, annual ryegrass (ARG) spike density, ARG seed production and wheat grain yield.

All data collected during the growing season was analysed using the Analysis of Variance function in GenStat version 15.0.

In 2018, annual rainfall received at Minnipa was 14% below the long-term average and the disparity for the growing season rainfall from the long-term average was only 8%. The rainfall received in August was more than double the long-term average and rainfall in October and November was also greater than the long-term average.

What happened?

Wheat plant density

Even though the same seed rate was used in the normal (25 cm) and wide row (37.5 cm) treatments, wheat plant density was slightly greater (4.5%) in the normal row spacing (P=0.04).

Table 1 Key management operations undertaken

Operation	Details
Seedbank soil cores	8 April 2018
Plot size	1.5 m x 10 m x 4 replicates, split plot design
Seeding date	13 June 2018
Fertiliser	At sowing – DAP (18:20) @ 60 kg/ha
Variety	Scepter wheat
Seeding rate	200 seeds/m^2
Herbicides	13 June 2018 (applied just before seeding) Boxer Gold 2.5 L/ha IBS Sakura 118 g/ha + Avadex 1.6 L/ha IBS Control (knockdown treatment only)

Herbicide treatments and seeder boots (SBU) did not have any adverse effect on wheat plant density. The average wheat plant density in the trial was 140 plants/m^2, which is highly suitable for this agro-ecological environment.

Annual ryegrass plant density and seedbank

As expected, herbicide treatment had a significant effect on ARG density (P<0.001). Favourable rain events in June were highly suitable for the activity of both pre-emergent herbicides investigated in this trial (Figure 1). Averaged across the row spacing and SBU treatments, Boxer Gold and Sakura + Avadex reduced ARG plant density by 88% and 90%, respectively.

Assessment of soil cores for ARG seedbank showed that the average seedbank at the trial site was 1117 ± 71 seeds/m^2. This level of ARG seedbank would be regarded as a moderate infestation. There was no significant variation in ARG seedbank identified across the replicates, which indicates relatively uniform weed infestation. The recruitment index (RI) of ryegrass (the ratio between ARG seedbank and plant density) was also significantly affected by the herbicide treatments (P<0.001). The RI of the untreated control was 0.22 (22% seedbank recruitment), which is identical to the TOS 2 in the other trial at Minnipa (EPFS Summary 2018 article "Effect of sowing time x seed rate x herbicides on ryegrass management in wheat"). The successful recruitment of ARG plants in the Boxer Gold treatment was 0.026 (2.6%) and 0.022 (2.2%) for Sakura + Avadex.

Annual ryegrass spike density and seed production

The density of ARG spikes was significantly influenced by the herbicide treatment (Figure 2). However, crop row spacing and seed boot (SBU) did not affect ARG spike density. SBU was only increased by about 25% (8% to 10% SBU for 25 cm spacing) when the DBS splitter boots were used. This was not a big enough change in SBU to have a significant effect on ryegrass. Both herbicide treatments caused a reduction ARG spike density (Figure 2). Boxer Gold reduced ARG spike density by 74% compared to the untreated control, whereas Sakura + Avadex caused 85% reduction in ARG spike density. The density of ARG spikes in Sakura + Avadex were lower than in the Boxer Gold treatment.

Consistent with the spike density data, ARG seed production was also significantly affected by the herbicide treatment (P<0.001), but not by wheat row spacing (P=0.272) or seed boot design (P=0.994). ARG produced 5740 seeds/m^2 in the untreated control, which was reduced by 74% by Boxer Gold and 86% by the mixture of Sakura + Avadex (Figure 3).

Wheat grain yield

Wheat grain yield was significantly influenced by crop row spacing (P=0.011) and herbicide treatments (P=0.012) but not by the seed boot design, the SBU (narrow vs wide spread) or by the interaction between these management factors (Figure 4). In 25 cm rows wheat produced 2.22 t/ha grain yield, which was greater than the yield in 37.5 cm rows (2.11 t/ha). Even though the difference between the row spacing treatments was only 5%, it was significantly different.

What does this mean?

Superior performance of Sakura + Avadex is most likely related to its longer persistence or activity in the soil. These results also highlight the difficulty of eliminating ARG through the use of pre-emergence herbicides alone. Even within the most expensive and effective treatment of Sakura + Avadex (>$55/ha), ARG was able to produce 788 seeds/m^2.

This moderate level of ARG seed production would be more than adequate to allow weed establishment in crops grown next year. Therefore, growers need to consider integration of harvest weed seed control or other management tactics to further reduce injection of ARG seeds into the seedbank.

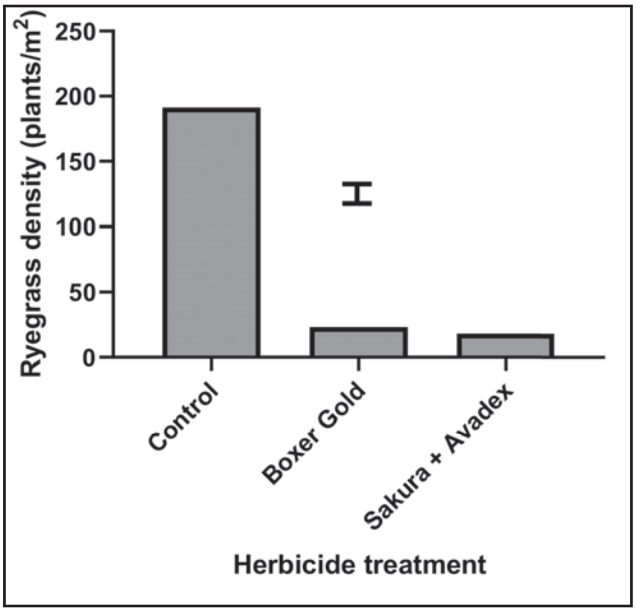

Figure 1 The effect of herbicide treatments on ryegrass plant density. The vertical bar represents the LSD (P=0.05).

