Lower EP Ag Expo 2021

Marble Range Sports Club
Lake Wangary
2nd March 2021

AIR EP
Ag Innovation & Research
Eyre Peninsula

SAGIT

LIVESTOCK SA

Contents

Program

TIME	TOPIC	SPEAKER
8.30am	Registrations open	
9.00am	Welcome	Bruce Morgan, Chair AIR EP Medium Rainfall RD&E Committee
9.15am	AIR EP Update	Naomi Scholz, EO AIR EP
9.25am	Soil CRC Social benchmarking survey results	Naomi Scholz, EO AIR EP
9.35am	*Speaker introduction*	*Chris Miller, Bendigo/Rural Bank*
9.40am	Grazing crops, autumn/winter feed gap	David Harbison, DR Agriculture
10.20am	MORNING TEA	
10.50am	*Speaker introduction*	*Bruce Morgan, Chair AIR EP Medium Rainfall RD&E Committee*
10.55am	Soil biology and soil amendments	Lukas van Zwieten, NSW DPI/David Davenport
11.35am	*Speaker introduction*	*Bruce Morgan, Chair AIR EP Medium Rainfall RD&E Committee*
11.40am	Cultural and chemical control of annual ryegrass	Ben Fleet, University of Adelaide
12.00pm	*Speaker introduction*	*Bruce Morgan, Chair AIR EP Medium Rainfall RD&E Committee*
12.05pm	SAGIT Powdery mildew and Soil amelioration research	Stuart Sherriff, Trengove Consulting
12.45pm	LUNCH	
1.35pm	*Grain Growers video*	*Grain Growers*
1.40pm	Herbicide residues	Lukas van Zwieten for Michael Rose, NSW DPI
2.10pm	*Speaker introduction*	*Bruce Morgan, Chair AIR EP Medium Rainfall RD&E Committee*
2.15pm	Intercropping and early sown pulses	Amy Gutsche, SARDI
2.35pm	*Speaker introduction*	*Bruce Morgan, Chair AIR EP Medium Rainfall RD&E Committee*
2.40pm	EP project updates	Andrew Ware, EPAG Research
3.00pm	Evaluation	Naomi Scholz, EO AIR EP
3.15pm	Close	Bruce Morgan, Chair AIR EP Medium Rainfall RD&E Committee
3.25pm	END	


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Welcome

Bruce Morgan

Chair, AIR EP Medium Rainfall RD&E Committee

Welcome to the first Lower EP Ag Expo hosted by the AIR EP Medium Rainfall RD&E Committee, carrying on the tradition of LEADA events with the aim to bring you the latest agricultural information relevant to your farming systems.

The merger of LEADA and EPARF to form AIR EP has so far been successful, in that the AIR EP Board members are dealing with the administration and governance requirements of running a not-for-profit organization, while the RD&E Committees can get on with the job of identifying and scoping out issues affecting their production, profitability and resilience, as well as reviewing current project progress and assisting with event planning.

I'd like to take this opportunity to thank past LEADA Committee members and staff for building the organization to the point where we are well placed to continue to attract RD&E investment for the benefit of Lower EP farmers.

Nominations are now open for RD&E Committee members, and I strongly encourage farmers and advisors to nominate themselves. Nominations close at midnight on Friday 12 March.

Now is also a great time to make sure you are signed up as a member – membership is free until 30 June 2021, so take this opportunity to see what the member benefits include, such as attending this Ag Expo and receiving technical newsletters.

Some of the activities of the past 12 months, although less than normal due to COVID restrictions, included the Lower EP Spring Crop Walk on 8 September, where 50 people attended and visited sites to look at deep ripping, soil moisture probes, new herbicides and resetting phenology of cereals to manipulate flowering time to avoid frost. Another stand-out event was the GRDC Pulse Field Day at Tooligie on 25 August, where 100 people attended and we officially launched AIR EP.

At the time of writing this, things are looking good for the event in terms of COVID-19 – and we really don't want to repeat the experience of last year's expo where everyone had potentially been exposed to COVID – a nerve wracking time for all involved, especially the organisers! Please ask lots of questions and be honest in your feedback to help us shape future events, and most of all enjoy the day!!

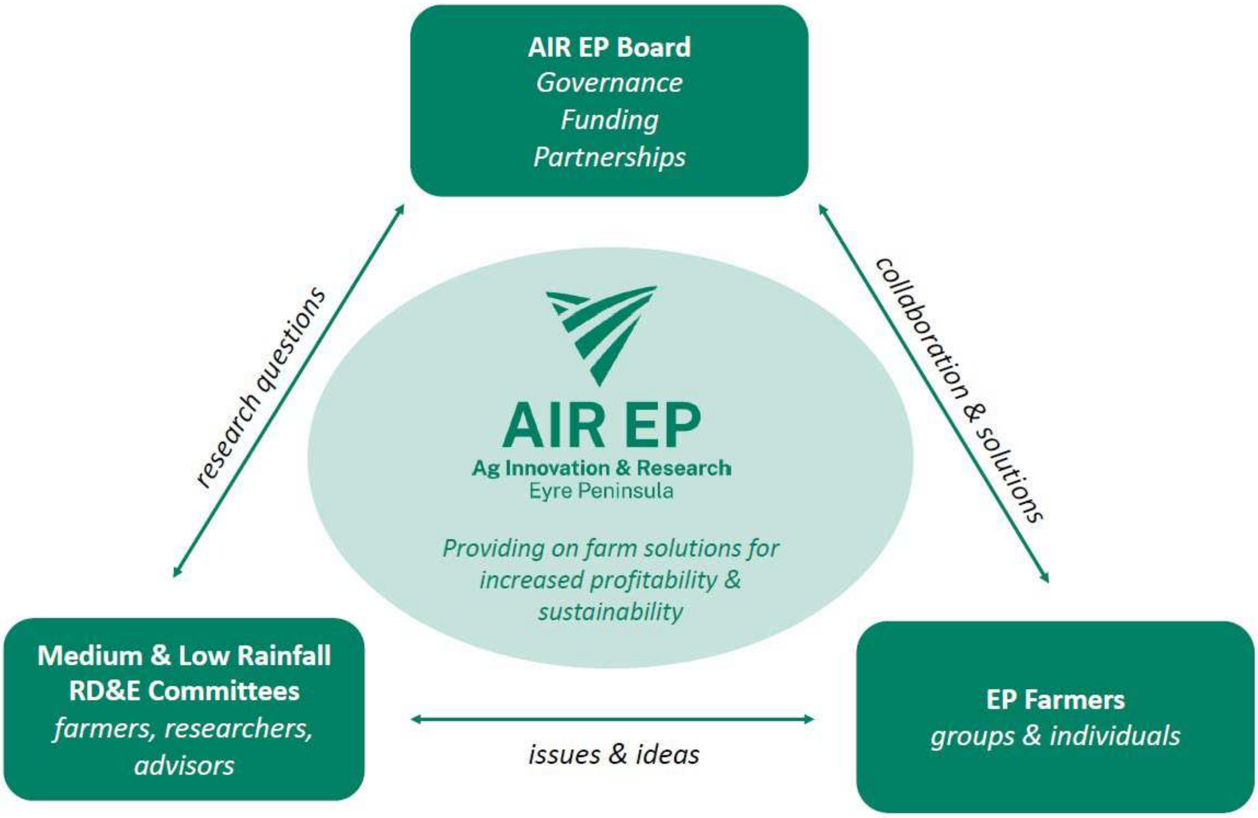
What is AIR EP?

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

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

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

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



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

Medium Rainfall RD&E Committee
Covers lower and parts of Eastern Eyre Peninsula and comprises Bruce Morgan (Chair), John Richardson (AIR EP Board member rep), Dan Adams, Mark Habner, George Pedler, Billy Pedler, Dustin Parker, Mark Dennis, Amy Gutsche, Derek MacDonald with support of Mark Stanley, Andrew Ware and David Davenport.

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

2020/2021 Focus
AIR EP is leading the new 'Resilient EP' project, where new and emerging technologies will be used to assist farmers make efficient use of soil moisture. The Eyre Peninsula has an extensive soil moisture probe network which is underutilised. A Regional Innovators group of farmers and advisers will engage researchers and link with the region's farmers to develop techniques to integrate information generated from the probe network, satellite imagery, climate and yield models. Farmers will be able to make more informed, timely decisions underpinned by innovations in agronomy and livestock management in order to optimise the region's productive potential whilst protecting soil and water resources in a changing climate. This project is funded by the Australian Government's National Landcare Program 2, Smart Farming Partnerships Program, and we are partnering with CSIRO, Regional Connections, SARDI, Square V and EPAG Research to deliver this exciting and ambitious project.

AIR EP is also excited to be partnering with SAGIT and EPAG Research to improve the capacity of grains research, development and extension in the Eyre Peninsula region by annually engaging a recent graduate to work as an intern – this program will expose a new graduate to a wide range of opportunities and experiences across EP and beyond.

AIR EP has a range of other projects that will be continuing in 2020/21 including:

- Pulse check groups to increase the knowledge of growers and advisers on sustainable pulse production
- Developing knowledge and tools to better manage herbicide residues in soil
- Increasing production on sandy soils
- Demonstrating and validating the implementation of integrated weed management strategies to control barley grass
- Using soil and plant testing data to better inform nutrient management and optimise fertiliser investments
- Taking South Australian Canola profitability to the next level

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

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Eyre Peninsula Regional Profile: Soil CRC Survey

Dr Claire Baker & Dr Hanabeth Luke
Southern Cross University

LANDHOLDERS IN THE EYRE PENINSULA

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

FARM MANAGEMENT

In operational terms, 78% of respondents report an income from agriculture on the Eyre Peninsula and of these 63% report a net profit of greater than $50,000 in the financial year 2018/2019. 51% bought additional land in the last 20 years and 16% subdivided or sold part of their property in the same period. Full-time farmers work an average of 53 hours on-property per week and 59% of respondents have another member of the family working on the property. Off-property income is received by 34% of respondents and 23% of their partners, with 43% being greater than $50,000 in the 2018/2019 financial year. 78% had completed secondary school or higher, with 16% holding tertiary qualifications.

ENGAGEMENT WITH INDUSTRY GROUPS

43% of respondents were members of an industry group (56% of full-time farmers), and only 44% have a property management or whole farm plan (53% of full-time farmers). 73% of respondents had completed a short course/workshop relevant to property management in the past 5 years (22% of partners also had), and 53% had attended field days/farm walks/demonstrations focused on soil health and productivity in the past 12 months.

FARMER TYPES AND PROFILES

Farmer types present a useful way to see how different priorities influence landholder management practices. Participants self-identify into one of four groups based on their engagement with farming: 62% of respondents identified as full-time farmers, 14% as part-time farmers, 8% as hobby farmers and 16% as non-farmers. These types often have a lot in common, but there are important and significant differences amongst the groups that will be examined in detail in the full report. There were no significant differences by rainfall zone. Some important characteristics of each type on the Eyre Peninsula are as follows:

- **Full-time farmers** represent the majority of respondents (62%), have the highest rate of male respondents (95%) and an average age of 54 years. As a group they have the highest rates of residency, with 91% living on their Eyre Peninsula property. They own the most land, with an average holding of 3709 hectares. They also have the longest family ownership of the property, with the median length sitting at 70 years, and are most likely to have another member of family working on the farm (79%). 78% have secondary school education and higher, including 12% at tertiary level. Their most likely land use is cropping (97%), sheep for wool and meat (both 74%) and pasture (54%).
- The second most common type is the **non-farmer** (16%). This group has the highest rate of female respondents (27%), has an average age of 62 years and is also the most highly

educated group, with 40% of respondents holding tertiary qualifications. Average property size in this group is 939 hectares. The median length of ownership is 20 years, and this group is most likely to use the land as an area of remnant native vegetation, for example trees, grasslands or wetlands (50%). They have the lowest rates of principal residency on their Eyre Peninsula property (41%) and least likely to have another member of the family working on the property (8%).

- **Part-time farmers** make up 14% of respondents. The average age of this group is 60 years and 90% of respondents were male. Average property-size is the second highest, with an average holding of 1156 hectares. 57% live on the property and the length of family connection is the second highest at a median of 40 years, with 40% reporting that other members of the family also work on the property. The most common land use is for cropping (83%), sheep for wool (64%) and pasture 63%). Similar to full-time farmers, 80% of part-time farmers have completed secondary school and higher and 9% have completed tertiary education, the lowest rates of tertiary completion amongst the four types.
- **Hobby farmers** make up just 8% of respondents and have the lowest average property size of 186 hectares. They have an average age of 60 years and 82% of respondents were male. This group has a similar level of residency as the part-time farmer group, with 59% living on the property as their principal place of residence. Hobby farmers have the shortest length of ownership or management of the property, with a median length of 15 years, and 37% have another family member working on the farm. This group uses their land for a range of activities, including sheep for meat (53%), pasture (33%) and set aside areas for remnant native vegetation (33%).

