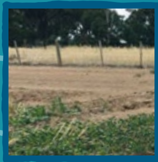
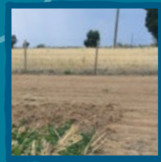
RiverinePlains

Research for the Riverine Plains 2021

A selection of research relevant to agriculture in the Riverine Plains

Farmers inspiring farmers





Research for the
Riverine Plains 2021

Farmers promoting excellence in farming systems by providing quality information, leading research and the sharing of ideas for the environmental, economic and agricultural benefit of the Riverine Plains region.

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Introduction

Research at work

Relevant research

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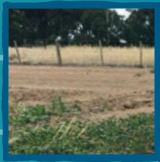

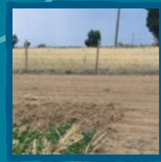

2021 Riverine Plains Board, support and staff

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Vice-chair	Fiona Marshall	Rennie	0427 324 123
Treasurer	Murray Scholz	Culcairn	0428 238 398
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Communications Officer	Michelle Pardy	Mulwala	(03) 5744 1713
Casual Field Assistant	Sue Campbell	Mulwala	(03) 5744 1713

Units of measurement

Riverine Plains Inc recognises that while the research sector has moved toward metric representation, many growers remain comfortable with imperial measurements.

Following is a quick conversion table for handy reference when reading the following trial result articles.

TABLE 1 Row spacing conversions

Inches	Centimetres
7.2	18.0
9.0	22.5
9.5	24.0
12.0	30.0
14.4	36.0
15.0	37.5

Standard units of measurement

Through this publication, commonly-used units of measurement have been abbreviated for ease of reading they include:

centimetres — cm

gigahertz — GHz

hectares — ha

hectolitres — hL

kilograms — kg

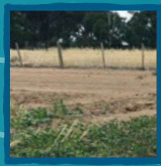
kilojoules — kJ

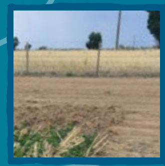
litres — L

metres — m

millimetres — mm

tonnes — t





Cereal growth stages

Why are they important to cereal growers?

A growth stage key provides a common reference for describing crop development, so we can implement agronomic decisions based on a common understanding of which stage the crop has reached.

Zadoks cereal growth stage

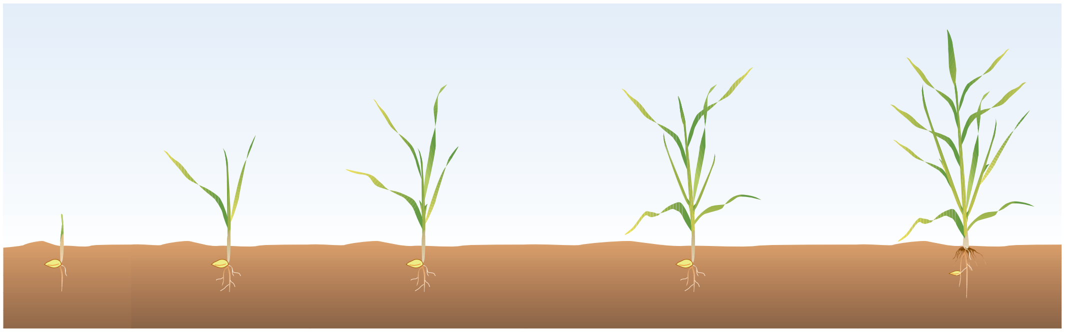
The most commonly used growth stage key for cereals is the:

- Zadoks decimal code, which splits the development of a cereal plant into 10 distinct phases of development and 100 individual growth stages.
- It allows the plant to be accurately described at every stage in its life cycle by a precise numbered growth stage (denoted with the prefix GS or Z e.g. GS39 or Z39)