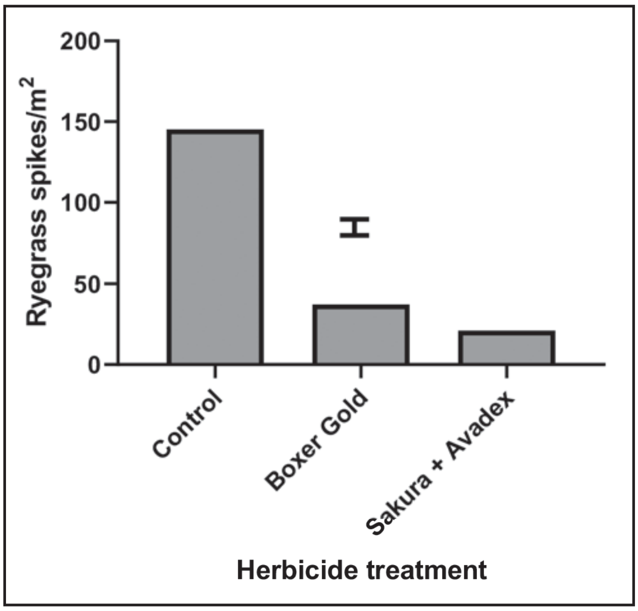

Figure 2 The effect of herbicide treatments on the density of ryegrass spikes. The vertical bar represents the LSD (P=0.05).

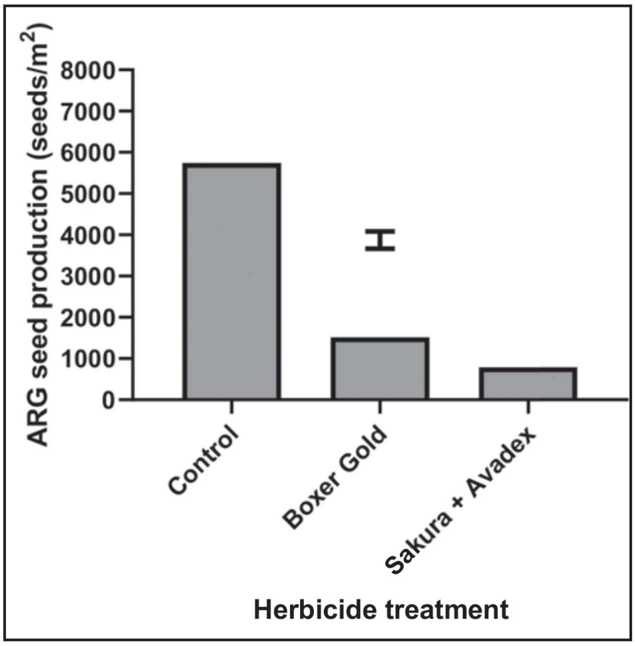

Figure 3 The effect of herbicide treatments on the ryegrass seed production. The vertical bar represents the LSD (P=0.05).

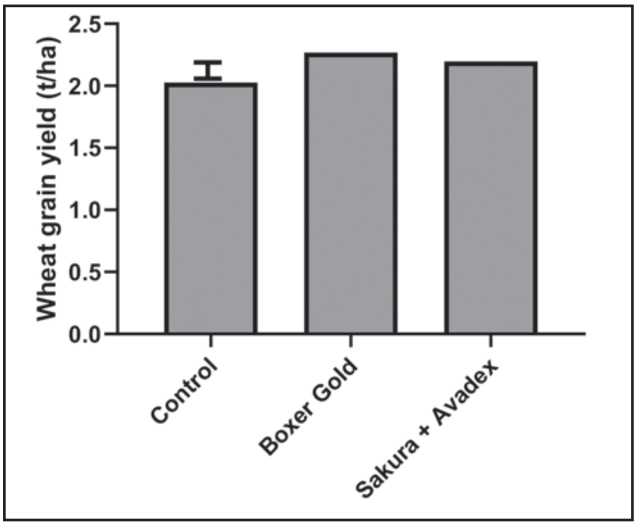

Figure 4 The effect of herbicide treatments on wheat grain yield. The vertical bar represents the LSD (P=0.05).

Application of Boxer Gold or Sakura + Avadex provided a significant increase in wheat grain yield (Figure 4). These results also highlight the point that ARG is not highly competitive in wheat. The presence of ARG at 190 plants/m² in the untreated control, only reduced grain yield by 11% compared to Boxer Gold or 8% compared to Sakura + Avadex. However, it was still profitable to control ARG with effective herbicide treatments. Based on a cash grain price of Australian Premium Wheat (APW) of $400/t in 2018, Boxer Gold would be expected to increase the gross margin by $68/ha as compared $12/ha increase for Sakura + Avadex.

Acknowledgements

The authors thank Bruce and Kathryn Heddle for hosting the site. Malinee Thongmee and Hue Thi Dang (University of Adelaide), Fiona Tomney, Steve Jeffs and Katrina Brands (SARDI) for their technical input to the trial. We also acknowledge the investment from GRDC for the research into 'Cultural management for weed control and maintenance of crop yield' (9175134).

Section Editor:
Amanda Cook
SARDI, Minnipa Agricultural Centre

Section 10

Pests

Russian wheat aphid - learnings from 2018 and how they can inform us in 2019

EXTENSION

Maarten van Helden[1], Thomas Heddle[1], Elia Pirtle[2], James Maino[2], Jessica Lye[2] and Paul Umina[2]
[1]SARDI; [2]cesar Pty Ltd

Key messages

- **Contrary to expectations, Russian wheat aphid pressure in Southern Australian cereal production seems low over the last two years (2017, 2018).**
- **Dry and hot summer conditions seem to reduce green bridge survival of Russian Wheat Aphids (RWA).**
- **Barley grass and Brome grasses are major hosts (van Helden 2018) supporting RWA survival over summer. Their development will strongly depend on summer rainfall.**
- **Development of regional economic thresholds are in progress at trial sites throughout South Australia, Victoria, Tasmania, and New South Wales. Use of international thresholds are still advised until Australian thresholds are developed.**
- **Observations suggest that crop infestations occur in autumn on early growth stages, then persist over winter and can build up in spring, especially when plants are drought stressed.**

Why do the trial?

Since first being discovered in South Australia in 2016, Russian wheat aphid (RWA) has been found widespread in cereal growing regions of South Australia, Victoria, New South Wales and Tasmania.