With these profiles and relative weightings in mind, it is interesting to consider the similarities and differences in landholder identification of issues at both the regional and property scale:

Figure A: Top 3 Most Important Regional Issues by Farmer Type

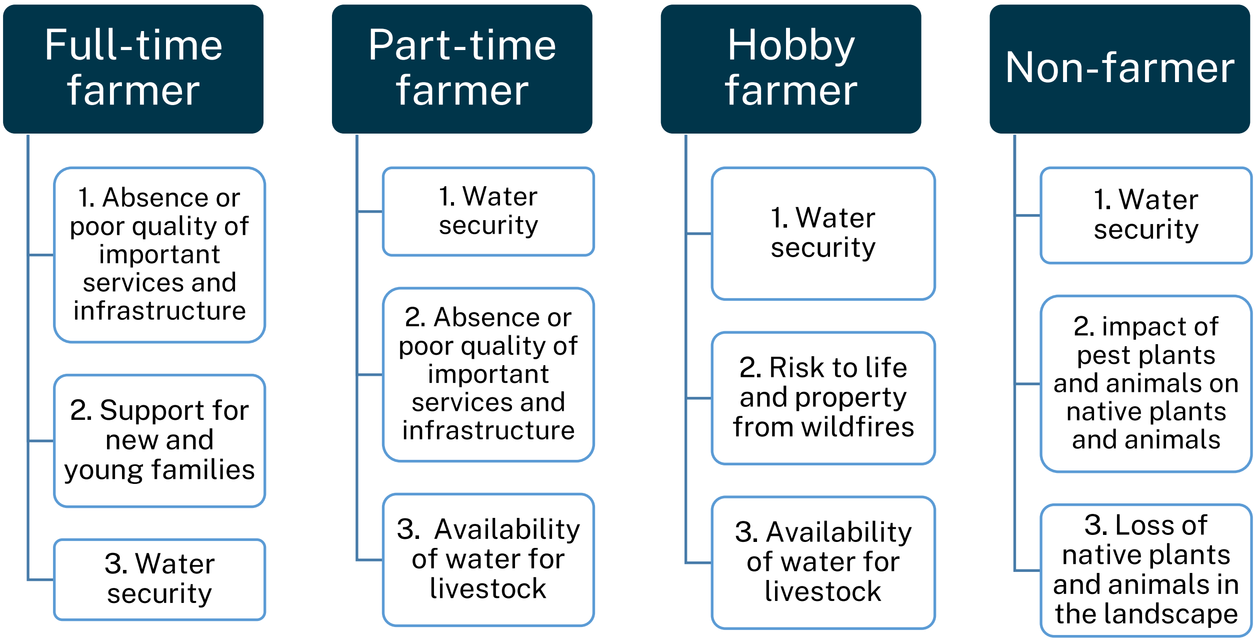
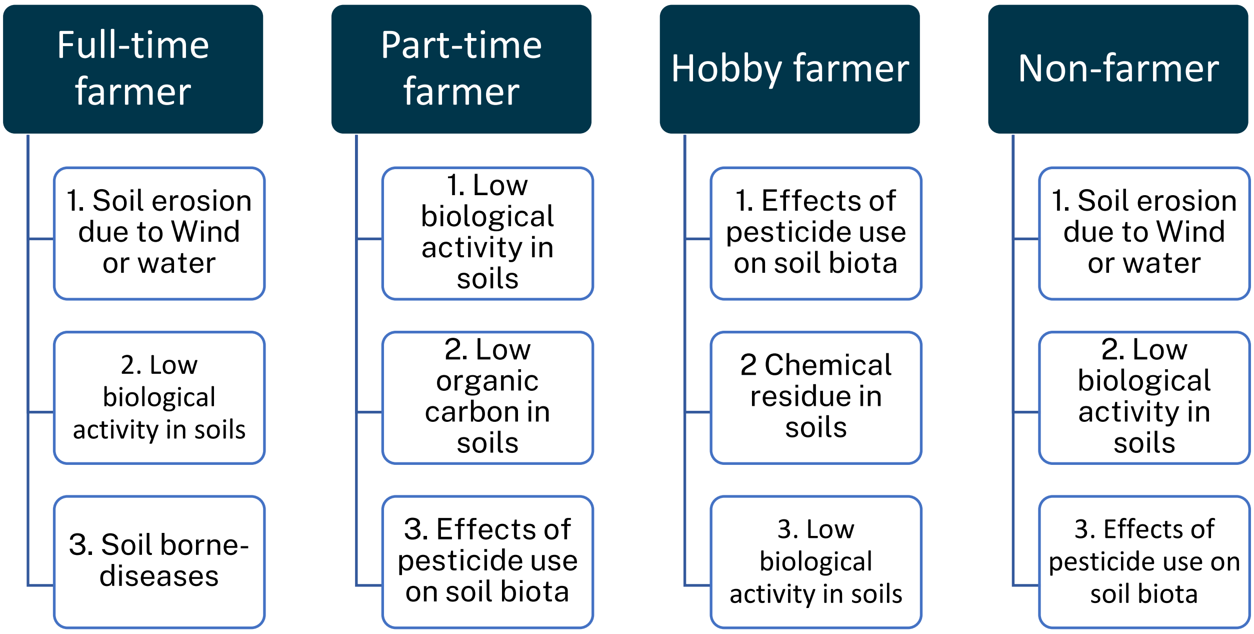


Figure B: Top 3 Most Important Soil-related Issues on the Property by Farmer Type



Notes: n = 302-442

ACCESS TO INFORMATION

Across all farmer types, respondents are most likely to seek information and advice on property management from other farmers (89% of full-time farmers and 85% of part-time farmers in particular). This shows a strong reliance on knowledge networks within the Eyre Peninsula and indicates the significant potential of these networks and relationships for knowledge transfer. Combined with the fact that 'Field Days' was the highest ranked mode of receiving information for full-time farmers (71%) and second for part-time farmers (57%), the benefits of combining networking and communication/education activities may be a useful mode of knowledge transfer in the region. The tables on the following page show the aggregated data across all farmer types and it can be seen that besides other farmers, the majority of respondents look to friends/neighbours/relatives, again emphasising the role of networked knowledge. Other knowledge sources for the majority of respondents are the Bureau of Meteorology, independent agricultural advisors, and PIRSA/SARDI.

Source of knowledge - all respondents

Other farmers ###	77%
Friends/neighbours/relatives ###	67%
Bureau of Meteorology ###	59%
Independent agricultural consultants, agronomists or stock agents ### ***	55%
PIRSA/SARDI ###	50%
Commercial agricultural consultants, agronomists or stock agents ###	40%
Local farming groups (e.g. Ag Bureau, Landcare) ### ***	35%
Eyre Peninsula NRM	33%
Rural R&D organisations (e.g. GRDC, MLA, AWI, SANTFA) ###	30%
EPARF ### ***	25%
LEADA### ***	19%
Direct contact with researchers/extension officers ###	14%
Local Council	13%
Commodity groups ###	12%
Environmental organisations, eg. Greening Australia ###	8%
Universities/CSIRO	7%
Soil CRC	5%

Mode of information - all respondents

Field days ###	56%
Websites ###	54%
Newspapers ###	53%
Magazines ##	49%
Email ###	49%
Local Radio ###	42%
Brochures/leaflets/newsletters ###	37%
EP Farming Systems Summary ### ***	35%
Television ***	34%
Books	25%
Journals (research papers) ###	25%
National/State radio	22%
Twitter ###	17%
YouTube ###	13%
Facebook	10%
Podcasts	6%
Instagram	2%
Whatsapp or Messenger groups	2%

N = 460-462
Significant difference by Farmer Type
**** Significant difference by Rainfall Zone*

Wire, water and grazing management in dual purpose crops

David Harbison
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Key words: Paddock layout, fencing, water, dual purpose crops

Key messages

- Paddock size, or available grazing area, is key to maximise grazing efficiency.
- Strip fencing may be necessary to 'create' the required stock density.
- Water sources must be of good quality and well located within each paddock.
- Identify the class of stock and their indicative weight and consumption needs before sowing to determine the likely area of grazing crop needed (use regional dry matter crop growth rates to assist) Increased profitability per hectare gross margin by comparison to crop only situations.

Introduction

Dual-purpose crops offer great opportunities for farmers with livestock in their system (their own or via potential agistment income) to utilise early-season sowing opportunities, spread risk, and increase per hectare (ha) returns. Critical to gaining the most from these opportunities, is getting much of the logistics right, and applying sound grazing management. Cropping machinery (in general) over the last 20–30 years has been getting larger and more efficient. As a consequence, livestock infrastructure has been reduced, and in many cases, removed. So, what does this mean for dual purpose crops? In short, many paddocks are now too large to graze efficiently. Water points are often minimal and of lesser quality and quantity, or the number of stock required to provide efficient grazing can be very large - creating its own sub-set of management issues.

Kirkegaard et al. (2016) reported that with good management, the period of grazing can increase net crop returns by up to $600/ha and have a range of system benefits including widening sowing windows, reducing crop height, filling critical feed gaps and spelling pastures. However, achieving this grazing return relies heavily on 'good management', with time of sowing, stock number, grazing management, crop growth (both pre grazing and recovery), water supply and other factors all critical to a successful outcome. The indicative stock density used to achieve the above profit was approximately 2000 dry sheep equivalent (dse) grazing days/ha. Put simply, it may be 40 dse/ha for 50 days of grazing.

Paddock infrastructure

There is no 'ideal' paddock size, or available grazing area. My experience is that smaller paddocks/areas (<40 – 50 ha) are likely to be far easier to manage and have more manageable water points than much larger paddocks. Getting the most from the grazing dry matter (DM) requires eating more of what is on offer, over a shorter period of time, and leaving a critical residual biomass to allow significant crop regrowth before the second (and potentially third) grazing. Understanding crop growth rates, and what drives them, from planting to first graze (autumn) and into winter, enables farmers and advisors to predict likely stock numbers and DM production. Stock number and predicted consumption determines how long a set amount of DM will last. Using the grazing day information from Kirkegaard et al (2016), a 40 ha paddock would require approximately 1600 dse (potentially 2000 lambs (or 230 - 250 weaner steers depending on size)) for two 25 day grazings. A paddock larger than this will proportionately increase the stock number needed to optimise grazing efficiency.

A significant limitation to larger paddocks (and by default mob size) is water. This is usually the most difficult infrastructure to accommodate in the dual purpose crop system. Many issues surround good stock water supply. Distance to, temperature and cleanliness of water, dam vs trough, and other factors all impact on animal intake and performance.

The Dept. of Primary Industries and Regional Development WA (2020) publication 'Water quality for livestock', guides farmers in the water needs of livestock. Stock avoid warm water, so deeper or shaded water sources will generally be preferred. Pipes carrying water above ground to moveable troughs may deliver hot and undrinkable water (pending time of the year and location). Similar outcomes can also occur in shallow troughs in full sun. While trough systems have many benefits, if mob size is too large or inflow rates too low, stock will walk off with less (and sometimes nil) water intake. Allowing at least one metre of trough per 130 sheep is their advice. Further, sheep not used to water troughs, and particularly young sheep, may take time to learn to drink from them, so always push them onto water in a new paddock.

Dams are still very valuable, and often the only option for many. If there has been a benefit of the recent drought and dry dam situation, it is the opportunity provided to clean out those dams that farmers will benefit from most into the future. Stock will always decrease the quality of dam water, often by urine and faeces contamination and most commonly just by mud and foot disturbance. If water quality is poor, livestock may drink less than they need, or rarely, may stop drinking altogether. Lower water intake decreases DM intake, thus resulting in decreased animal performance. Many experiments have demonstrated the benefits of cleaner trough water over dam water, but it is not available to all. Lardner et al (2005), in their study of cattle performance, showed that by improving water quality with pumping and aeration to a trough, weight gains of 9 – 10% were achieved over the control mob over a 90 day grazing period in most years.

Dry matter, grazing management and stock density – the numbers

Kirkegaard et al. (2016) expressed DM production in terms of dse days/ha. They write that "earlysown, slower-maturing crops have the longest vegetative period and provide the most grazing potential, but typical grain-only spring crop varieties can also be sown early and provide useful grazing without significant yield loss following the same principles – but the potential grazing is much reduced, and closer management of lock-up timing is required". Further, when it comes to planning, preparation and sowing (i.e. all key management activities), they quote that "each week delay in sowing wheat after early March, reduces grazing potential by 200-250 dse.days/ha and yield by 0.45 t/ha".

So, the challenge is to convert this DM into red meat as best we can, without penalising ourselves in grain yield. Again, I refer you to Kirkegaard et al. (2016) for a very explicit description of that critical time to destock, or "shut the gate" so that little or no grain penalty occurs. You will note that this decision is driven by the plant, through its stage of growth and critical residual biomass needs and not by a date on a calendar. If maximising grain yield is a key target, it is imperative to get this destocking decision right.

Understanding plant growth, time to first graze and regrowth rates enables us to predict how many stock, of what class, will be required during the season. In the late 2000's, working with a grower at Cumnock (Central West Slopes), we aimed to get 60 – 75 days grazing from the early sown cereals. This was usually achieved in two or three grazings but required good estimations of DM prior to and during grazing, and what growth rate could be expected during the 'rest or recovery period'. Figure 1 provides DM growth rates for the Central West Slopes (NSW DPI – Prograze, 2000), for a range of pastures species, with oats included as a reference. The oat growth curve line is 'indicative' of a cereal crop's daily growth rate (kg DM/ha/day) in this region, and while I accept that wheat may be slightly lower or it may be sown slightly later, it can be used to estimate a potential grazing situation. There are good data sets of DM rates available from more recent NSW DPI/GRDC trials should you wish to fine tune your future DM estimates for areas closer to home.

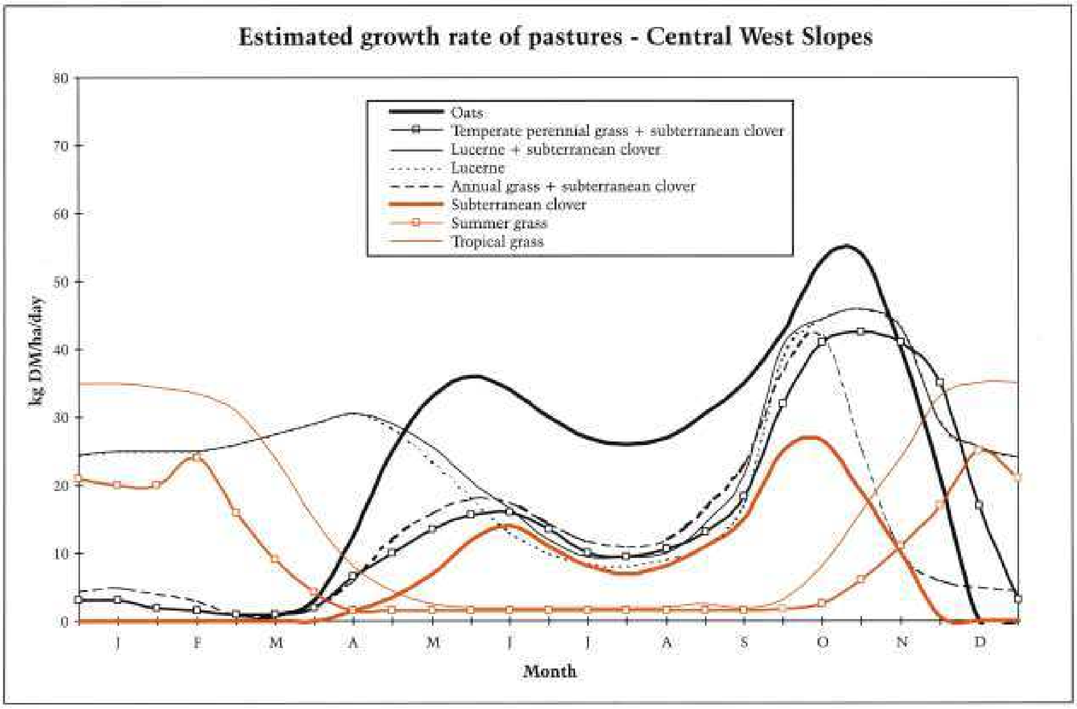

Figure 1 Estimated growth rate (kg Dry Matter/ha/day) of pasture species on the Central West Slopes of NSW (Source NSW DPI - Prograze)

By providing a working example of DM utilisation, it may make the following numbers more understandable. Using the oat growth rate line (the top thick black line from May to October) from Figure 1 as a guide (and knowledge of more recent wheat DM growth rates from various locations), one can estimate how much DM could be on hand by a certain point in the growth cycle. By sowing early (March 1) into a well prepared and planned paddock, one could estimate DM by mid-May to range from 1800–3000 kg DM/ha pending species/varieties/growing conditions. If sowing date was a month later (April 1st), this same DM is likely to be achieved by mid to late June. So how do we use it?