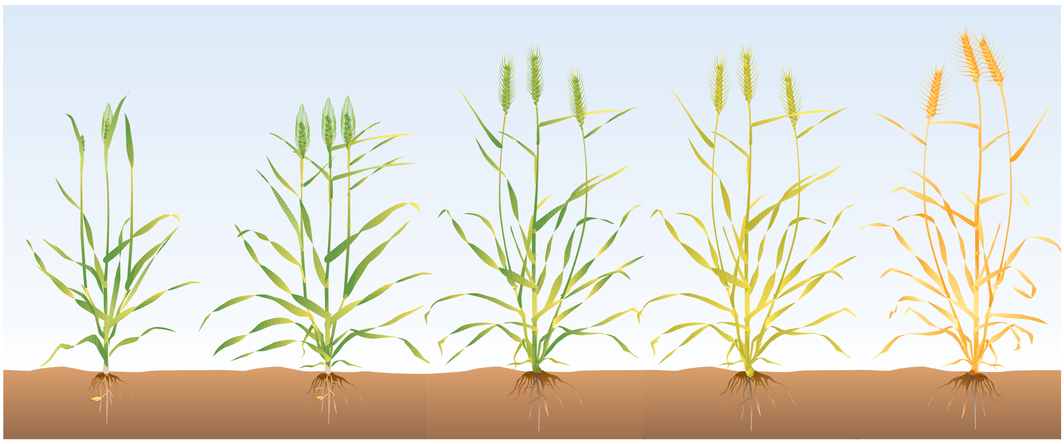
Within each of the 10 development phases there are 10 individual growth stages, for example, in the seedling stage:

- GS11 describes the first fully unfolded leaf
- GS12 describes two fully unfolded leaves
- GS13 describes three fully unfolded leaves
- GS19 describes nine or more fully unfolded leaves on the main stem.

This information has been reproduced with the permission of the Grains Research and Development Corporation (GRDC) and is taken from *Cereal Growth Stages: The link to crop management*, by Nick Poole.



Zadoks growth stage	GS00–09	GS10–19	GS20–29	GS30–39	GS40–49
Development phase	Germination	Seedling growth	Tillering	Stem elongation	Booting



Zadoks growth stage	GS 50–59	GS60–69	GS70–79	GS80–89	GS90–99
Development phase	Ear emergence	Flowering	Milk development (grain fill period)	Dough development (grain fill period)	Ripening

Preface

Trials versus demonstrations — what the results mean

Research on the Riverine Plains takes different shapes and forms, each of which has the potential to make an important contribution to increasing the understanding about agricultural systems in the area. However, it is important to keep in mind results from the different forms of research need to be analysed and interpreted in different ways.

It is important to understand the difference between trials and demonstrations in the use of results for benefit on farms. A replicated trial means that each treatment is repeated a number of times and an averaged result is presented. The replication reduces outside influences producing a more accurate result. For example, trying two new wheat varieties in a paddock with varying soil types and getting an accurate comparison can be obtained by trying a plot of each variety, say four times. Calculation of the average yield (sum of four plots then divided by four) of each variety accounts for variations in soil type.

Statistical tests, for example, analysis of variance (ANOVA) and, least significant difference (LSD), are used to measure the difference between the averages. A statistically significant difference is one in which we can be confident that the differences observed are real and not a result of chance. The statistical difference is measured at the 5% level of probability, represented as '$P<0.05$'.

Table 1 shows an LSD of 0.5t/ha. Only Variety 3 shows a difference of greater than 0.5t/ha, compared with the other varieties. Therefore Variety 3 is the only treatment that is significantly different.

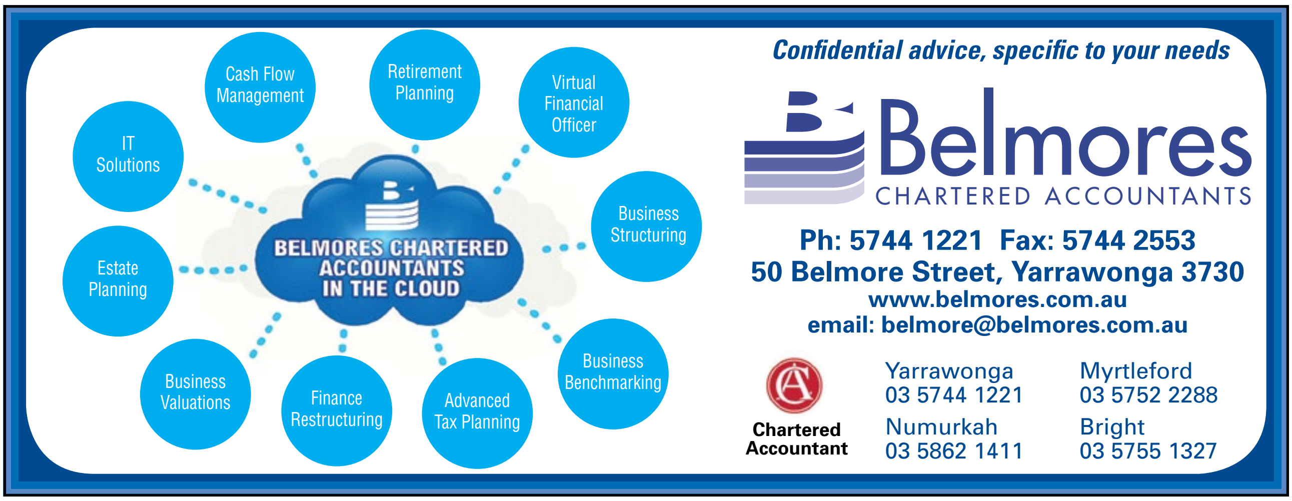
TABLE 1 Example of a replicated trial with four treatments