Avila *et al* (2019) assessed the potential spread and establishment of RWA in Australasia using a re-parameterised CLIMEX model, showing that RWA has the potential to establish in all key grain growing regions in Australia.

RWA feeding results in acute and observable plant symptoms in young plants, but the presence of RWA in an area does not automatically mean the crop will be infested, and even the presence of RWA in a crop does not automatically translate into yield loss. In many areas of the world RWA is present without any significant yield loss (Savary *et al.* 2019). Reports of RWA issues to SARDI have been less than anticipated in the last two years. Overall RWA populations in Australian crops seem slightly higher in low rainfall areas (<400 mm/year).

A new GRDC investment, '*Russian wheat aphid risk assessment and regional thresholds*' has been launched to investigate regional risk and management tactics for RWA.

What happened?

The South Australian Research & Development Institute (SARDI) and cesar are assessing the regional pressure of RWA with the aim of developing regional economic thresholds and gaining a better understanding of the role that green bridges are playing in supporting RWA populations between cereal cropping periods.

Currently only provisional intervention thresholds for RWA are available, which are based on US research (Pike and Alisson, 1991): >20% of all plants infested with aphids up to GS30 and >10% of tillers infested from late stem elongation (following GS30) to the end of flowering. Since initial detection of RWA in Australia growers have been advised to use these thresholds as they represent the best current knowledge. However, this threshold is likely to vary depending on cereal variety and climatic regions.

Development of regional economic thresholds

In 2018, 15 trial sites were set up throughout South Australia, Victoria, New South Wales, and Tasmania in collaboration with regional organisations. A subset of five of these trial sites were artificially inoculated with the aphid at GS20 to ensure thresholds could be developed. This trial site work builds on SAGIT Time of Sowing trials conducted by SARDI in 2017 and 2018 in three regions: Bool Lagoon, Roseworthy and Loxton. SA trials in 2018 were done in Keith, Riverton, Loxton, Minnipa and Cummins.

Each trial site included wheat, barley and a third commodity (durum wheat, winter wheat or oat) and three treatments: Gaucho seed treatment, Chlorpyrifos treatment, and an untreated control. Yield data and observations on RWA abundance, presence of beneficials, and RWA migration times were also collected.

None of the 15 trials sites showed significant 'natural' infestation levels in 2018. The five inoculated trials (including Riverton, Keith and Loxton in SA) showed very high aphid numbers and symptoms, and yield loss on the untreated (inoculated) controls.

Since we currently have only one season of trial site data no inferences can yet be made. Trials will be repeated in 2019, which will strengthen our data set and enable further investigation into the relationship between RWA numbers, plant symptoms and yield loss across regions.

Green bridge surveillance and risk assessment

Surveillance for RWA over spring and summer from October 2018 to February 2020 on volunteer cereals and grasses (native and weedy) at the landscape scale is generating data about types of vegetation the aphid is surviving on outside of the cropping season, and what environmental conditions support its survival over this period. Relating aphid abundance to climatic conditions (such as rainfall and temperature) will allow us to predict aphid population growth over this critical period.

The ultimate aim of the project is to develop additional guidelines for RWA management that are regionally specific. While trial site results are not discussed here, due to limited data so far, there is information included on preliminary findings of green bridge surveillance.

Where has Russian wheat aphid been found?

Our most current data indicates that RWA is present in a large, and still expanding, area covering all cereal growing regions of South Australia, Victoria, Tasmania and most of New South Wales. Our spring sampling shows that the aphid is widespread across these regions in at least low numbers, however we do not know how typical this spring distribution is, as we have only sampled for one season. In late 2018 the aphid was detected at Coonabarabran and the Liverpool Plains (New South Wales), which is a northerly extension of range for this aphid. The second sampling round done in January 2019 shows the numbers reduced compared to earlier samples, but aphids can still be found almost everywhere.

An interactive distribution map showing reports of RWA from different sources and the results of the current green bridge sampling is available. This map updates in real time, and lists information sources for each data point, evidence of absence data, and allows users to toggle with the timeframe between 2016 and 2019. You can find it on the RWA Portal (see resources section).

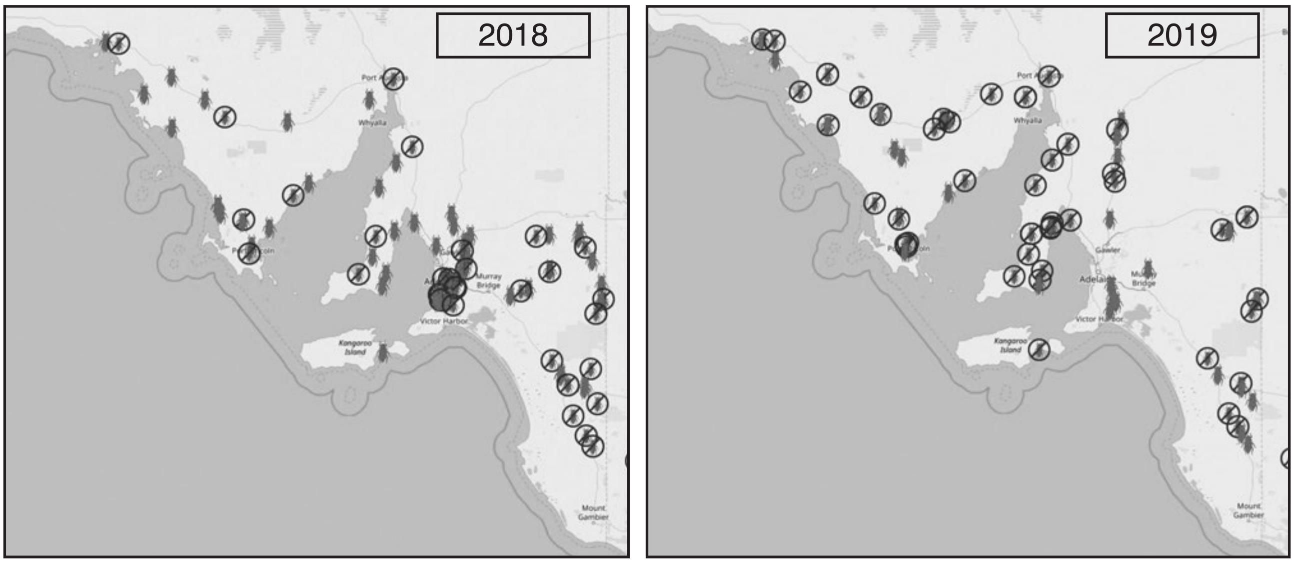

Figure 1 RWA interactive map for South Australia. Detections span 2018 (left) with data sourced from 2018 green bridge surveillance and advisor reports to PestFacts and 2019 (right) with data from the second round of green bridge survey in January/February 2019. Aphid denotes RWA present, crossed circle indicates no RWA found (Map developer: Dr James Maino, cesar).