DM utilisation is the amount of DM consumed by the animal as a % of total on offer. For cereals, I estimate 60–70% utilisation pending row spacing, and I am aware of data showing higher utilisation rates in canola. The caution here is not to over-estimate potential DM on offer, as running out of crop DM is far worse than having more left in the paddock than first planned. It takes experience, and lots of it, as no two seasons are the same, and growth rates can change rapidly in response to dry spells, frosts and nutrient deficiencies to list a few. The second variable to consider before stocking is how much residual DM to aim for to enable speedy recovery/regrowth. Best regrowth occurs when there is 1000 – 1400 kg DM remaining (typically 10 – 12 cm high in cereals). Eating below this range restricts regrowth rates for a period, thus decreasing overall DM available for consumption during the season. As Kirkegaard et al. highlight, “not leaving enough residual biomass after the last grazing is very damaging in terms of grain recovery”.

So, for the first grazing, if we average possible DM on hand (2400 kg/ha), and likewise average what residual DM we want left (1200 kg/ha), we can determine there to be 1200 kg DM/ha that we have available to eat. If this is consumed at 65% utilisation, then we eat 780 kg DM. Now the stock class and size and continued crop growth comes into play. Using a 35 kg lamb (0.8 dse), one estimates they will consume 3-4% of their body weight a day (1.05–1.4 kg DM/day, average 1.2 kg DM/day), while from figure 1, growth rate of the crop will continue at say 30 kg DM/day. So just to “hold” the crop where it is, one needs to eat the daily growth (30 kg DM @ 65% = 19.5 kg) which will require 16 lambs/ha. Should we wish to eat the available 780 kg DM over the next 3 weeks, then 780 kg DM /21 days = 37 kg DM/day is further required to be eaten. Again at 1.2 kg DM/day eaten by each lamb, this existing DM needs another 31 lambs/ha. Multiply this by grazable crop area, and this is where paddock size and water source(s) become critical to total stock number required. This above example indicates more than 45 lambs per ha (at a point in time) could be required to get the best grazing efficiency, and thus productivity and profit.

The balancing act of having this amount of quality feed on offer for an extended period means that usually three paddocks or areas of similar size will be required so a 21 day rotation as indicated in the above example can be practiced. This allows approximately 42 days between grazings, enough for significant DM growth if good grazing management principles are applied, and minimum DM limits obeyed.

Similar calculations can be run for grazing crop situations, it just requires DM estimates and predicted DM growth rates, keeping in mind that when the crops near 'lock up' time, these stock, if not ready for sale, need to go somewhere else! As noted earlier in this paper, additional gross margin returns of $600/ha are quite achievable in the current livestock market, with a significant range, pending crop season length, from $300/ha to more than $1000/ha.

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Soil biology and soil amendments

Lukas Van Zwieten [1,2,3], Mick Rose[1], Dave Davenport[4], Ehsan Tavakkoli[5], Yunying Fang[6], Nigel Wilhelm[7]
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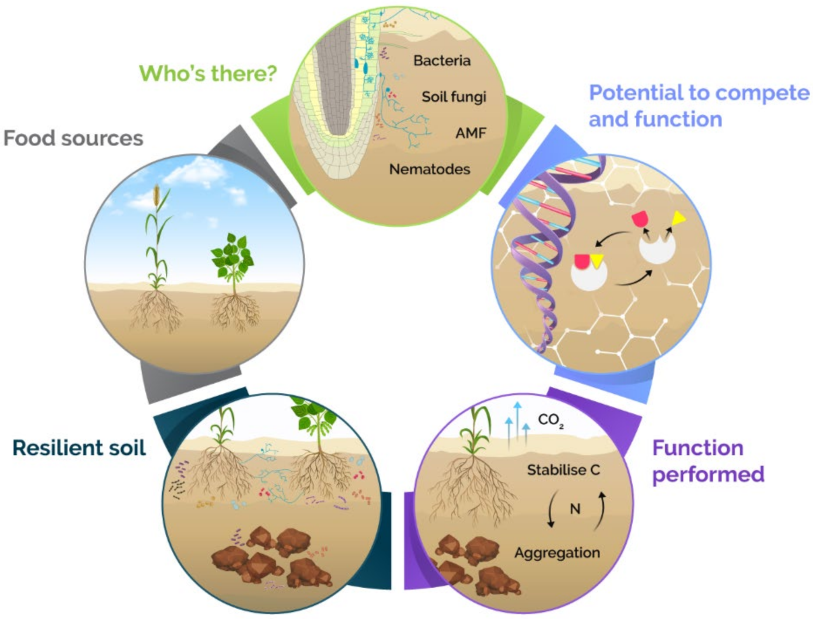
There is a growing interest and recognition of the role of soil biology in agricultural production and sustainability. Lehman et al (2015) suggests that some of the key reasons for manipulating the soil biology include (i) increasing nutrient availability (ii) protecting crops from pests, pathogens, weeds; and (iii) managing other factors limiting production, provision of ecosystem services, and resilience to stresses like drought.

While "soil biology" can now be relatively easily measured, understanding what the data means can be perplexing, for both scientists and farmers alike. Scientific advances have resulted in new ways to measure the diversity, abundance and function of soil microbiota. However, many of the proposed indicators are too general, too specific, change too quickly or don't change quickly enough. In summary, "microbial metrics of soil health are currently poorly validated and lack interpretability, but the affordability and availability of data offers great potential to improve this interpretability and make these measures more useful" (Fierer et al 2020). To address this complexity in evaluating soil biology, we have proposed a framework to guide decisions on which tests to use, and more importantly, what questions to ask (this should come first!).

Framework for assessing soil biology



1) Food source: The microbial food source is where it all starts. The food source is derived from products of photosynthesis, either as root exudates, litter, or soil organic matter. Importantly for this presentation, amendments can also contribute to this food source, or indeed manipulate the availability of microbial food sources by changing the pH, by changing the mineralisation (loss as CO_2) of C from soil, or changing the nutrient stoichiometry (for example, the ratio of carbon to nitrogen). The quality and quantity of the food source is an important factor controlling the soil biology and the functions that are performed. Understanding these factors may allow us to manipulate the soil biology to perform a specific function.

2) Identification of the microbial communities: We can also now assess "who's there" as there are many new methodologies available. While it can be valuable to know who is there, this really is only a part of the picture when assessing soil biology, as there is significant functional redundancy in soil. For example, if one particular genus or species is affected by a particular practice or event, there will usually be some other microorganism that steps up and completes the same function.

3) Assessment of the potential microbial functions: Methods are now available that allow us to quantify a wide range of functions that the soil biology can potentially perform. This can include the ability of soil to cycle carbon and nutrients, to produce enzymes that help to protect against fungal pathogens, the potential to degrade specific pollutants etc.

4) Evaluation of what the microbes actually did: The potential to undertake a function does not always relate to what has actually happened in soil, particularly when this is integrated over time where there may have been fluctuations in soil moisture content or temperature. Examples of functions that are relevant to soil productivity include the mineralisation of C and N to deliver plant available nutrients from either amendments or soil organic matter and the development of aggregation resulting from microbial 'glues.'

5) After we have understood who's there, and what they can do, there is still a lingering question around what does it really mean? If an amendment has been used, does it make the soil more productive or more resilient to stressors such as drought? Are nutrients cycled more effectively? The presentation will discuss some new concepts on understanding soil resilience and how this can control the processing and quality of food sources, thus manipulating the soil biology, changing the potential functions that can be performed, thus influencing productivity.

Case Study: Impacts of ripping and amendments on enzyme activity and nutrient availability
As an example of one of the assessments of the potential for soil to perform a function, we measured the activity of a range of enzymes at plant germination across field demonstration sites in SA. Results showed little difference in enzyme activity in the 0-10cm layer, but differences were particularly noticeable in the rip lines in the 10-30 cm layer (Table 1).

It appears that generally, enzyme activity was stimulated by the amendments in the rip-line this suggests an improved environment for microbial activity deeper in the soil. This could be a result of higher C and/or nutrient levels or availability, reduced compaction and increased root proliferation in that zone. Post-harvest soil analyses showed a significant correlation between Colwell P and phosphatase activity.

Table 1 Soil enzyme activity (mmol/g/h) 10-30 cm layer.

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

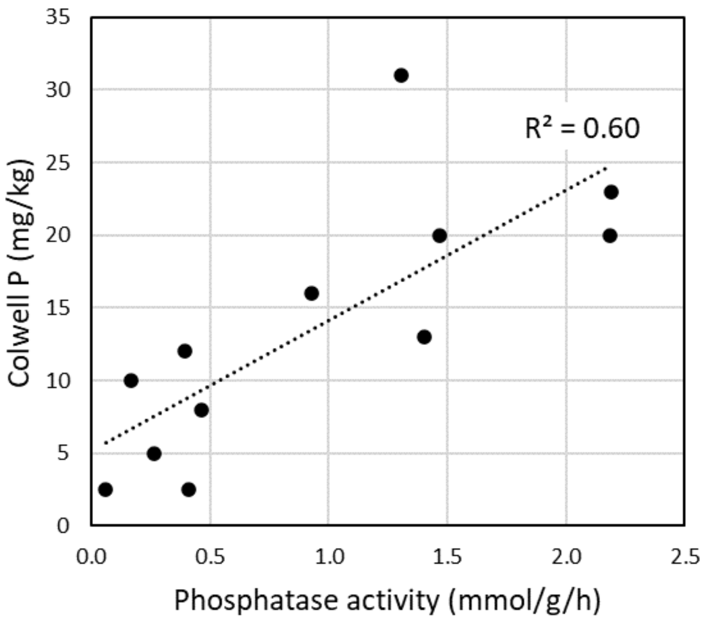


Figure 1 Correlation between soil phosphatase activity and Colwell P in the 10-30 cm profile.

What does this mean?

While further research is required to validate these findings the data suggests that measurement of enzyme activity may potentially be used to identify the efficacy of amendments in addressing nutritional constraints. Also, in collaboration with other soil analyses may provide a general indication of soil health.

Amelioration of sandy soils – 2020 (year 6) results

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GRDC project code: CS00203

Keywords
- deep ripping, chicken litter, spading, amelioration

Key messages
- In the 2020 season, deep ripping produced a 0.44 t/ha (57%) yield increase compared to non-ripped plots, six years after the initial treatment. This reinforces results from the first five seasons where deep ripping has consistently delivered large yield increases, averaging 0.6 t/ha yield increase over the six years.
- High rates of chicken litter increased lentil grain yield by 37% and 54% in 2020 and 2017 respectively, here annual fertiliser response was variable.
- In the 2016 season with decile 9 rainfall, the combination of high rates of chicken litter and fertiliser was required to maximise yield.
- Large differences in grain yield between chicken litter applied at 20 t/ha and matched fertiliser at 3 t/ha were observed in 2019 and 2020 and appear to be increasing. The slow release of nutrients from chicken litter through mineralisation may expose these nutrients to less losses (leaching and volatilization) compared with mineral fertiliser application, providing greater treatment longevity.

Background
Sandy dune soils are an important feature of the dune swale landscape of the northern Yorke Peninsula. Common characteristics of these sands include low water holding capacity, low organic matter, low nutrient availability, compaction, non-wetting and high risk for wind erosion. In 2015 a trial site was established on a sand hill near Bute, SA, to investigate options for amelioration of these constraints. This paper will report on the year six 2020 results of these trials and briefly summarise the six years of yield responses.

Method
Two trials were established on a sand hill near Bute in 2015 investigating treatments including deep ripping, spading, clay, chicken litter (rate and placement) and fertiliser. The soil at the site is described as a siliceous sand and has good levels of P and K, but low Organic carbon and Cation Exchange Capacity. The site had high levels of compaction, with penetrometer resistance exceeding 2,500 kPa from 20 cm depth and peaking at over 4,000 kPa at 30 cm depth. Treatment responses were measured in six consecutive cropping seasons of Grenade CL Plus wheat in 2015, Spartacus CL barley in 2016, PBA Jumbo 2 lentils in 2017, Scepter wheat in 2018, Compass barley in 2019 and PBA Jumbo 2 lentils in 2020. Fertiliser treatments were applied in each season, with all other treatments applied once only at trial initiation in 2015. The trials were randomized complete block designs with three replicates. Plots were 10 m * 1.8 m and were sown with knife points and press wheels on 300 mm row spacing.

Treatment details
<u>Deep ripping</u>: ripping was conducted with the Peries-Wightman subsoiler, with 2 tynes spaced 800mm apart and working to a depth of 450-500 mm. This machine has 125 mm diameter pipe behind each tyne for delivery of bulk products to near the bottom of the rip line. This same machine was also used for subsoil manure application in Trial 2.
<u>Spading</u>: Farmax spader working to 300 mm deep.
<u>Clay</u>: sourced from the 0-40 cm layer from the adjacent swale, 30% clay content. At 130 t/ha commercial application for this was costed at $400/ha.

Chicken litter: Supplied from a broiler shed on the Wakefield plains. Nutrient analysis shown below (Table 1).
Fertiliser: MAP 90kg/ha, MoP 30kg/ha, SoA 100kg/ha, Urea 100kg/ha. P (MAP) and K (MoP) were applied to the soil at seeding in each season and Zn, Cu and Mn were applied as sulphates post emergent as a foliar application in 2015, 2016, 2017 and P was applied at seeding in 2018, 2019 and 2020. N (urea and SoA) and S (SoA) were applied post emergent to the cereals in 2015, 2016, 2018 and 2019 and S was applied to lentils in 2017 as gypsum pre seeding, no S was applied in 2020.

Table 1 Nutrient concentration of applied chicken litter.

Nutrient		Nutrient conc. dry weight	Nutrient conc. fresh weight	Kg nutrient per tonne fresh weight	Kg nutrient per 5 tonne fresh weight	Kg nutrient per 20 tonne fresh weight
N	Nitrogen	3.8%	3.50%	35.0	175	699
P	Phosphorus	1.72%	1.58%	15.8	79	316
K	Potassium	2.31	2.13%	21.3	106	425
S	Sulfur	0.55%	0.51%	5.1	25	101
Ca	Calcium	3.48%	3.20%	32.0	160	640
Mg	Magnesium	0.73%	0.67%	6.7	34	134
Zn	Zinc	0.46g/kg	0.42g/kg	0.4	2.1	8.5
Mn	Manganese	0.51g/kg	0.47g/kg	0.5	2.3	9.4
Cu	Copper	0.13g/kg	0.12g/kg	0.1	0.6	2.4
B	Boron	0.05g/kg	0.05g/kg	0.05	0.2	0.9
Fe	Iron	4.33g/kg	3.98g/kg	4.0	19.9	79.6

Trial 1: this was a factorial trial with 24 treatments (2*2*2*3), assessing four inputs:

- Deep ripping - yes or no
- Annual fertiliser - yes or no
- Clay - yes (130 t/ha) or no
- Chicken litter - 0, 5 or 20 t/ha

Trial 2: this trial assessed:

- placement of chicken litter or fertiliser: surface placement vs subsoil (300-400mm deep)
- spading
- matching nutrition of chicken litter with synthetic fertiliser: 20t/ha chicken litter vs matched NPKS from fertiliser. That is 1026 kg/ha urea, 800 kg/ha MAP, 420 kg/ha SoA and 704 kg/ha MoP. This synthetic fertiliser nutrition is actually marginally less than that supplied by 20 t/ha chicken litter, however rates were applied before final chicken litter analysis was available.
-

For a complete list of treatments see table 6.