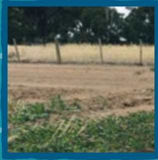
Treatment		Average yield (t/ha)
1	Variety 1	4.2
2	Variety 2	4.4
3	Variety 3	3.1
4	Control	4.3
	LSD ($P<0.05$)	0.5

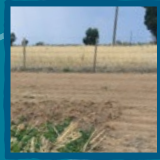
A demonstration is a comparison of a number of treatments, which are not replicated. For example, splitting a paddock in half and trying two new wheat varieties or comparing a number of different fertilisers across a paddock. Because a demonstration is not replicated results cannot then be statistically validated. For example, it may be that one variety was favoured by being sown on the better half of the paddock. We can talk about trends within a demonstration but cannot say that results are significant. Demonstrations play an important role as an extension of a replicated trial that can be tried in a simple format across a large range of areas and climates.

Demonstrations are accurate for the paddock chosen under the seasonal conditions incurred. However, take care before applying the results elsewhere.

Trials and demonstrations play a different role in the application of new technology. Information from replicated trials is not always directly applicable but may lead to further understanding and targeted research. Demonstrations are usually the last step before the application of technology on farm.







Chairman's Report

Welcome to the 2021 edition of Research for the Riverine Plains.

The year in review 2020–21

The year 2020 was an absolute dichotomy. For many members it was one of the best production years in memory, whilst for the general population it was one of the most difficult and challenging years.

With COVID-related lockdowns and border restrictions, businesses along the border found the challenges particularly difficult. Riverine Plains was no exception, having to deal with the vagaries of snap state lockdowns, as well as having to cancel multiple face-to-face extension activities or change them to an online format. These challenges were all met with a great deal of pragmatism and professionalism, and my gratitude to our staff, and particularly Fiona Hart, is absolute.

Perhaps our biggest achievement during 2020 was the successful restructure of the group. The restructure saw the creation of the CEO position and some significant changes to the constitution, which also saw a much smaller and more traditional board structure replace the larger committee.

The appointment of Catherine Marriott to the CEO role was a significant step and we officially welcome Catherine to the organisation. Catherine brings with her a wealth of experience in member-based organisations and a reputation for making positive change and creating opportunities that are going to be valuable for Riverine Plains moving forward.

Extension Report

Despite the challenges COVID threw at us, Riverine Plains was able to deliver over 30 separate events during 2020 in a mixture of online and in-person formats.

Carbon Information Meetings — On 30 January and 4 February, carbon information workshops were held at Mulwala, Rand and Murchison for Australian Cool Farm Initiative participants. Each workshop was attended by 5–6 farmers, with in-depth discussions around the farming practices influencing the accumulation of carbon in soils, as well as soil-health related issues.

Sykesy's Buraja Meeting — On 6 February, over 80 people attended Sykesy's Buraja Meeting. Chris Minehan (Rural Management Strategies), facilitated a 2019 season debrief and Michael Straight (FAR Australia), spoke about the 2019 Riverine Plains wheat germplasm trials at the Riverine Research Centre, Yarrawonga. Rosie Dye (IK Caldwell) discussed canola performance, and also participated in a barley discussion with Rob Herrod (Elders) and David Eksteen (David Eksteen Agricultural Consulting). A grain market update was also provided by Ben McCluskey (Market Check).

Pulse Check Meeting — A pre-sowing meeting of the GRDC Dookie Pulse Check group was held at St James on Thursday 13 February, attended by 14 people. A discussion took place about 2019 on-farm pulse performance, while Jason Brand (Agriculture Victoria) also discussed best bets from the Southern Pulse Agronomy Trial and profitability of pulses in crop rotations. Richard Saunders (Rural Directions), provided an economic and risk analysis that showed pulses could improve the profitability of rotations in the region.