What we know about the environmental conditions under which RWA will thrive

Despite few RWA issues reported to PestFacts services during the 2018 cereal growing season, our spring sampling detected RWA in all cereal growing regions where RWA has been reported previously and RWA was also detected around each of the trial sites. The presence of RWA in an area does not automatically mean it will cause damage to crops. RWA needs to infest cereals in early autumn in order to develop into damaging population levels in spring during booting and flowering.

While we are still accruing data about conditions that support RWA survival and can give limited advice; here is what we can say:

- Hot and dry summer conditions reduces over-summering populations of the aphid, with RWA likely to persist where there is available moisture and green material (from rainfall or irrigation).
- Higher than average temperatures are unfavorable for RWA survival.
- Localised summer rainfall events resulting in germination of weeds like barley grass can provide summer refuges for the aphid.
- Field observations and experiments over the last three seasons indicate that RWA abundance and development on crops is higher in low rainfall zones (<400 mm per year) and on drought stressed crops.
- This year's field trial observations support international research findings that indicate mature crops (GS40 or higher) are less attractive and are less likely to be invaded by RWA in spring.

This research is ongoing; RWA is still a very new pest to Australia and we are continuing to learn about its biology as the current investment progresses. More pertinent information about environmental influences is likely to be gained at crop establishment, particularly in regard to area-wide aphid abundance and flight timing. Significant early infestation of a crop will only occur through a combination of abundant green bridge and good autumn flight conditions that would aid RWA migration to cereal paddocks during the seedling stage in early autumn. Good flight conditions for aphids are calm, warm days over 20°C. Over the 2018 season these conditions were not met in southern Australia.

What does this mean?

- Monitoring for the aphid itself on green bridge hosts is advisable, as classic RWA symptoms have been rarely observed on grass species over spring and summer.
- Volunteer cereals and weedy grasses found within next season's cereal paddocks should be controlled at least 4 weeks prior to sowing.
- Registered neonicotinoid insecticide seed treatments are very effective to avoid autumn infestation of crops if RWA are migrating. However, such migrations into crops did not occur in 2018. The decision to seed treat needs to be balanced against risks (such as increased resistance in RWA and other exposed pests).
- We urge growers to use neonicotinoid seed treatments judiciously, according to the regional risk, and using the FITE (Find, Identify, Threshold, Enact) approach.
- RWA is easy to detect in autumn and winter before yield is impacted. If RWA is present in potentially damaging numbers it can be controlled efficiently by insecticide sprays around growth-stage 32-40, eliminating the aphids before there is a risk of yield loss. The overseas threshold is >20% of all plants infested up to GS30 and >10% of tillers infested from late stem elongation (GS30 or later).

Useful resources

To view the RWA Interactive Map
http://www.cesaraustralia.com/sustainable-agriculture/rwa-portal/

GrowNotes Tips & Tactics for Russian Wheat Aphid
https://grdc.com.au/data/assets/pdf_file/0025/289321/GRDC-Tips-and-Tactics-Russian-Wheat-Aphid.pdf

Russian Wheat Aphid Tactics for Future Control
https://grdc.com.au/__data/assets/pdf_file/0027/244377/Russian-Wheat-Aphid-Tactics-for-Future-Control.PDF

Russian Wheat Aphid Dynamics in 2017 (research update)
https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2017/08/russian-wheat-aphid-dynamics-in-2017

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Acknowledgements

Project 9176535 is a GRDC investment that seeks to deliver information on Russian wheat aphid management for grain growers. This project is being undertaken by the South Australian Research & Development Institute (SARDI) and cesar. The project team would like to acknowledge 2018 trial site contractors in South Australia, Victoria, New South Wales, and Tasmania.

Optimising baiting for snails

Helen Brodie, Greg Baker, Kate Muirhead and Kym Perry
SARDI Entomology Unit

EXTENSION

Key messages

- **For effective snail baiting, apply baits at the right time and at sufficient pellet density to ensure snails encounter the pellets.**
- **Bait in autumn as soon as snails become active and before they lay eggs, check spreader calibration, apply an adequate rate and select an appropriate product for the field conditions.**

Why do the trial?

Snail baiting trials were conducted to investigate the optimal rates and timing to maximise effectiveness of snail baiting programmes.

Background

Four introduced snail species (two round: Common white snail, *Cernuella virgata*; Italian snail, *Theba pisana*; two pointed: Conical snail, *Cochlicella acuta*, Small pointed snail, *Prietocella barbara*) are major pests in grains crops. The export market access threat posed by snails (due to harvest contamination) is increasing. Modern low disturbance farming systems create an ideal paddock environment for snails to survive and reproduce and make some options for summer control (e.g. burning, cultivation) less practical. Effective snail baiting programmes remain critical for managing snail populations. Baiting MUST occur at the right time (before egg lay) and using an adequate rate of product to ensure snails encounter the pellets.

SARDI, with GRDC investment support, is undertaking research investigating (1) baiting performance under different pellet densities, snail densities and environmental conditions; and (2) how the movement activity and reproductive status of snails changes during the season according to weather conditions, in different regions of Australia. The work aims to provide refined guidelines to assist growers to maximise the impact of their baiting programmes.

This article provides a brief snapshot of selected trials from two sites – Palmer (SA Mallee) and Urania (Yorke Peninsula) – in South Australia, focusing on the common white snail.

How was it done?