Table 2 Rainfall received in seasons 2015-2020 and trial seeding dates.

	2015	2016	2017	2018	2019	2020
GSR	204 (decile 1)	441 (decile 9)	209 (decile 1)	210 (decile 1)	213 (decile 2)	301 (decile 6)
Annual rainfall	309 (decile 2)	696 (decile 10)	369 (decile 5)	310 (decile 2)	240 (decile 1)	390 (decile 6)
Sowing date	20 May	20 May	17 May	11 May	16 May	15 May
Harvest date	2 Dec	29 Nov	8 Nov	16 Nov	6 Nov	21 Nov
CLL sample date			13 Nov	19 Nov	29 Nov[h]	

Results and discussion

Trial 1 - Grain yield

In the sixth season from treatment implementation all treatments continue to influence crop growth and in some cases yield. In 2020, deep ripping produced a 0.44t/ha (57%) increase in lentil yield (Table 4a). This is consistent with previous seasons, where deep ripping has increased yield and generated high returns (Figure 1a).

Clay application improved emergence, reduced herbicide damage and increased vigour and NDVI at both timings (Table 4b). However grain yield was slightly reduced (-0.08t/ha). In previous seasons clay application has had no impact on grain yield (Figure 1B) but has increased grain protein (2018 and 2019, data not presented).

Application of fertiliser at seeding increased the herbicide damage score but the crop recovered and vigour scores and NDVI where higher where fertiliser was applied. However, similar to the clay application this increase in vigour and NDVI did not translate into lentil grain yield, this is a similar result to the 2017 lentil grain yield where clay and fertiliser had no effect or reduced yields.

Chicken litter applied at 5 and 20 t/ha in 2015 increased lentil grain yield in 2020 by 0.18 t/ha (22%) and 0.31 (37%) t/ha, respectively. This increase in grain yield is consistent with the lentil response in 2017 where yield increases of 34% and 55% were measured. Over the six trial seasons the greatest response to chicken litter observed was a 65% increase in response to 20 t/ha in the higher yielding season of 2016 (decile 9 rainfall). Standard fertiliser treatments did not meet the crops nutritional requirements and a combination of high rates of chicken litter and annual fertiliser was required to maximise grain yield.

Table 4 2020 GreenSeeker NDVI, grain yield as affected by; A - deep ripping, B - clay application 130t/ha, C – annual fertiliser application, D - chicken litter application.

A.

Ripping	Emergence score June 16	Herbicide score July 6	Vigour July 6	NDVI August 5	NDVI Sept 15	Grain yield (t/ha)
No	6.6	3.1	6.6	0.254	0.460	0.77
Yes	7.3	3.2	7.2	0.272	0.533	1.21
Pr(>F)	*0.039*	*0.736*	*0.003*	*0.007*	*<0.001*	*<0.001*
LSD (0.05)	*0.2*	*ns*	*0.1*	*0.004*	*0.009*	*0.03*

B.

Clay (t/ha)	Emergence score June 16	Herbicide score July 6	Vigour July 6	NDVI August 5	NDVI Sept 15	Grain yield (t/ha)
0	6.5	4.1	6.1	0.236	0.461	1.03
100	7.3	2.1	7.7	0.290	0.531	0.95
Pr(>F)	*0.011*	*<0.001*	*<0.001*	*<0.001*	*<0.001*	*0.031*
LSD (0.05)	*0.6*	*0.3*	*0.4*	*0.013*	*0.027*	*0.08*

C.

Fertiliser	Emergence score June 16	Herbicide score July 6	Vigour July 6	NDVI August 5	NDVI Sept 15	Grain yield (t/ha)
No	6.8	3.5	6.3	0.243	0.479	1.03
Yes	7.1	2.8	7.4	0.283	0.514	0.95
Pr(>F)	*0.379*	*<0.001*	*<0.001*	*<0.001*	*0.013*	*0.049*
LSD (0.05)	*ns*	*0.1*	*0.1*	*0.004*	*0.009*	*0.03*

D.

Chicken litter (t/ha)	Emergence score June 16	Herbicide score July 6	Vigour July 6	NDVI August 5	NDVI Sept 15	Grain yield (t/ha)
0	7.1	3.6	6.2	0.229	0.437	0.83
5	7.1	2.9	7.1	0.253	0.477	1.01
20	6.6	2.8	7.4	0.306	0.574	1.14
Pr(>F)	*0.330*	*0.001*	*<0.001*	*<0.001*	*<0.001*	*<0.001*
LSD (0.05)	*ns*	*0.4*	*0.5*	*0.016*	*0.033*	*0.10*

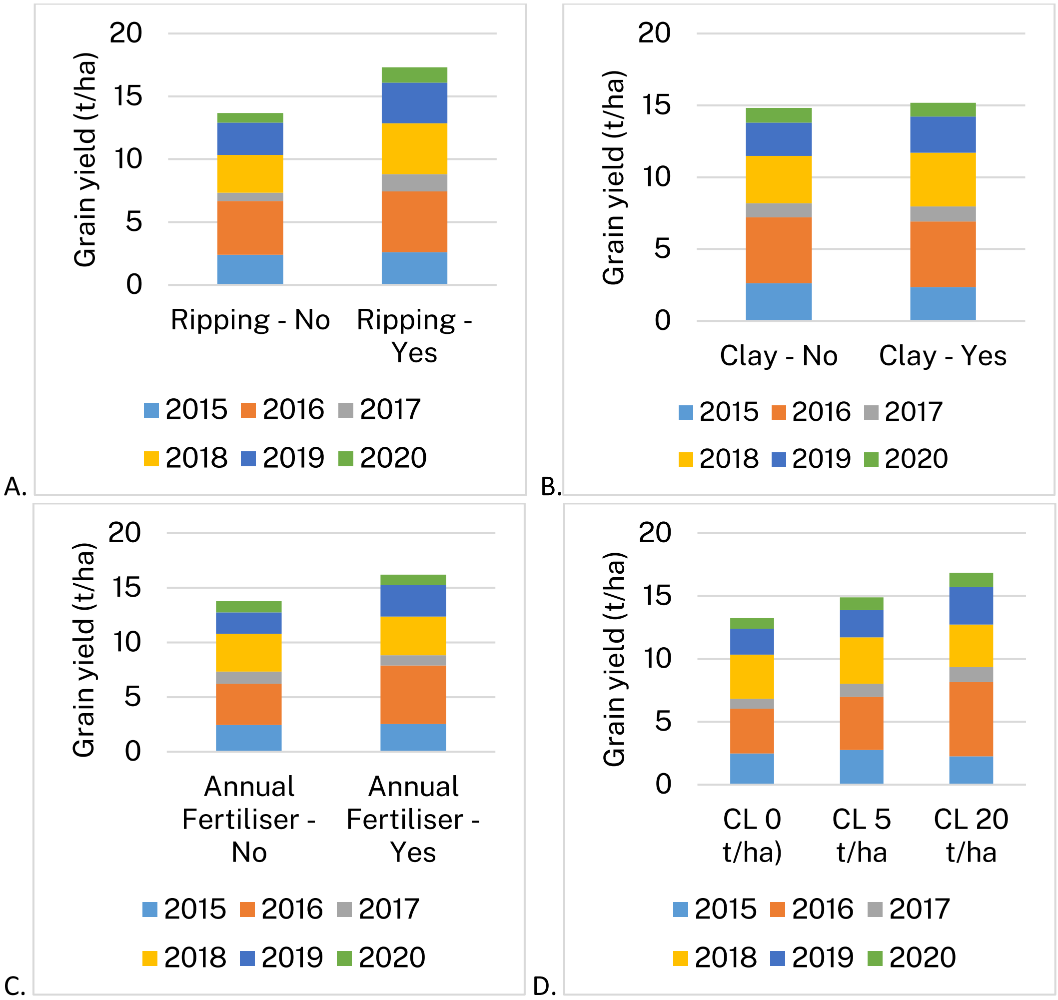

Figure 1 Cumulative grain yield results for Bute soil amelioration trial - 2015 wheat, 2016 barely, 2017 lentil, 2018 wheat, 2019 barley and 2020 lentil.

Trial 2 - Grain yield

Surface vs Deep Placement

Treatment 2 vs Treatment 3 & Treatment 6 vs Treatment 7 (Table 6). In 2020 there was no difference between surface and subsurface application (in 2015) of either chicken litter or synthetic fertiliser. In 2019 deep placement of 20t/ha chicken litter was not significantly better than surface applied, however 3 t/ha matched fertiliser placed deep increased yield by 49% over surface applied amendments (Figure 2). In 2018 both amendments were best applied deep, whereas in the first three seasons the trend was toward surface application being better.

Amendment type: Chicken Litter (20 t/ha) vs Matched Fertiliser (3 t/ha)

Treatment 10 vs Treatment 8. In 2020 there was a 0.43 t/ha yield advantage for chicken litter over the matched fertiliser treatment. In the previous season this advantage for chicken litter over fertiliser was 1.25 t/ha. Possible explanations relate to nutrient release and loss mechanisms. All nutrients are in mineral form in the matched fertiliser treatment at application timing, these are subject to losses through leaching, particularly the nitrate and sulphate, on a leachable sandy soil. Given the very wet 2016 season, it is possible that a large amount of nutrient was lost through leaching in that season. Whereas the nutrients in chicken litter are released more slowly through mineralisation and are less available for loss in large quantities. However, given such high rates of application, nutrition responses were unlikely to be observed in the first few seasons. However, as nutrient reserves are used up, differences due to nutrient losses may become more important.

Spading

Treatment 2 vs Treatment 5.

There was a slight yield reduction due to spading and ripping compared to ripping alone in 2020 in lentil. In most previous seasons (2016-2019) there has been no measurable difference between these treatments at this site (Table 6). In 2015 the incorporation of 20t/ha chicken litter caused excessive canopy growth and the crop hayed off early, this is indicated by the low yield for treatment 5 in 2015. In comparison, spading with no additional nutrition (treatment 4) yielded well in 2015. However, as no fertiliser was applied to this treatment in the first 4 years of the trial it performed poorly in 2016 where nutrient demand was high due to decile 9 rainfall. Since that year it has produced reasonable grain yield.

Table 6 Full treatment list for trial 2, herbicide score (1 = no damage 6 = death), vigour score (1 = poor vigour 9 = high vigour), NDVI and grain yield.

Treatment	Amendment	Placement	Ripping	Clay (t/ha)	Spading	Annual Fertiliser	Herbicide score July 6	Vigour July 6	NDVI August 5	NDVI Sept 15	Grain yield (t/ha)
1	Nil	-	No	0	No	No	5.7	5.3	0.19	0.35	0.76
2	CL 20 t/ha	Surface	Yes	100	No	Yes	1.5	8.7	0.37	0.65	1.27
3	CL 20 t/ha	Subsoil	Yes	100	No	Yes	1.8	8.7	0.32	0.59	1.24
4		-	No	0	Yes	2019 + 2020	2.0	8.7	0.28	0.51	1.14
5	CL 20 t/ha	Surface	Yes	100	Yes	Yes	1.5	9.0	0.42	0.69	1.13
6	Fert 3 t/ha	Surface	Yes	100	No	No	2.7	7.7	0.23	0.44	1.04
7	Fert 3 t/ha	Subsoil	Yes	100	No	No	3.0	7.2	0.24	0.52	1.06
8	Fert 3 t/ha	Subsoil	Yes	0	No	No	4.0	6.7	0.21	0.45	0.99
9	CL 20 t/ha	Subsoil	Yes	0	No	No	4.0	7.7	0.26	0.46	1.22
10	CL 20 t/ha	Subsoil	Yes	0	No	No	3.8	6.7	0.24	0.51	1.42
LSD (0.05)							*1.5*	*1.4*	*0.02*	*0.03*	*0.09*

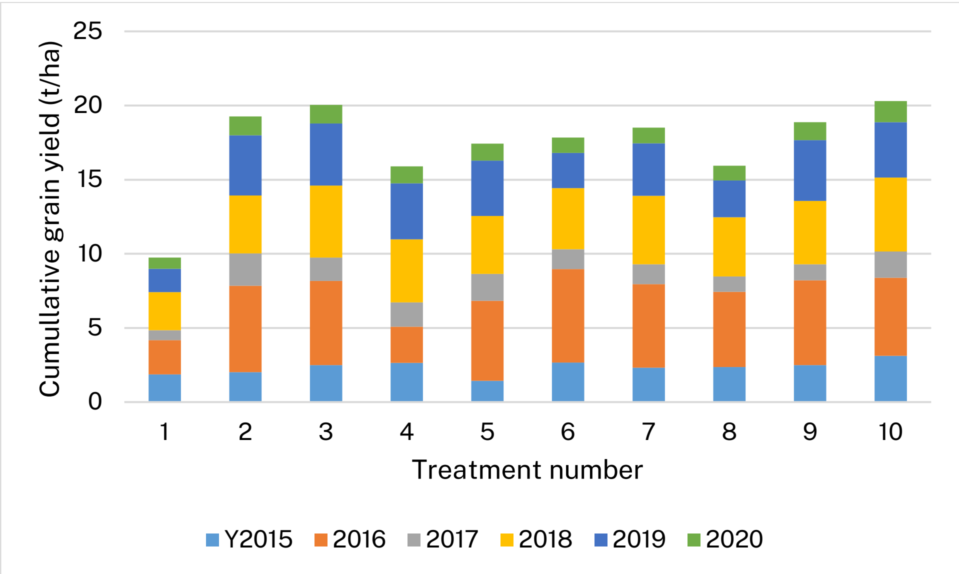

Figure 2 Cumulative grain yield for subsoil amelioration at Bute 2015-2020.

Summary

After six seasons significant impacts from treatments applied in 2015 continue to be measured. In particular, the deep ripping treatment has been a standout in terms of consistent and large responses across seasons, delivering high return on investment. Long term yield responses to one off chicken litter applications also continue to be measured. Responses to fertiliser and chicken litter were heightened in high rainfall and high yield potential seasons, highlighting the importance of getting nutrition right on these sands. The benefit of chicken litter for long term slow-release nutrition has also been demonstrated in trial 2, in comparison with the 3 t/ha matched fertiliser treatment where responses have declined.

Acknowledgements

Funding for this trial is gratefully acknowledged from GRDC project CSP00203 'Increasing production on sandy soils in low and medium rainfall areas of the Southern Region. Earlier trial years were supported by GRDC (TRE00002), the Northern and Yorke Landcare Project Community Capacity Component and SAGIT (TC116) and is gratefully acknowledged. Max and Bill Trengove are thanked for hosting the trial on their property and assistance with applications of pesticides throughout the season.