Excel Microsoft Masterclass series — A three-part series of excel training workshops, facilitated by Steve Young (EXCELutions), was held during March, covering a variety of basic-intermediate Excel functions. The first workshop was held on 16 March at the Riverine Plains office in Mulwala, with 8 people attending. Due to COVID-19 restrictions, the remaining workshops were moved online (23 and 30 March, 2020). *This workshop series was funded by the Australian Government's Drought Communities Program, in conjunction with Federation Council.*

Time Management — A time management and productivity workshop was held on 11 March, at Corowa, with 16 people attending. The workshop was facilitated by Rebecca Fing (House Paddock Training and Consulting) and covered planning and goal setting, time management, optimising productivity and improving administrative efficiency. *The workshop was funded by the Australian Government's Drought Communities Program, in conjunction with Federation Council.*

Effective Communication — An Effective Communication workshop was held on 12 March, at Corowa, attended by ten people. The workshop was facilitated by Rebecca Fing and covered understanding different people, effective communication, conflict management and negotiation, as well as difficult conversations. *The workshop was funded by the Australian Government's Drought Communities Program, in conjunction with Federation Council.*

Farmers inspiring farmers

Compliance Confidence for Employment Matters — An online workplace relations workshop with Gracia Kusuma (NSW Farmers) was held on 31 March, with 10 people attending. Participants learnt about the differences between contractors and employees, the Pastoral Award, salary, record keeping and tenancy issues. *This workshop was funded by the Australian Government's Drought Communities Program, in conjunction with Federation Council.*

John Hanrahan Scholarship Recipients Announced — During March, Riverine Plains and the Hanrahan family announced Sophie Hanna from Walwa, Victoria and Lachlan Quibell from Marungi, Victoria, as the 2020 John Hanrahan Scholarship recipients.

Irrigation Discussion Group Virtual Farm Tour — The GRDC Riverine Plains Irrigation Discussion Group field walk on 27 March was cancelled due to COVID-19, with a 'virtual paddock walk' document produced and distributed to 32 discussion group members in its place. The document summarised maize crop agronomy, irrigation systems and pumping costs for two farms and was supplemented with information on pumping costs (Denis Watson, DEDJTR), double cropping (Tim Anderson, Advanced Ag) and local maize fungicide research (Michael Straight, FAR Australia). *The Riverine Plains Irrigation Discussion Group is part of a GRDC investment, led by Irrigated Cropping Council.*

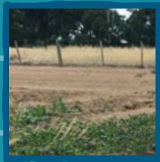
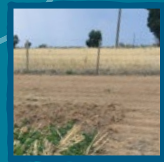
NSW Young Farmers Business Workshops — Eight young farmers attended two business workshops hosted by Riverine Plains on 19 (in-person) and 26 March (online). The workshops aimed to improve the access of young farmers to business information and focussed on financial literacy and farm business principles. Anna Dye (Corowa), worked with Jan Barned (Financial Management Training) and Tim Haines (Farmanco) to ensure workshops covered financial topics, practical goal setting, budgeting for a farm purchase, paddock record keeping and cashflow spreadsheeting tools. *This project was supported by the NSW Department of Primary Industries through the Young Farmer Business Program*.

Irrigation Discussion Group Field Day — An Irrigation Discussion Group paddock walk was held at Yarrawonga and Bundalong on 17 June, attended by around 20 people. Evan Ryan spoke on his family's Yarrawonga farming operation and the day also included a visit to Bundalong farmer, Rod Vodusek. Glenn Menhenett (Upton Engineering) discussed pivot maintenance and Tim Anderson (Advanced Ag) spoke on preparing paddocks for irrigation, while Glenn Melton (Xirasol) spoke about Dual Axis Tracking solar panels. *The Riverine Plains Irrigation Discussion Group is part of a GRDC investment, led by Irrigated Cropping Council*.

Top: The NSW Young Farmers Business Skills Program tour included visits to some of the region's leading farmers.
Above: Sykesy's Buraja Meeting was held during February.

NSW Young Farmers Business Skills Program tour — On 31 July, Riverine Plains Inc hosted on-farm visits as part of the Young Farmers Business Skills series. Six young farmers attended the day, which was designed to show how local agricultural businesses have implemented business plans and strategies, as well as their drivers of profitability and risk. Participants heard from Ian and Tim Trevethan, Owen Smith, Susie Cay and Tim Hicks. *This project was supported by the NSW Department of Primary Industries through the Young Farmer Business Program*.