Trial 1: Seasonal changes in the reproductive status of snails

This trial assessed the seasonal reproductive cycle of snails to better understand the optimal timing and weather conditions for baiting (to pre-empt reproduction). Common white snails were collected each month (approx. 50 per month) from Palmer (SA) and dissected in the laboratory to allow measurement of the length of their albumen glands (reproductive gland). Swollen albumen glands indicate that snails are reproductively active.

Trial 2: Seasonal changes in snail mortality response to bait

This trial assessed whether the susceptibility of snails to bait changes during the year. Common white snails were collected each month from Palmer (SA) and Urania (SA), then exposed to Metarex baits in laboratory trials.

Each month, the field collected snails (five snails per arena x 10 arenas (n=50 snails) per treatment) were placed into moist arenas (500 ml ventilated plastic food containers with moist substrate) in the laboratory at 21°C and provided with one of two treatments: (1) Metarex® pellets or (2) placebo pellets (Metarex® pellets minus the active ingredient). Pellets were removed after 2-3 nights and snail mortality assessed after a further 4-5 nights. The amount of bait consumed, snail weight, body moisture content, shell size and reproductive stage were also measured.

What happened?

Trial 1: Seasonal changes in reproductive status of snails

Measuring the albumen glands of snails collected monthly from Palmer SA revealed a strong seasonal pattern of reproductive activity over four years (Figure 1). Generally, swelling of the albumen glands commenced around March and peaked in April to June. Commencing in July, an increasing proportion of snails 'shut down' reproduction, as shown by albumen glands returning to 'normal' size (see Figure 1 and caption). A high proportion of non-reproducing snails were found from August onwards in 2015 and 2016.

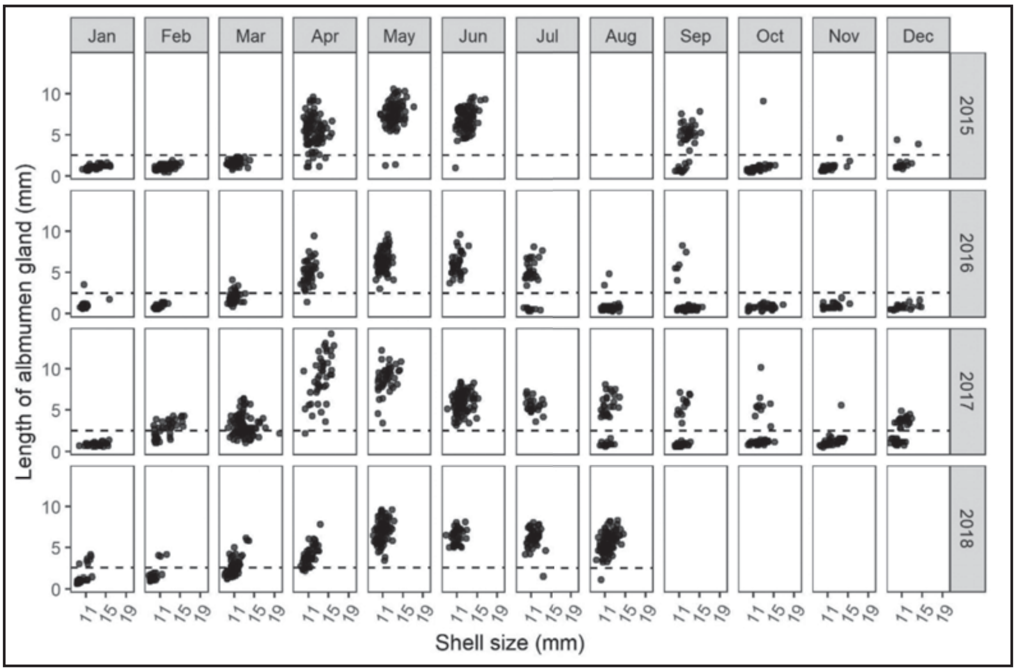

Figure 1 Scatterplot showing the length of the albumen glands, with respect to shell size, of common white snails collected each month from Palmer SA over four years. *Each black dot represents one snail. Swollen glands indicate that snails are (or are about to become) reproductively active. Non-reproducing snails have small glands and appear below the dotted line on each panel.*

The seasonal pattern is driven by rainfall and adequate moisture allowing snails to feed and mature their reproductive organs. Although some reproduction may have been possible prior to April in 2017 and 2018 (shown by some snails with swollen glands), the vast majority of reproduction occurred from April to mid-winter. Although summer moisture can trigger snail movement events, in this trial little reproduction occurred prior to at least March. Similar trials are yet to be conducted in very wet summers.

Trial 2: Seasonal changes in snail mortality responses to bait

Laboratory trials found that snails' susceptibility to Metarex bait changes during each season (Figure 2). Mortality ranged between approximately 15% and 80% despite a similar amount of bait consumed across the season (not shown). A similar seasonal trend in mortality response was observed for snails collected from two sites - Palmer and Urania: Generally, mortality was highest during April to August (Palmer - 3 year dataset) or May to July (Urania - 9 month dataset), coinciding with the period of peak reproductive activity (Figure 1). At both sites we observed decline in mortality from August onwards.

What does this mean?

Snail movement and reproductive activity is regulated by environmental conditions, and particularly the onset of sufficient moisture following summer aestivation (dormancy). Baiting when snails are moving sufficiently to encounter pellets, but prior to significant reproduction, is essential for managing snails.

Laboratory baiting trials suggested snails may be physiologically more or less susceptible to baits at certain times of year (Figure 2). At two sites, baiting efficacy was highest during periods of snail reproduction (Figures 1, 2). This suggests baiting efforts should be concentrated during the autumn and early winter period for maximum efficacy, but most importantly to prevent reproduction. Baiting either prior to March or after late winter may be less effective.

Snapshots

Baiting rates

A recent snail research project (DAS00134), conducted by SARDI with GRDC investment support, thoroughly investigated baiting rates and performance under different snail densities, bait pellet densities and environmental conditions in more than 30 trials.