Management of fungicide resistant wheat powdery mildew

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Keywords
- wheat powdery mildew, fungicide resistance.

Key messages
- Improving varietal resistance from susceptible to very susceptible (SVS) to moderately susceptible (MS) had a greater impact on reducing powdery mildew infection than use of any registered fungicide.
- In furrow and seed treatments provided early powdery mildew control, however this effect dissipated as the growing season progressed.
- Demethylation inhibitors (DMI) and quinone outside inhibitors (QoI) fungicides provided powdery mildew control, despite reduced sensitivity and resistance being detected within the population to these modes of action.
- Yield loss related to powdery mildew stem infection assessed at mid booting (GS45) ranged from 4-9.4 kg grain/ha/stem pustule across three trials, resulting in yield loss of up to 17%.
- Cost of control and likely return on investment (ROI) should take into consideration the spatially variable nature of powdery mildew.

Background
Wheat powdery mildew (WPM) has been documented to cause up to 25% yield loss in Australia (https://grdc.com.au/news-and-media/newsletters/paddock-practices/protecting-cereal-crops-from-powdery-mildew). Common wheat varieties that are currently being grown have poor varietal resistance, with many having ratings of susceptible to very susceptible (SVS), and only a few varieties rated as moderately susceptible to susceptible (MSS) or moderately susceptible (MS). There has been a large shift in area sown to SVS varieties in the last four years, with the dominant variety Mace[A] that is MSS being superseded by Scepter[A] that is SVS. Consequently, there is a heavy reliance on fungicides for WPM control. Fungicide options have relied heavily on the DMI group 3 (triazole) products such as tebuconazole and epoxiconazole, and these are the basis of many fungicide mixes. In more recent years, there has also been increasing use of the QoI group 11 (strobilurin) actives in mixtures with DMI fungicides in products such as Amistar Xtra® (azoxystrobin + cyproconazole). Often the fungicide strategy has been targeting other pathogens, such as stripe rust and Septoria, with application timing and product selection targeted to these pathogens. The use of these products has also been providing some control of susceptible populations of WPM provided suitable application coverage is achieved. However, by its nature, WPM often infects low down in the canopy covering lower leaves, leaf sheathes and stem where good spray coverage can be difficult with late application timings.

Fungicide resistance in WPM was identified in the northern Yorke Peninsula region in 2019, with testing performed by the Centre for Crop and Disease Management (CCDM). DMI and QoI groups were both implicated. With reduced efficacy expected from these modes of action, currently the registered alternative mode of action options are limited to the succinate dehydrogenase inhibitors (SDHI) (group 7) products such as Aviator® Xpro® (bixafen + prothioconazole) or Elatus™ Ace (benzovindiflupyr + propiconazole), which are mixtures of group 7 (SDHI) and group 3 (DMI) active ingredients.

Trials were initiated in 2020 as part of a SAGIT project to better understand the best practice management of WPM given emerging fungicide resistance issues.

Method
In 2020 five trials were implemented near Bute, northern Yorke Peninsula. Each of the five trials had a particular focus, these were:

1. Varietal resistance and post emergent fungicides (sown 11 May).
   - Four varieties with disease ratings for WPM ranging from MS to SVS and four fungicide strategies.
2. Pre-emergent fungicides (sown to Chief CL Plus[A], 11 May).
   - Seven pre-emergent fungicides +/– post emergent fungicide.
3. Post emergent fungicides (sown to Scepter[A], 4 May).
   - A range of post emergent fungicide treatments applied twice at GS32 and GS45.
4. Fungicide timing (sown to Scepter[A], 4 May).
   - Fungicide applied at four timings (GS14, 32, 45 and/or 65) in 10 timing combinations.
5. Fungicide sequencing (sown to Chief CL Plus[A], 11 May).
   - A trial focused on controlling resistant powdery mildew using 15 combinations of pre-emergent and post emergent fungicides from a range of fungicide groups.

The trials were located at a site where fungicide resistant WPM was detected in a survey during 2019. At this site in 2019, 64% of the powdery mildew population had reduced sensitivity to the DMI (Group 3) fungicides and 1.5% of the population was resistant to the strobilurin (Group 11) fungicides.

Powdery mildew assessments were made on three occasions for each trial targeting early infection, mid-season infection and late infection in the head. For the first two assessment timings, individual pustules were counted on the stem and each leaf. Where pustules merged, an individual pustule was counted as an area of $2mm^2$. For the head infection a 0 – 9 score was used where 0 = no powdery mildew, 5 = 50% coverage of powdery mildew, 9 = 90% coverage, etc.

Wheat powdery mildew was first identified at the site on 22 June 2020 at GS14, with a single pustule being observed. Rainfall at Bute in 2020 was characterised by periods of wet and dry throughout the growing season, with a dry early mid-winter and dry early spring (Figure 1). In particular, the trials appeared moisture stressed in mid-September, losing significant green leaf area as a result, and potentially limiting disease progression. These results should be interpreted in that context.

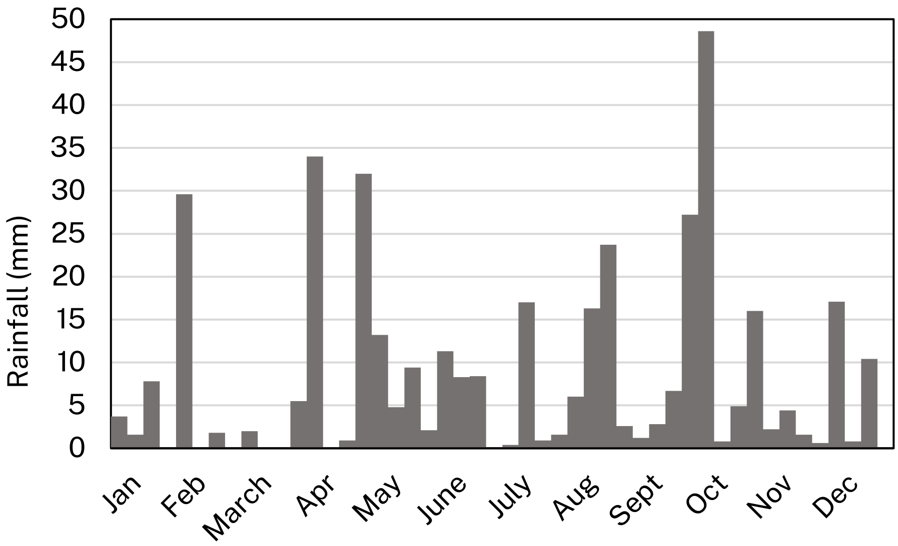


Figure 1 Weekly rainfall at Bute in 2020. April to October rainfall 301 mm, 2020 annual rainfall 390 mm.

Results and discussion

Varietal resistance to wheat powdery mildew

Four varieties were selected for this trial with a range of resistance levels to determine the benefit of varietal resistance and its interaction with fungicide use. The varieties were Kord CL Plus[A] (MS), Mace[A] (MSS), Scepter[A] (SVS) and Chief CL Plus[A] (SVS). Scepter[A] and Chief CL Plus[A] were both chosen as they have commonly been grown in the area and field observations indicated that Chief CL Plus[A] may be more susceptible, despite both being rated SVS in 2019. Kord CL Plus[A] was chosen despite being lower yielding, as it is one of the only MS rated main season varieties available for this area.

Wheat powdery mildew pustule counts showed that varietal resistance had a much greater impact on infection level than the application of epoxiconazole at GS32 (Figure 2). Epoxiconazole use reduced pustule number by 22-51%, whereas changing from an SVS variety (Chief CL Plus[A] or Scepter[A]) to an MS variety (Kord CL Plus[A]) reduced pustule number by 74-82%.

Comparing yields of untreated with yields of best performing fungicide treatment for each variety indicates yield gain from fungicide use of up to 17%, 9%, 8% and 1% for Chief CL Plus[A], Scepter[A], Mace[A] and Kord CL Plus[A], respectively (Figure 3). The scale of yield increase in response to fungicide treatment is reasonably consistent with varietal resistance rating, where the yield response to fungicide declines with improved varietal resistance.

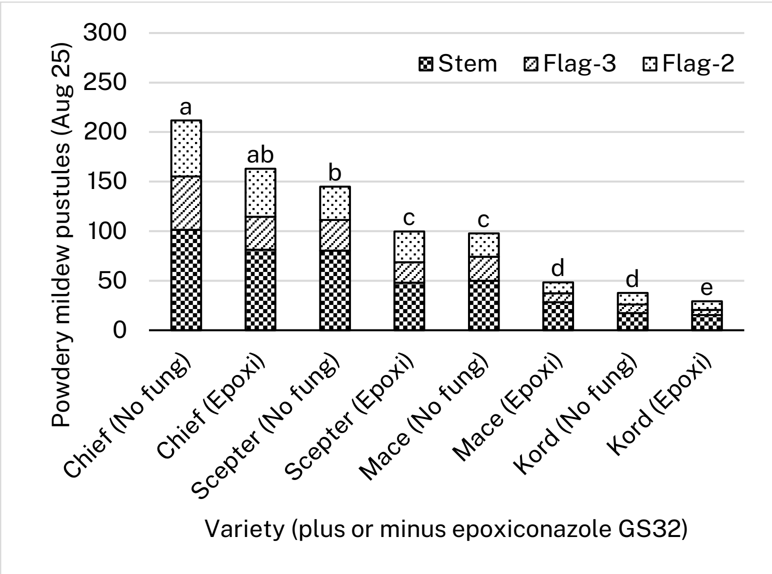


Figure 2 Variety and epoxiconazole fungicide effect on pustule number at GS45 (25 August) on the stem and leaves flag – 3 and flag – 2. Epoxiconazole (125 g/L) applied at 500 ml/ha at GS32 (16 July). Pr (>F) value = 0.027. Letters denote significant differences between pustule totals.

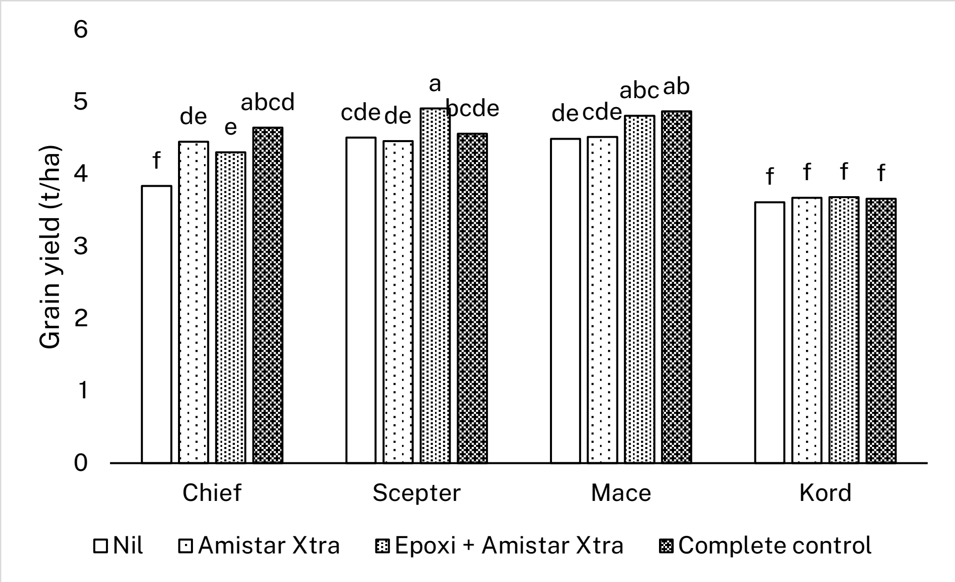
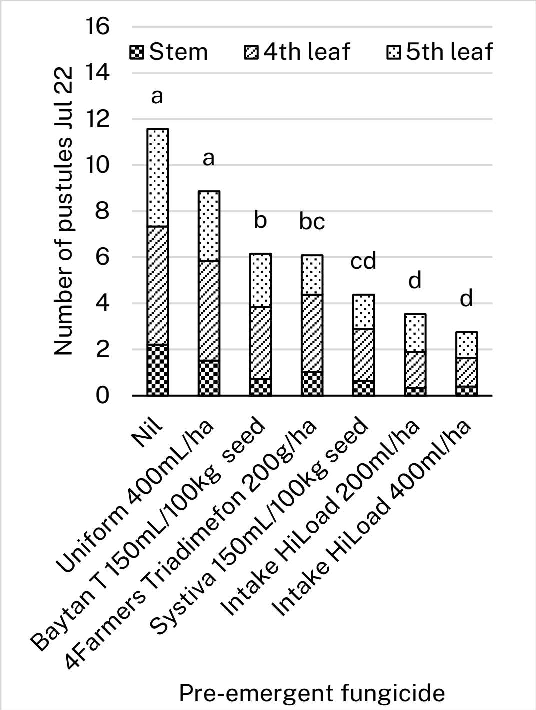


*Figure 3 Variety and fungicide effect on grain yield. Epoxiconazole (125 g/L) applied at 500 ml/ha at GS32 (16 July). Amistar Xtra® (azoxystrobin + cyproconazole) applied at 400 ml/ha at GS45 (25 August). Variety*fungicide Pr (>F) = 0.057, LSD (0.1) = 0.41 t/ha, variety Pr (>F) = <0.001, LSD (0.05) = 0.19 t/ha, fungicide Pr (>F) = 0.004, LSD (0.05) = 0.19 t/ha.*

Pre-emergent fungicides

Several in furrow fungicide treatments reduced WPM infection early in the season (Figure 4a). Flutriafol treatments appeared to be the best of these, reducing pustule number by up to 76%, whereas Uniform® treatments were similar to the untreated control. However, all treatments were ineffective as the season progressed and were not able to provide a long-term benefit in this instance (Figure 4b), despite the application of benzovindiflupyr + propiconazole (Elatus Ace) at 500 ml/ha at GS32 and azoxystrobin + cyproconazole (Amistar Xtra) at 400 ml/ha at GS45. The change in pustule number from 22 July (Figure 4a) to 24 August (Figure 4b) indicates the large increase in disease pressure over that timeframe. No yield benefit was observed in response to in furrow fungicide treatment, however a 6.7% (0.26 t/ha) increase was observed in response to post emergent fungicide application of Elatus Ace followed by Amistar Xtra (data not shown).