The work concluded that:

- A minimum of 30 bait pellets per square metre (up to 60 pellets per square metre at very high snail densities) should be applied to ensure a sufficient density of bait points and chance of encounter. The higher rates may be needed in heavily infested areas, such as perimeters, fence lines or calcareous outcrops.
- Where current label rates do not permit this, a repeat application should be considered.
- Pellet densities for registered rates of commercial products are available in the SARDI Snail and Slug baiting guidelines brochure at http://www.pir.sa.gov.au/__data/assets/pdf_file/0004/286735/Snail_and_slug_baiting_guidelines.pdf

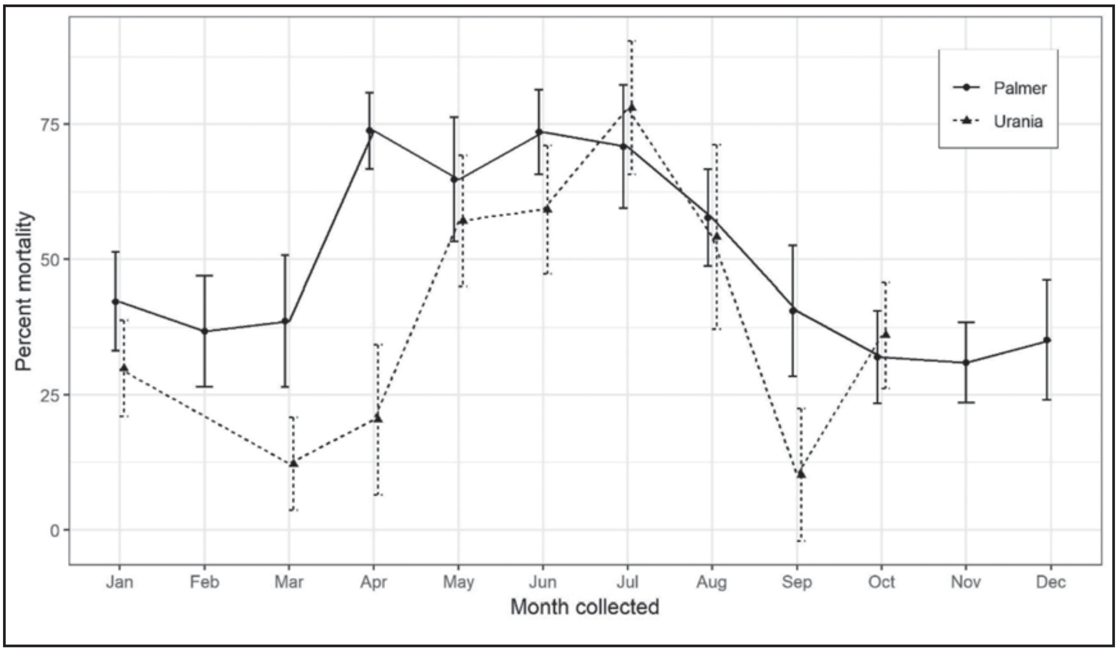

Figure 2 Mortality response of common white snails collected monthly from Palmer SA and Urania SA and exposed to Metarex baits in laboratory arena trials. *Dots represent mean mortality + 95% confidence limits across ten replicate arenas (n=50 snails in total). For Palmer, the means include monthly averages of trial data across three years.*

Bait spreader calibration

Research by the Yorke Peninsula Alkaline Soils Group and SARDI has shown:

- Spreaders calibrated for other applications (e.g. urea) may not broadcast baits as widely as expected.
- Single spinner ute spreaders generally perform poorly with limited spread widths and uneven bait distribution.
- Different bait products have different hardness and ballistic properties.

Therefore, for your preferred bait product:

- Have your spreader professionally calibrated to evenly broadcast the target pellet density over the entire spread width.
- Actively check pellet distribution across the entire spread width.

Other research and next steps

A number of GRDC-funded snail research initiatives are underway. A brief snapshot:

- Under a current GRDC project led by SARDI (DAS00160) in collaboration with DPIRD WA, the University of South Australia and farming systems groups, fixed cameras are being used to track snail activity with respect to climate variables, which are also being collected. SARDI are presently modelling these data to determine environmental triggers (e.g. humidity, moisture etc.) for movement and hence baiting opportunities.
- A separate CSIRO-SARDI project, funded by GRDC aims to import, rear and release a new genetic strain of the parasitoid fly, *Sarcophaga villeneuveana*, in efforts to enhance biological control of the conical snail. This will involve releases of the fly on Eyre Peninsula.
- An updated version of the 'Bash em Burn em Bait em' snail management manual is due for release in late 2019. This version will incorporate recent research findings to provide revised management guidelines for growers.
- New initiatives are also underway - more details soon.

Acknowledgements

Project codes: DAS00160, DAS00134, YPA00002.

The work presented here was conducted under GRDC project DAS00160. SARDI acknowledges GRDC for investment support for this work, and many growers for trial cooperation.

Chemical product trademark list

Knock Down + Spikes

Alliance – registered trademark of Crop Care Australasia Pty Ltd
Boxer Gold – registered trademark of Syngenta Australia Pty Ltd
BroadSword - registered trademark of Nufarm Australia Limited
Brodal Options - registered trademark of Bayer
Bromicide 200 - registered trademark of Nufarm Australia Limited
Buttress- registered trademark of Nufarm Australia Limited
Goal – registered trademark of Dow Agrowsciences
Gramoxone - registered trademark of Syngenta Group Company
Hammer - registered Trademark of FMC Corporation
Kyte 700 WG - registered trademark of Nufarm Australia Limited
Nail 240EC – registered trademark of Crop Care Australasia Pty Ltd
Nuquat - registered trademark of Nufarm Australia Limited
Revolver- registered trademark of Nufarm Australia Limited
Roundup Attack - registered trademark of Monsanto Australia Limited.
Roundup PowerMax – registered trademark of Monsanto Technology LLC used under licence by Nufarm Australia
Spray Seed - registered trademark of Syngenta Group Company
Striker - registered trademark of Nufarm Technologies USA Pty Ltd
TriflurX – registered trademark of Nufarm Australia Limited
Weedmaster DST – registered trademark of Nufarm Australia Ltd