It is important to put these results in the context of a small-scale plot trial where airborne spores from adjacent plots with poorer control will increase infection load on treatments with better control that were kept clean early. In the case of a highly effective pre-emergent fungicide in a broad scale situation, such as a large paddock, the response to the pre-emergent fungicide may last longer then reported here, as there will be less inoculum load present as a result of good early control. This impediment is a common problem in plot trials where different treatment times are being compared and airborne pathogens are involved.

a) 

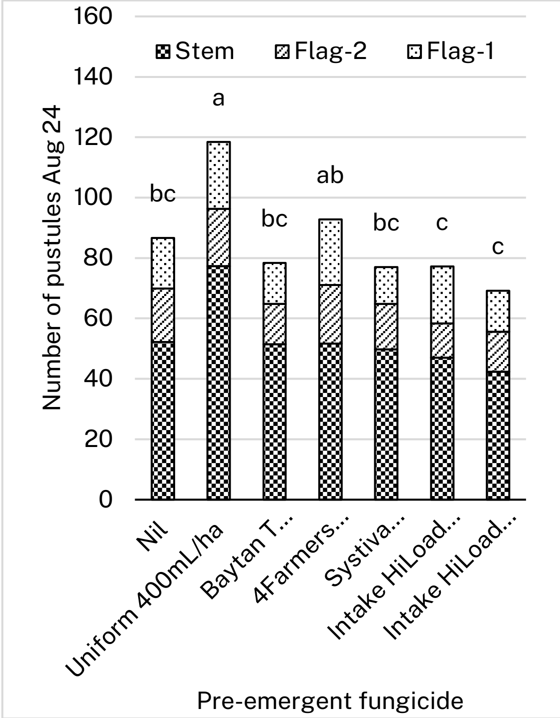
b) 

Figure 4 a) Number of pustules on the stem, 4th leaf and 5th leaf on 22 July, Pr (>F) = <0.001, LSD (0.05) = 0.11, b) Number of pustules on the stem, flag -2 and flag -1 on 24 August, Pr (>F) = 0.002, LSD (0.05) = 0.13, averaged across plus and minus post emergent Elatus™ Ace fungicide treatments. Letters denote significant differences between pustule totals.

Post emergent fungicides

Demethylation inhibitors (Group 3) and strobilurin (Group 11) fungicides applied individually provided 56-76% pustule reduction at 13 August and 28-76% pustule reduction at 11 September (Figure 5 and 6), despite reduced sensitivity (64%) and fungicide resistance (1.5%) being detected in WPM at this site in 2019, respectively. There was a difference within the group 3 fungicides, with the commonly used fungicide, epoxiconazole performing poorer than both the tebuconazole and tebuconazole + prothioconazole (Prosaro®) fungicides. This could suggest a better performance of particular DMI fungicides when reduced sensitivity has developed due to the emergence of specific mutations at the DMI target site. The combination of group 3 and group 11 fungicides was better than either applied alone at the earlier assessment and that continued at the 11 September assessment, where epoxiconazole + azoxystrobin (Tazer Xpert™) was one of the best registered treatments. However, cyproconazole + azoxystrobin (Amistar Xtra) did not provide a significant advantage over the better DMIs such as tebuconazole or Prosaro. While the QoI treatments worked reasonably well, the continuous use of this group of fungicides will inevitably lead to the accumulation of resistant individuals and disease control problems in the future.

New SDHI plus DMI fungicide mixtures, bixafen + prothioconazole (Aviator Xpro) and benzovindiflupyr + propiconazole (Elatus Ace) provided 58 and 67% pustule reduction, respectively at the earlier assessment and 59 and 84% reduction at the later assessment (Figure 5 and 6). These provide little or no improvement compared with the better DMI actives, posing the question 'do the SDHI actives provide much WPM control, or is it the DMI mix partner doing most of the work?' A standalone SDHI fungicide (A (7)), not registered in wheat, performed poorly, suggesting that the group 3 DMI mix partner in the SDHI products were providing a significant level of the control.

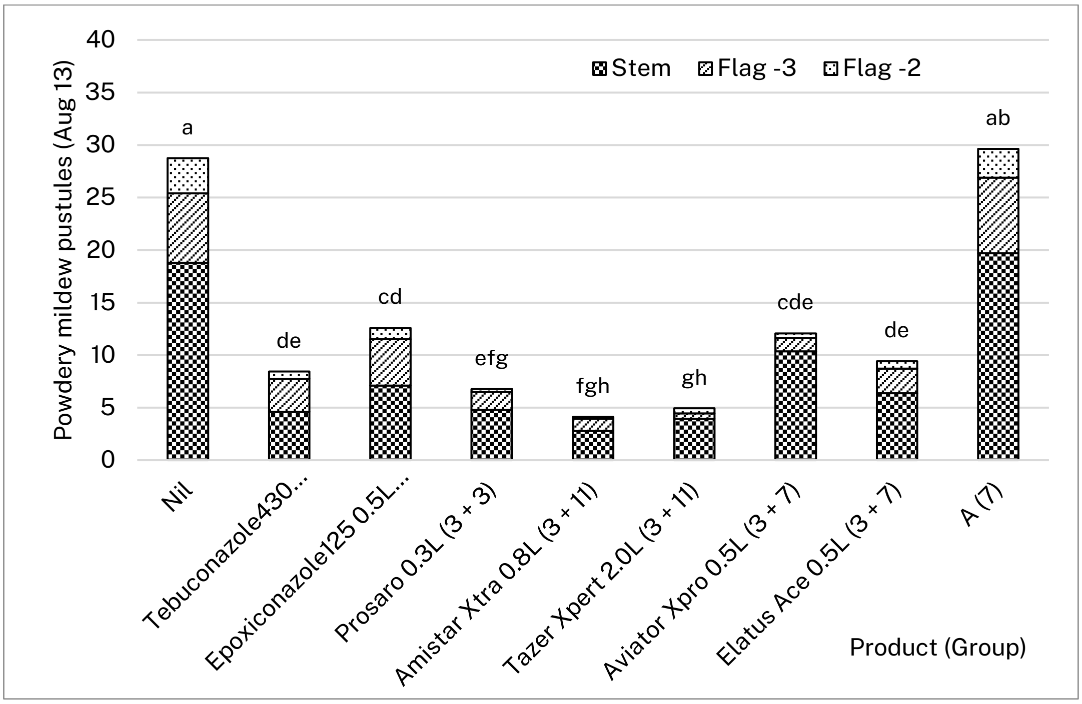


Figure 5 Number of powdery mildew pustules for selected treatments on the stem and flag leaf minus 3 and 2 counted 13 August 2020. Post emergent fungicides applied 16 July. Letters denote significant differences between log transformed totals Pr (>F) = <0.001.

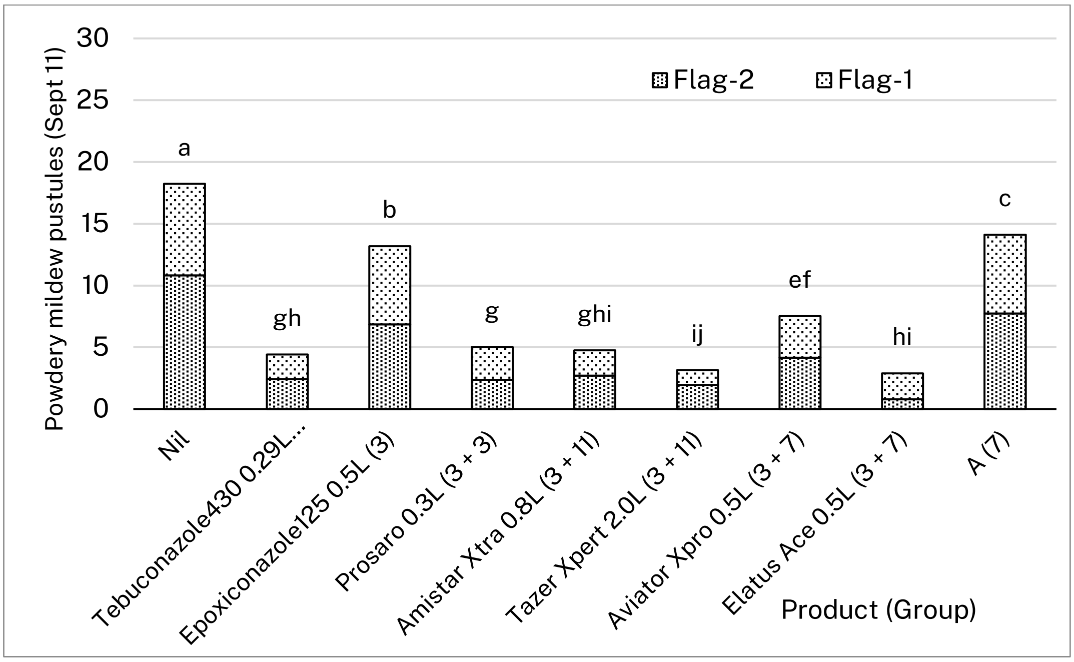


Figure 6 Number of powdery mildew pustules for selected treatments on flag leaf minus 2 and 1 counted 11 September 2020. Post emergent fungicides applied 16 July and 25 August. Letters denote significant differences between log transformed totals Pr (>F) = <0.001.

Linear regression between stem pustules assessed at mid booting (GS45) and grain yield indicates yield loss in the range of 4-9.4 kg/ha/stem pustule across three trials (Figure 7). This may provide a guide to predicting yield loss in season but requires further validation across multiple sites and seasons.

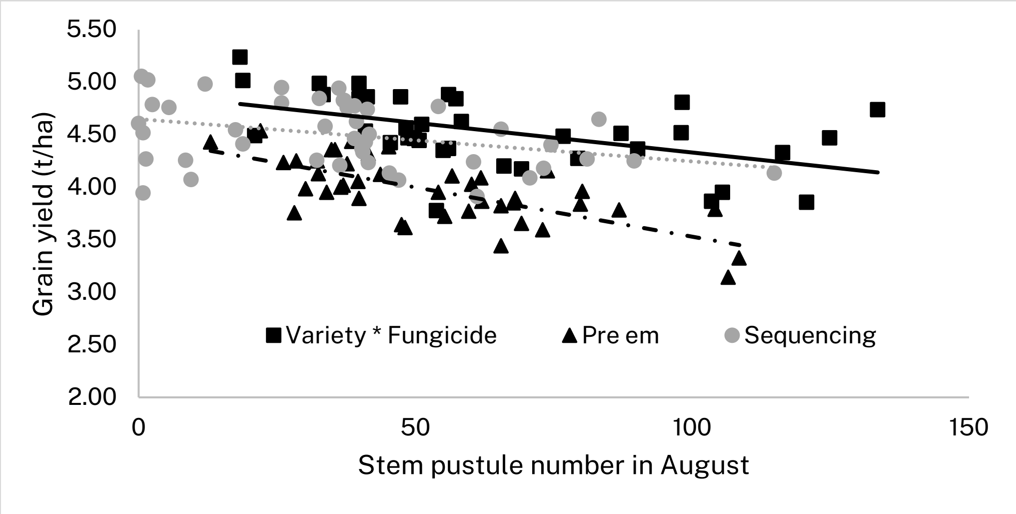


*Figure 7 Linear regression of stem pustule numbers in August and wheat grain yield (t/ha) for the variety * fungicide (y = -0.0057x + 4.8967, R^2 = 0.2572), pre-emergent fungicide (y = -0.004 + 4.6494, R^2 = 0.1239) and sequencing fungicide trials (y = -0.0094x + 4.4692, R^2 = 0.4938).*

Sensitivity analysis of fungicide costs versus potential yield loss

Wheat powdery mildew incidence and severity has been observed to be highly variable spatially, particularly in the northern Yorke Peninsula region where this work has been undertaken. Typically, the disease is worst where the crop is growing on the lighter textured sands and dunes, whereas on the heavier textured soils in the swales, disease incidence tends to be much lower. The basis for these differences is not well understood. The area at high risk of severe WPM infection will have an impact on the likely returns from investment in fungicide.

Partial gross margin (PGM) sensitivity analysis indicates that with a $23/ha fungicide cost, 14% of the area or greater would need to be at high risk from severe WPM infection to generate a positive return on fungicide investment across the whole paddock, given the assumptions listed in Table 1. Where fungicide resistance increases and alternative modes of action are required, fungicide price is likely to increase. In this example if the fungicide cost increases to $37/ha then 22% of the area or greater would need to be at high risk of severe WPM infection to generate a positive return on fungicide investment, given the assumptions listed in Table 2.

This is a simplistic model of spatial distribution of WPM. It is likely that there will be some benefit of additional fungicides on other areas of the paddock that do not have the high WPM pressure seen on sandy rises. Therefore, these PGMs may underestimate the returns, and therefore, a smaller area of high WPM pressure will be required to cover fungicide costs.

Table 1 Partial gross margin sensitivity analysis for varying areas of soil type more susceptible to wheat powdery mildew (WPM). Analysis uses the following assumptions: farm gate wheat price $250/t, additional fungicide cost including application $23/ha, potential wheat yield 4 t/ha, yield loss associated with WPM in more susceptible areas 17%.

Paddock area with high WPM	Paddock area with low WPM	Paddock average yield with no additional fungicide (t/ha)	Farm gate gross income without additional fungicide ($/ha)	Farm gate gross income with additional fungicide ($/ha)	Partial gross margin (PGM) ($/ha)
0%	100%	4.00	1000	977	*-23*
10%	90%	3.93	983	977	*-6*
20%	80%	3.86	966	977	11
30%	70%	3.80	949	977	28
40%	60%	3.73	932	977	45

Table 2 Partial gross margin sensitivity analysis for varying areas of soil type more susceptible to wheat powdery mildew (WPM). Analysis uses the following assumptions: farm gate wheat price $250/t, additional fungicide cost including application $37/ha, potential wheat yield 4 t/ha, yield loss associated with WPM in more susceptible areas 17%.

Paddock area with high WPM	Paddock area with low WPM	Paddock average yield with no additional fungicide (t/ha)	Farm gate gross income without additional fungicide ($/ha)	Farm gate gross income with additional fungicide ($/ha)	Partial gross margin (PGM) ($/ha)
0%	100%	4.00	1000	963	*-37*
10%	90%	3.93	983	963	*-20*
20%	80%	3.86	966	963	*-3*
30%	70%	3.80	949	963	14
40%	60%	3.73	932	963	31

Conclusion

Shifts in fungicide sensitivity and resistance to both DMI group 3 and QoI group 11 fungicides have been detected in WPM. Despite this, fungicides from these groups are currently still providing reasonable control. Selection of varieties with improved WPM resistance can reduce disease pressure more than any currently registered fungicide and negates the need for fungicide use for this pathogen.

Acknowledgements

The research undertaken as part of this project is made possible by the significant contributions of growers through both trial cooperation and the support of SAGIT, the authors would like to thank them for their continued support. The input during this project from Michael Brougham, Hugh Wallwork, Tara Garrard, Kejal Dodhia and Nick Poole is gratefully acknowledged.

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[A] Varieties displaying this symbol beside them are protected under the Plant Breeders Rights Act 1994

Developing knowledge and tools to better manage herbicide residues in soil

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Key messages

- Herbicide persistence and crop toxicity is affected by soil type, rainfall, temperature, crop type and their interaction.
- Herbicide toxicity rankings (and thresholds) have been established for clopyralid and imazapyr residues in sand and two different soil types, for eight crop species.
- These thresholds can help diagnose the cause for crop injury if establishment is poor.
- Additional work will help to refine soil testing protocols and their interpretation for herbicide residues.