Cereal Broad Leaf

2,4-D amine – registered trademark of Dow AroSciences
Agritone 750 – registered trademark of Nufarm Australia Limited
Ally - registered trademark of Du Pont (Australia) Ltd or its affiliates
Amicicde625 - registered trademark of Nufarm Australia Limited
Archer - registered trademark of Nufarm Australia Limited
Broadside – registered trademark of Nufarm Australia Limited
Broadstrike – registered trademark of the Dow Chemical Company or an affiliated company of DOW
BromicideMA – registered trademark of Nufarm
Dual Gold - registered trademark of a Syngenta Group Company
Ecopar – registered trademark of Sipcam Pacific Australia Pty Ltd
Logran 750WG - registered trademark of Syngenta Group Company
Lontrel – registered trademark of Dow AroSciences
LV Ester 680 - registered trademark of Crop Care Australasia. Pty Ltd
LVE MCPA - registered trademark of Dow AroSciences
Tigrex - registered trademark of Bayer
Velocity - registered trademark of Bayer

Clearfield Chemical

Intervix - registered trademark of BASF

Triazine Tolerant (TT)

Gesaprim 600Sc - registered trademark of Syngenta Group Company
Lexone - registered trademark of Du Pont (Australia) Ltd or its affiliates
Supercharge - registered trademark of Syngenta Group Company

Adjuvants

Bonza - registered trademark of Nufarm Australia Limited
Chemwet 1000 – registered trademark of Nufarm
Hasten – registered trademark of Victorian Chemical Company Pty. Limited
Kwicken - registered Trademarks of Third Party SST Australia Pty Ltd
LI 700 - registered trademark of United Agri Products.
Spreadwet – registered trademark of SST Australian Pty Ltd

Grass Selective

Avadex Xtra - registered trademark of Nufarm
Clethodim – registered trademark of Syngenta Group Company
Elantra Xtreme – registered trademark of Sipcam Pacific Australia Pty Ltd
Factor – registered trademark of Crop Care Australasia Pty Ltd
Hoegrass - registered trademark of Bayer
Monza - registered trademarks of Monsanto Technology LLC used under license by Nufarm Australia Limited
Propyzamide - 4 Farmers Australia Pty Ltd
Raptor - registered trademark of BASF
Rustler – registered trademark of Cheminova Aust. Pty Ltd.
Sakura - registered trademark of Kumiai Chemical Industry Co. Ltd
Select – registered trademark of Arysta Life Sciences and Sumitomo Chemical Co. Japan
Targa - registered trademark of Nissan Chemical Industries, Co Japan
Verdict - registered trademark of the Dow Chemical Company or an affiliated company of DOW

Insecticide

Alpha Duo – registered trademark of registered trademark of Syngenta Group Company
Astound Duo - registered trademark of Nufarm Australia Limited
Dimethoate - registered trademark of Nufarm Australia Limited
Dominex Duo - registered trademark of Crop Care Australasia Pty Ltd
Karate Zeon - registered trademark of Syngenta Group Company
Lemat - registered trademark of Bayer
Lorsban – registered trademark of Dow Agrowsciences

Fungicide

Baytan - registered trademark of the Bayer
Cruiser Maxx – registered trademark of a Syngenta Group Company
EverGol - registered trademark of the Bayer
Gaucho - registered trademark of the Bayer
Helix – registered trademark of a Syngenta Group Company
Impact – registered trademark of Cheminova A/S Denmark
Jockey - registered trademark of the Bayer
Prosaro - registered trademark of Bayer
Raxil - registered trademark of the Bayer
Stayer - registered trademark of the Bayer
Uniform – registered trademark of a Syngenta Group Company
Vibrance - registered trademark of a Syngenta Group Company

Contact list for authors

Name	Position	Location	Phone Number	E-mail
Arsego, Fabio	Research Agronomist	SARDI Port Lincoln/Minnipa	0401 653 389	fabio.arsego@sa.gov.au
Brace, Dot	Executive Officer	EPARF	(08) 8680 6202	eparf31@gmail.com
Cook, Amanda	Research Officer	SARDI Minnipa Agricultural Centre	(08) 8680 6217	amanda.cook@sa.gov.au
Davenport, David	Land Management Consultant	Rural Solutions SA	(08) 8688 3404	david.davenport@sa.gov.au
Davey, Sjaan	Research Officer	SARDI Struan	0467 732 672	sjaan.davey.sa.gov.au
Day, Sarah	Research Officer	SARDI Clare	(08) 8842 6264	sarah.day@sa.gov.au
Desbiolles, Dr Jack	Agricultural Research Engineer	University of South Australia	0419 752 295	jack.desbiolles@unisa.edu.au
Dzoma, Brian	Research Agronomist	SARDI Loxton	(08) 8303 9327	brian.dzoma@sa.gov.au
Evans, Margaret	Senior Research Officer	SARDI Plant Research Centre	(08) 8303 9379	marg.evans@sa.gov.au
Farquharson, Dr Liz	Research Officer	SARDI Plant Research	(08) 8429 4423	liz.farquharson@sa.gov.au
Fleet, Ben	Research Officer Soil & Land Systems	University of Adelaide	0417 976 019	benjamin.fleet@adelaide.edu.au
Frischke, Alison	Grain & Graze Systems Officer	BCG	(03) 5437 5352 0429 922 787	alison@bcg.org.au
Gill, Dr Gurjeet	Associate Professor - Weed & Crop Ecology	University of Adelaide	(08) 8313 7744	gurjeet.gill@adelaide.edu.au
Gontar, Blake	Research Agronomist	SARDI Waite	(08) 8429 0290 0430 597 811	blake.gontar@sa.gov.au
Gunn, Jessica	Research Officer	SARDI Minnipa Agricultural Centre	Ph (08) 8680 6227	jessica.crettenden@sa.gov.au
Gupta, Dr Vadakattu	Senior Research Scientist Microbial Ecology	CSIRO Entomology	(08) 8303 8579	gupta.vadakattu@csiro.au
Hull, Jake	Farm Manager	SARDI Minnipa Agricultural Centre	0428 388 033	jake.hull@sa.gov.au
Lake, Lachlan	Senior Research Officer	SARDI Plant Research Centre	0400 424 942	lachlan.lake@sa.gov.au
Low, Megan	Executive Officer	LEADA	0427 393 065	LEADAEXEC@gmail.com
Mason, Dr Sean	Principal Consultant	Agronomy Solutions	0422 066 635	sean@agronomysolutions.com.au
Masters, Brett	Soil & Land Management Consultant	Rural Solutions SA	0428 105 184	brett.masters@sa.gov.au
Moodie, Michael	Principal Consultant	Frontier Farming Systems	0448 612 892	michael@moodieag.com.au
Oxborrow, Rachael	Communication and Marketing Specialist	AgCommunicators	0416 705 193	rachael.oxborrow@agcommunicators.com.au
Perry, Kym	Entomologist	SARDI Waite Campus	(08) 8303 9370	kym.perry@sa.gov.au
Porker, Kenton	Research Scientist	SARDI Waite	(08) 8303 9480 0403 617 501	kenton.porker@sa.gov.au
Rathjen, Judith	Research Officer	SARDI Plant Research Centre	(08) 8303 9364	judith.rathjen@sa.gov.au
Ruchs, Craig	GRDC Senior Research Manager - South	GRDC Southern Office Adelaide	(02) 6166 4500	craig.ruchs@grdc.com.au
Scholz, Naomi	Project Manager	SARDI Minnipa Agricultural Centre	(08) 8680 6233 0428 540 670	naomi.scholz@sa.gov.au