Background

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

There are currently very few tools to assist growers to determine the level of herbicide residues present and if they negatively affect soil and crop performance. This project is developing knowledge and tools to better understand the factors regulating herbicide persistence and bioavailability. This will give farmers an increased confidence in crop choice, timing of sowing and herbicide management to ensure soil and crop performance are not limited by herbicide residues.

Toxicity thresholds

Several commercial service providers can measure herbicide residues in soil, but there are very few publicly available phytotoxicity thresholds to help interpret what the soil test results actually mean. We have now established phytotoxicity thresholds (i.e. the concentration of herbicide residue in soil that causes a 20% shoot biomass reduction) for 60 herbicide-soil-crop combinations. This includes thresholds for clopyralid, imazapyr, pyroxasulfone and diuron. Examples are given in Figure 1 and Table 1.

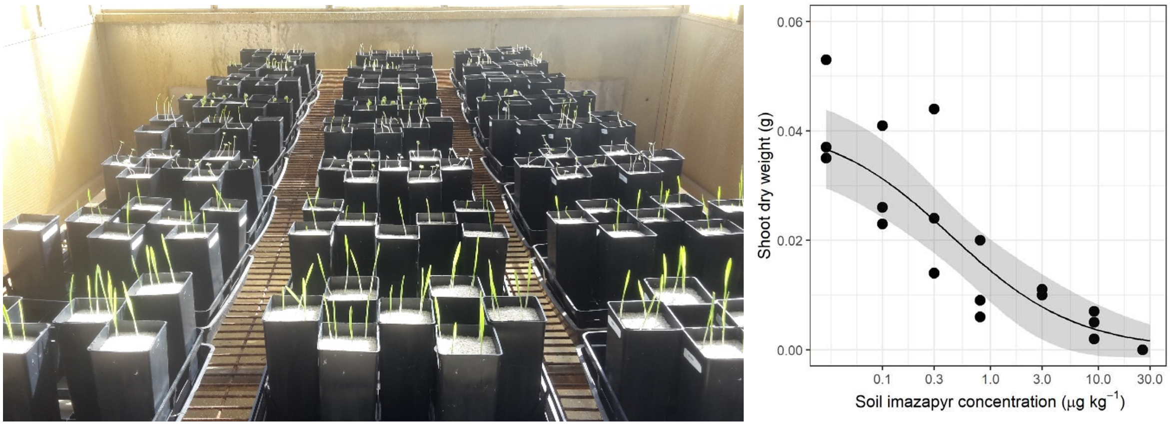

Figure 1 Randomised block design for herbicide toxicity bioassay against 8 different crop species in sand (left); and an example dose-response curve for imazapyr toxicity to canola growing in sand.

Table 1 Preliminary phytotoxicity dose thresholds (µg/kg) for 20% shoot biomass reduction (ED_{20}) for different crop species growing in sand or soil spiked with clopyralid or imazapyr. Note that these data have not yet been finalized and may be slightly different depending on best model fits.

Species	**Clopyralid**		**Imazapyr**	
	Sand	**Minnipa Soil**	**Sand**	**Minnipa Soil**
Lupin	8.8	54	19	>30
Wheat	>100	>100	1.0	1.3
Canola	>100	>100	0.1	3.9

Case Study: Damage to lupins upper EP
Poor establishment of lupins was observed in upper EP paddock (see details in Table 2).

Table 2 Details of paddock operations where poor lupin establishment was observed.

Operation	**Date**	**Details**
Herbicide application (Barley crop)	25 June 2019	Lontrel (clopyralid) at 100 ml/ha
Sowing	8 May 2020	Mandelup lupin
Soil sampling	24 June 2020	Soil and plant samples taken and sent to NSW DPI Wollongbar for herbicide analysis

Soil and plant sample taken approximately 6 weeks after sowing were analysed for clopyralid residues. Clopyralid residues in soil (6 reps – 3 from 'healthy' lupin area; 3 from 'poor' lupin area) varied from 0-8 ng/g, with an average of 3.5 ng/g. There was no significant difference in *average* clopyralid concentrations between the healthy and poor area. These values are below the threshold for 20% seedling shoot biomass reduction in sand (8.8 ng/g). However, because the samples were taken 6 weeks after sowing, it is likely that some additional clopyralid breakdown/dissipation from soil would have occurred.

To help determine whether clopyralid residues were the cause for poor establishment, lupin leaf tissue was also analysed. The average clopyralid concentration was 0.3 mg/kg in 'healthy' plants and 0.4 mg/kg in 'poor' plants. Although this difference is minor, previous research in other sensitive plant species (tomato, eggplant) has shown that a concentration of 25 ng/g of clopyralid in soil resulted in leaf tissue concentrations of 0.2-0.5 mg/kg and significant damage (Namiki et al., 2019). Thus, although we only measured an average of 3.5 ng/g clopyralid in soil at

6 weeks after sowing, it is possible that clopyralid concentrations at sowing were up to 25 ng/g. At this level, significant damage to lupins in likely in sandy soils.

Where to from here?

Growers and consultants have expressed interest in being able to send soil samples for herbicide residue analysis to gauge whether a crop is likely to suffer herbicide damage. Feedback also suggests that post-injury diagnostic testing of plant tissue to determine the cause of unknown crop damage would also be valuable to prevent future occurrences or help decision making on whether or not to replant crops. There is also still a knowledge gap around the potential for clopyralid herbicide to be released from crop stubble and the extent at which this can cause damage.

A key consideration for toxicity thresholds is that herbicide bioavailability, and therefore the toxicity threshold based on total extractable herbicide, will vary from soil to soil depending on how quickly and strongly herbicides bind to the soil. Work in this project will continue to refine toxicity thresholds for different soil types so that more accurate thresholds can be predicted for the actual soil where herbicide residue damage is suspected. Additional work is testing whether herbicide persistence can be accurately predicted using site-specific details, including the time and rate of herbicide application, key soil properties (e.g. pH, organic matter and clay content) and weather conditions. This will help give a preliminary recommendation on whether a soil test is necessary, and also help to better understand how different herbicides behave under different weather conditions.

Acknowledgements

This work has been supported by the Cooperative Research Centre for High Performance Soils whose activities are funded by the Australian Government's Cooperative Research Centre Program, as part of the 'Improved management of herbicide residues in soil' project (4.2.001). More information https://soilcrc.com.au/current-projects/#project_4_2_001. Thanks to Scott Petty, Kelvin Spann, Ian Richter, Steve Jeffs and Katrina Brands for technical support.

Exploiting the indeterminate nature of pulses

Amy Gutsche[1], Penny Roberts[2,3], Dylan Bruce[2]
[1]SARDI Agronomy, Port Lincoln, [2]SARDI Agronomy, Clare, [3]Affiliate of The University of Adelaide

Key messages

- Preliminary data shows faba bean are consistently a better option for early sowing opportunities in seasons where an early break occurs compared to wheat and lentil.
- PBA Marne was consistently the highest yielding bean variety when sown early.
- Lentil has a more variable response to time of sowing.

Why do the trial?

To look at exploiting the indeterminate nature of pulses, trials were established at Wudinna and Tooligie on the Eyre Peninsula in 2020. The aim of the trials was to identify opportunities to sow a pulse crop prior to optimum cereal sowing windows in seasons where an early break occurs. This would provide growers the chance to have each crop species in the ground at a time that would achieve an optimum flowering window, working to close the yield gap.

How was it done?

To look at the response of pulses to early sowing, four replicated trials were conducted across different environments throughout South Australia in 2020. Trials were not localised and covered different rainfall zones and soil types at Wudinna, Tooligie, Warnertown and Farrell Flat. The Wudinna trial examined early sowing in three varieties of lentil and faba bean on pH of 8.52 (H_2O). This was replicated at Tooligie with three varieties of wheat included to look at comparisons between pulse and cereal responses to early sowing on pH 8.33 (H_2O). The selected varieties represented varying phenological characteristics (Table 1).

Table 1 Phenological characteristics of each crop variety compared with the phenology observed at Tooligie and Wudinna, 2020.

Crop Type and Variety		Phenology Characteristics		Observed Phenology Dates			
				Tooligie		Wudinna	
		Flowering	Maturity	TOS1 50% Flowering	TOS2 50% Flowering	TOS1 50% Flowering	TOS2 50% Flowering
Faba Bean	PBA Marneⓓ	Early	Early-Mid	18-Jun	27-Jul	25-Jun	4-Aug
	PBA Bendocⓓ	Mid	Early-Mid	25-Jun	30-Jul	17-Jul	4-Aug
	PBA Samiraⓓ	Mid	Early-Mid	2-Jul	3-Aug	17-Jul	4-Aug
Lentil	PBA Jumbo2ⓓ	Mid	Mid	22-Jun	5-Aug	17-Jun	11-Aug
	PBA Boltⓓ	Early-Mid	Early-Mid	22-Jun	5-Aug	17-Jun	11-Aug
	PBA Highland XTⓓ	Early	Early-Mid	22-Jun	5-Aug	17-Jun	11-Aug
Wheat (Tooligie only)	Longreach Trojanⓓ		Mid-Slow	5-Aug	14-Sep		
	Scepterⓓ		Mid	15-Jul	14-Sep		
	Illaboⓓ		Mid quick + Winter	14-Sep	30-Sep		

All sites were sown with an experimental plot seeder, with Tooligie sown at 25 cm spacing and Wudinna sown at 27 cm spacing. The first time of sowing for Wudinna was 31 March and Tooligie 2 April (Table 2). To simulate an early break, Wudinna was irrigated with the equivalent of 14 mm rainfall on all plots and received 7 mm of natural rainfall three days post-sowing. Tooligie received 10 mm of irrigation on all plots and 8 mm of natural rainfall was recorded two days post-sowing. The second time of sowing at Tooligie and Wudinna was 6 and 7 May, respectively. The Tooligie site received 8 mm rainfall within the following two days and the Wudinna site received 2 mm.

Table 2 Trial details for early sown pulses at Wudinna and Tooligie, Eyre Peninsula, 2020.

		TOS 1	TOS 2
Wudinna	**Sowing Date**	31 March	7 May
	Harvest Date	6 November	6 November
Tooligie	**Sowing Date**	2 April	6 May
	Harvest Date	28 October	24 November

Measurements taken throughout the trial included key phenological stages, biomass yield, grain yield, harvest index and grain quality. Key phenology dates were recorded at emergence, canopy closure, flowering, pod development and maturity to identify the phenological progression and timing of each individual variety. Biomass yields were recorded at 50% flowering to distinguish any benefits from early sowing for early plant growth. These trials were analysed using Genstat 20th Edition using a mixed model (REML) analysis.

What happened?

The first three months of 2020 experienced drier than average conditions at both Tooligie and Wudinna. Good early rains occurred in April at both sites and then below average rainfall was recorded throughout the winter months leading up to a wet spring. The growing season rainfall (April – October) totalled 195 mm at Wudinna and 255 mm at Tooligie. A below zero frost event occurred on 23 July at Tooligie, coinciding with the flowering windows of the early sown pulses and wheat (cv. Scepter) (Table 1).

The earlier sown plots at Tooligie experienced weed control issues due to simulated rainfall and tillage. In lentil and wheat, early sowing showed a significant decrease in biomass yield which may have been a response to increased weed density (Figure 1 & 2). In an ideal year, with average rainfall during May and winter, larger biomass would be expected. The large biomass associated with these crop types is known to cause increased incidence of disease, pest problems, lodging and necking. It is expected that earlier sown spring wheat will experience accelerated phenology and will not tiller as much as wheat sown in optimal May timing, resulting in reduced biomass and grain yield. Early sown faba bean recorded increased biomass yield at both sites (Figure 2).

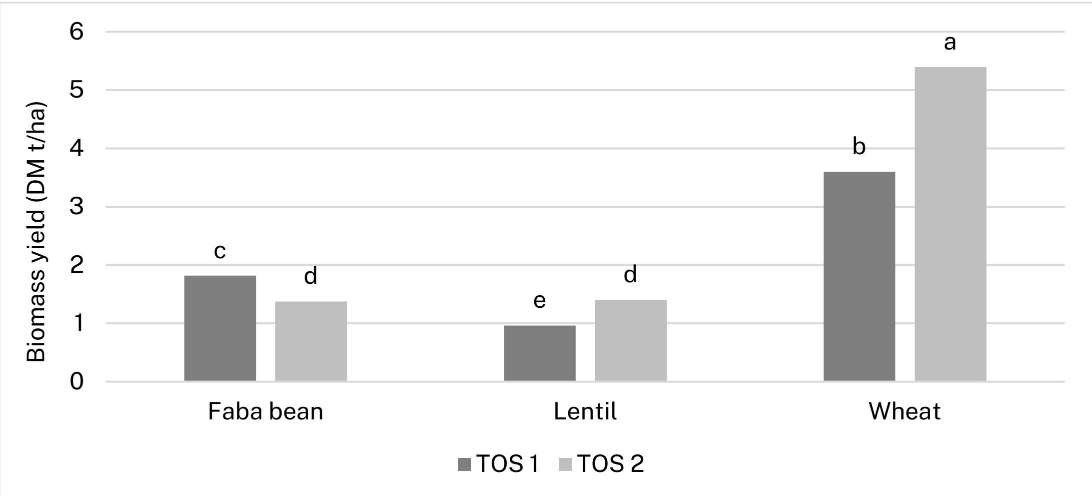

Figure 1 Biomass yield (t/ha) response to TOS in faba bean, lentil and wheat at Tooligie, Eyre Peninsula, 2020. Bars labelled with the same letters are not significantly different.

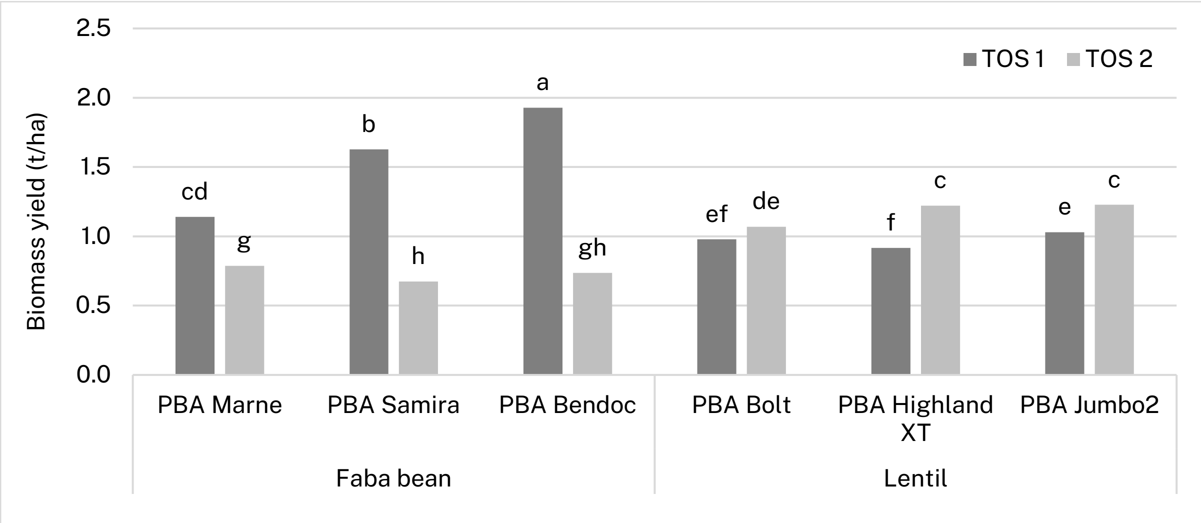

Figure 2 Biomass yield (t/ha) response to TOS in faba bean and lentil at Wudinna, Eyre Peninsula, 2020. Bars labelled with the same letters are not significantly different.