Name	Position	Location	Phone Number	E-mail
Smith, Bryan	Chair	EPARF	0427 256 145	kai.smith@bigpond.com
Stanley, Mark	Principal Consultant	Regional Connections Pty Ltd	0427 831 551	mark@regionalconnections.com.au
Tomney, Fiona	Research Officer	SARDI Minnipa Agriculture Centre	(08) 8680 6200	fiona.tomney@sa.gov.au
Trengrove, Sam	Principal Consultant	Trengrove Consulting	0428 262 057	samtrenny34@hotmail.com
Van Helden, Maarten	Entomologist	SARDI Waite	(08) 8429 0642	maarten.vanHelden@sa.gov.au
Van Rees, Harm	Consultant	Cropfacts Pty Ltd	0419 325 252	harm@cropfacts.com.au
Wallwork, Hugh	Principal Cereal Pathologist	SARDI Plant Research Centre	(08) 8303 9382 0427 001 568	hugh.wallwork@sa.gov.au
Ware, Andrew	Principal Consultant	EPAG Research	0427 884 272	andrew@epagresearch.com.au
Wheeler, Rob	GRDC NVT Manager	GRDC Southern Office Adelaide	0401 148 935	rob.wheeler@grdc.com.au
Wilhelm, Dr Nigel	Farming System Leader Scientific Consultant	SARDI Minnipa Agricultural Centre Waite	0407 185 501	nigel.wilhelm@sa.gov.au

Acronyms and Abbreviations

ABA	Advisory Board of Agriculture
ABARES	Australian Bureau of Agriculture and Resource Economic and Sciences
ABS	Australian Bureau of Statistics
ADWG	Average daily weight gain
AFPIP	Australian Field Pea Improvement Program
AGT	Australian Grain Technologies
AH	Australian Hard (Wheat)
AM fungi	Arbuscular Mycorrhizal Fungi
APSIM	Agricultural Production Simulator
APW	Australian Prime Wheat
AR	Annual Rainfall
ASW	Australian Soft Wheat
ASBV	Australian Sheep Breeding Value
AWI	Australian Wool Innovation
BCG	Birchip Cropping Group
BYDV	Barley Yellow Dwarf Virus
CBWA	Canola Breeders Western Australia
CCN	Cereal Cyst Nematode
CfoC	Caring for our Country
CLL	Crop Lower Limit
DAFF	Department of Agriculture, Forestry and Fisheries
DAP	Di-ammonium Phosphate (18:20:00)
DCC	Department of Climate Change
DEWNR	Department of Environment, Water and Natural Resources
DGT	Diffusive Gradients in Thin Film
DM	Dry Matter
DMD	Dry Matter Digestibility
DOMD	Dry Organic Matter Digestibility
DPI	Department of Primary Industries
DSE	Dry Sheep Equivalent
DUL	Drained Upper Limit
EP	Eyre Peninsula
EPARF	Eyre Peninsula Agricultural Research Foundation
EPFS	Eyre Peninsula Farming Systems
EPNRM	Eyre Peninsula Natural Resources Management Board
EPR	End Point Royalty
GM	Gross Margin
GRDC	Grains Research and Development Corporation
GS	Growth Stage (Zadocks)
GSR	Growing Season Rainfall
HLW	Hectolitre Weight
IPM	Integrated Pest Management
LEADA	Lower Eyre Agricultural Development Association
LEP	Lower Eyre Peninsula
LSD	Least Significant Difference
LW	Live weight
MAC	Minnipa Agricultural Centre
MAP	Monoammonium Phosphate (10:22:00)
ME	Metabolisable Energy
MED	Molar Ethanol Droplet
MIR	Mid infrared
MLA	Meat and Livestock Australia
MRI	Magnetic Resonance Imaging
NDF	Neutral Detergent Fibre
NDVI	Normalised Difference Vegetation Index
NLP	National Landcare Program
NRM	Natural Resource Management
NVT	National Variety Trials
PAWC	Plant Available Water Capacity
P	Probability
PBI	Phosphorus Buffering Index
PEM	*Pantoea agglomerans, Exiguobacterium acetylicum* and *Microbacteria*
pg	Picogram
PGR	Plant growth regulator
PIRSA	Primary Industries and Regions South Australia
RD&E	Research, Development and Extension
RDTS	Root Disease Testing Service
SAGIT	South Australian Grains Industry Trust
SANTFA	South Australian No Till Farmers Association
SARDI	South Australian Research and Development Institute
SASAG	South Australian Sheep Advisory Group
SBU	Seed Bed Utilisation
SED	Standard Error Deviation
SGA	Sheep Genetics Australia
SU	Sulfuronyl Urea
TE	Trace Elements
TT	Triazine Tolerant
UNFS	Upper North Farming Systems
WP	Wilting Point
WUE	Water Use Efficiency
YEB	Youngest Emerged Blade
YP	Yield Prophet

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