Faba bean displayed positive results as an early sowing option at both Tooligie and Wudinna in 2020 (Figure 3 & 4). PBA Bendoc and PBA Marne showed a significant increase in grain yield when sown in early April, compared to May sowing time. To a lesser extent, PBA Samira also showed a significant increase in grain yield compared to PBA Bendoc and PBA Marne when sown early. PBA Marne recorded the highest grain yield in faba bean, particularly when sown early.

No consistent trend in grain yield was recorded in early sown lentils at Wudinna or Tooligie (Figure 3 & 4). At the Warnertown site in the Mid-North, there was a positive response recorded in early sown lentil (data not shown). This preliminary data suggests that further research is required for early April sowing in lentil.

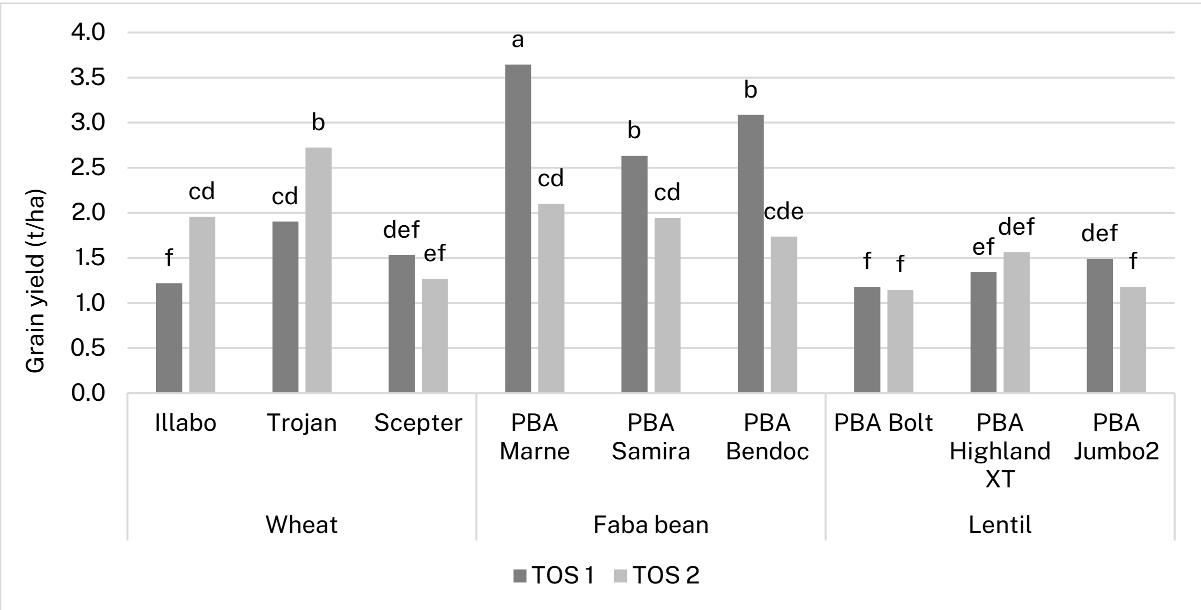

Figure 3 Grain yield (t/ha) response to TOS in faba bean, lentil and wheat at Tooligie, Eyre Peninsula, 2020. Bars labelled with the same letters are not significantly different.

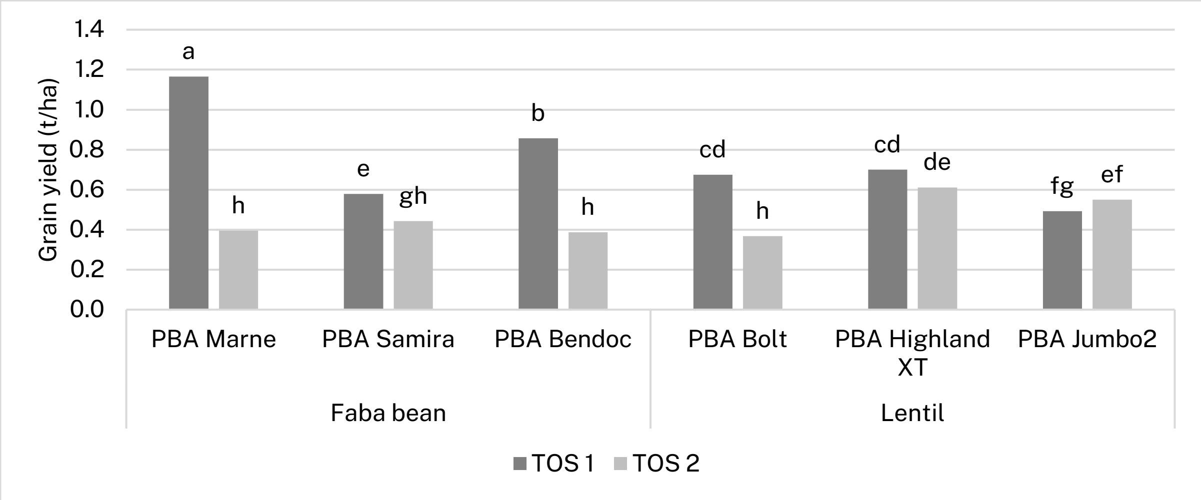

Figure 4 Grain yield (t/ha) response to TOS in faba bean and lentil at Wudinna, Eyre Peninsula, 2020. Bars labelled with the same letters are not significantly different.

What does this mean?

Under the conditions of this trial, faba bean recorded the greatest positive response to early sowing, with significant increases in biomass and grain yield in all varieties trialled. This suggests an opportunity to sow faba bean early in seasons where an early break occurs. Preliminary data suggests PBA Marne is best suited to early sowing in low to medium rainfall environments.

Although time of sowing in pulses has been researched by Roberts *et al.* (2019) previously, further seasons of data are required to draw accurate conclusions on the responses of pulse crops to early April sowing. A broader phenology range in lentil also needs to be investigated to explain the variable response to time of sowing observed in these trials.

References

Penny Roberts, Christine Walela, Larn McMurray and Helena Oakey (2021), (Paper in preparation).

Acknowledgements

The research undertaken as part of this project was made possible by the significant contributions of growers, through both trial co-operation and the support of the GRDC (DAV00150), and the authors would like to thank them for their continued support. The continued assistance in trial management from SARDI Agronomy groups at Port Lincoln, Minnipa and Clare is gratefully acknowledged and appreciated.

Mixed species cropping, intercropping: where, how and why?

Penny Roberts[1,3] and Amy Gutsche[2]
[1]SARDI, Clare, [2]SARDI, Port Lincoln, [3]Affiliate of The University of Adelaide

Key messages
In 2020, intercropping was more productive than monoculture cropping at the medium rainfall site of Tooligie Hill. The results from this one-year trial are consistent with the outcomes of previous intercropping work in South Australia. Adoption of an intercropping system needs careful planning including the species mix, variety choice, and the logistics of seeding, weed control and harvest. This planning can lead to productivity gains and ancillary benefits including soil health.

Why do the trial?
The aim of this work is to increase combined pulse-oilseed productivity and profitability in the medium rainfall zone Additionally, to increase the knowledge of mixed cropping systems and begin dialog around adapting from a monoculture system to mixed species systems.

There is a need for more robust break crop systems in the low and medium rainfall zones where traditional break crop systems are not yield stable, and risk leaving paddocks susceptible to erosion. Intercropping is a system that has been shown to provide production and sustainability benefits in low rainfall cropping systems. Nine field trials conducted across South Australia from 2016 to 2020 achieved productivity gains of 30 to 80% compared to monoculture, with combinations of canola and either lentil or vetch. Early season ground cover was improved in some intercrop combinations over traditional monoculture systems (Roberts et al. 2019 and Roberts, unpublished). This work demonstrated that intercropping has the potential to increase both productivity and could lead to ancillary benefits such as increasing groundcover on erosion prone soils.

How was it done?

Treatments	Whole plot Sole faba bean Sole canola Sole lentil (PBA Hallmark XT) Sole chickpea (CBA Captain) Lentil + faba bean mixed row Lentil + canola mixed row Lentil + faba bean skip row Lentil + canola skip row Chickpea + faba bean mixed row Chickpea + canola mixed row Chickpea + canola skip row Chickpea + faba bean skip row Sub plot Short variety (ATR Bonito/PBA Marne) Tall variety (Nuseed Diamond/PBA Samira) Imi tolerant variety (Pioneer43Y92/PBA Bendoc)

What happened?
To determine the relative productivity benefit of intercropping, compared to growing crops as monocultures, land equivalent ratio (LER) values were calculated. The LER is expressed as:

LER = LA + LB = YA/SA + YB/SB

Where LA and LB are the LER for the individual crop yield components, YA and YB are the individual crop yields in the intercrop combinations, and SA and SB are the yields of the monocultures (adapted from Mead and Willey, 1980). An LER value of 1.0 means the productivity of the intercrop components was equivalent to the monocultures. An LER value of <1.0 means the productivity of the intercrop components are less than the monocultures, while an LER value >1.0 means the intercrop components are more productive than the monocultures, which is referred to as 'over-yielding'.

Consistent with the results from previous work the intercropping treatments at Tooligie Hill over-yielded, meaning it was more productive to grow the two crops as a mix compared to growing them as separate monoculture crops (Figure 1). The largest productivity benefit was achieved when growing the pulse crop with a short stature and low yielding canola variety for this environment. Canola-pulse combinations generally performed better than pulse-pulse combinations, however, lentil-faba bean appeared promising from this first year trial. With the exception of the chickpea-faba bean combination, all other intercrop combinations could be harvested, and the two grain types separated with ease.

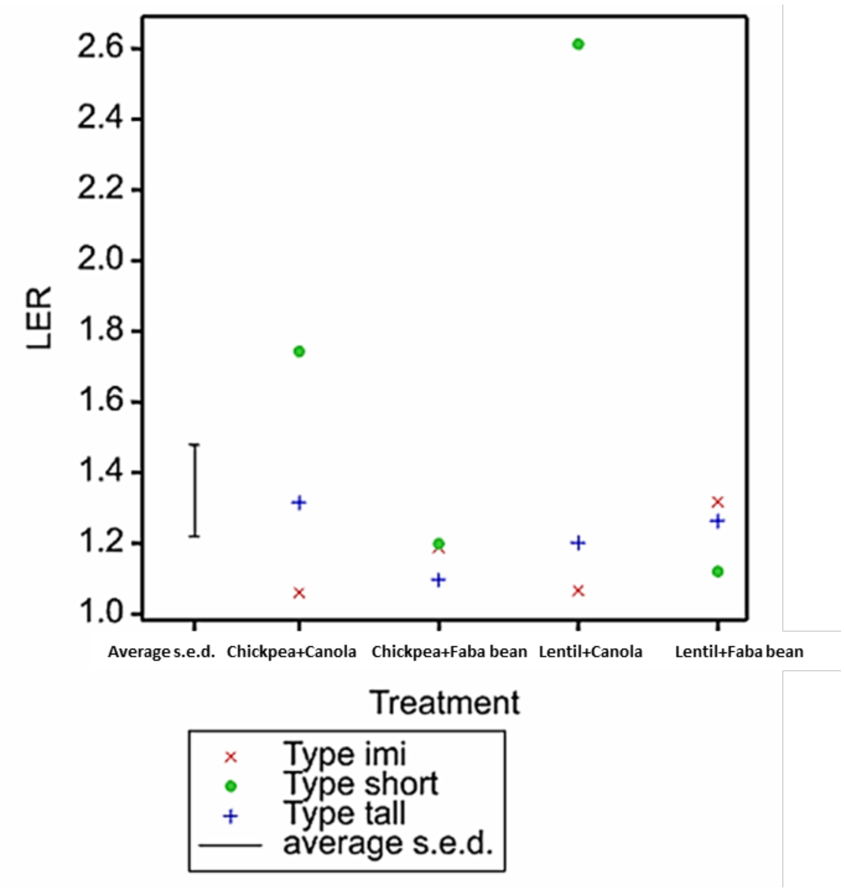

Figure 1 Intercropping demonstrates grain yield benefits for the intercrop combinations with land equivalent ratio (LER) values of greater than one at Tooligie Hill, 2020.

What does this mean?
This work demonstrated the suitability of intercropping in the medium rainfall zone of the Eyre Peninsula for some combinations. Whilst the data represents only one season, results are consistent with previous intercropping work undertaken in the low to medium rainfall zones of South Australia and it is reasonable to conclude that some intercropping combinations can be

more productive than monoculture cropping in this environment. All intercrop combinations in these trials over-yielded, meaning they were more productive than growing the components as monoculture crops. The best intercropping combinations measured by productivity gain (LER) in this trial were canola-pulse and lentil-faba bean. This supports previous work demonstrating vetch-canola and vetch-lentil as the most promising combinations for the lower rainfall environments.

The additional complexity of intercropping systems includes logistical challenges during sowing, harvest, handling and grain storage. Some types of intercropping lend themselves to a more seamless integration into current farming practices than others. However, with careful planning including the species mix, variety choice, and the logistics of seeding, weed control and harvest, these systems can be successfully adopted at a broadacre scale as demonstrated by grower adoption of intercropping in Australia. To support an increase in adoption of intercropping systems there is a need to support growers through a combination of peer-to-peer learning and further focused research and validation trials.

Acknowledgements
The research undertaken as part of the GRDC funded research project DAV00150 and the authors would like to thank them for their support. The authors would like to acknowledge the significant contributions of growers through trial cooperation and the support of the research team at Minnipa Agricultural Centre and David Holmes of SARDI Port Lincoln in making the trial possible.

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Resilient EP project

ResilientEP
For a profitable farming future

Aim
The existing Eyre Peninsula soil moisture probes and other technologies will be used to assist farmers make efficient use of limited soil water. A Regional Innovators group of farmers and advisers will engage researchers and link with the region's farmers to develop techniques to integrate information generated from the probes as well as satellite imagery, climate and yield models, in a user-friendly format to help make more profitable decisions.

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This project is funded by the National Landcare Program 2,
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