In-Season Update — The Riverine Plains In-Season Update was held online on 11 August, with approximately 30 people attending. Dale Grey (Agriculture Victoria) spoke on climate drivers and the outlook for spring, while Bruce Larcombe (Larcombe Agronomy) spoke on key diseases



and fungicide strategies for local crops. Lee Menhenett (Incitec Pivot Fertilisers) spoke on nitrogen fertiliser strategies for optimal yield and protein in cereals and canola. A farmer round-up with John Bruce (Barooga), Dave Gooden (Lockhart), Jamie Cummins (Burramine) and Daniel Moll (Gerogery) provided an update on local conditions.

Dookie/Murchison Pulse Check Group — On 10 August, 17 farmers and agronomists attended an online meeting of the GRDC Dookie/Murchison East Pulse Check Group. Tim Anderson (Advanced Ag), Andrew James (Dodgshun Medlin) and Scott Bartlett, (Agpro Consulting) provided agronomic updates on sowing, fungicide and herbicide strategies as well as varietal options.

Paperless Office Workshops — Two online workshops were held on 17 and 24 September to help farming and regional businesses transition to a paperless office environment. The workshops were facilitated by Bernie McKenzie and Ben Clurey (Belmores Chartered Accountants) and attended by around 17 people. Various cloud storage and accounting options were discussed, with tips on working more effectively in the online environment and managing cybersecurity issues. *These workshops were funded by the Australian Government's Drought Communities Program, in conjunction with Federation Council*.

Burramine Cover & Intercropping Virtual Field Day — On 8 October, Riverine Plains delivered a virtual cover and intercropping field day, with around 30 people attending. Dr Cassandra Schefe (AgriSci) introduced the trial which is investigating the effect of increasing species diversity using winter or summer cover crops. Professor Terry Rose (Charles Sturt University) spoke on key results from 2019 — 20, while Brendan Christy (Agriculture Victoria) spoke on the Intercropping to exploit rainfall for profit trial also sown at the site. Trial host, Nathan Lawless, spoke on the role of summer cropping and intercropping within their farming operation. *This field day was part of the Plant-based solutions to improve soil performance through rhizosphere modification project, supported by the Cooperative Research Centre for High Performance Soils (Soil CRC) and led by Southern Cross University. This project is also supported by the Goulburn Broken Catchment Management Authority's 'From the Ground Up' program through funding from the Australian Government's National Landcare Program. The Intercropping to exploit rainfall for profit trial at Burramine, is funded by the Victorian Grains Innovation Partnership with Agriculture Victoria and GRDC*.

Dookie/Murchison East Pulse Check Meeting — An online meeting of the Dookie/Murchison East GRDC Pulse Check and Pyramid Hill Pulse Check groups, was held on 1 September, with 13 Riverine Plains region attendees. Helen Burns (NSW DPI) spoke on soil acidity and how it is best measured. Ross Ballard (SARDI) spoke on acid tolerant rhizobia, while Kate Coffey (Riverine Plains) spoke on results from local nitrogen fixation demonstrations.

Rand Pulse Check Meeting — Kurt Lindback (NSW DPI) was a guest at the GRDC Northern Pulse check online meeting held on Wednesday 2 September, attended by 18 people. Kurt answered farmer questions on disease in pulses and covered disease pressure in pulse crops, fungicide applications, disease identification and conditions conducive to spread.

Hyper Yielding Crops project update — On 18 September, Riverine Plains held an online update for the GRDC Hyper Yielding Crops project, with 18 farmers and advisors attending. The project is designed to push yield boundaries in wheat, barley and canola in the higher rainfall zone and project leader Nick Poole (FAR Australia) gave an update on growing hyper yielding crops and using fungicides in wheat, while Jon Midwood (Techcrop) spoke about the Hyper Yielding Awards.

Transforming Regions Development Program (8 workshops) — This program, facilitated by Dennis Hoiberg (Lessons Learnt Consulting), was designed to assist farming and regional businesses achieve long-term profitability and sustainability. Two workshops were delivered in March before the program was paused in response to COVID-19, with the program resuming online during August — September. Modules included; "Emotional preparedness and passion in your business", "Positioning your business to thrive", "Shaping your future", "Managing Finances", "Managing relationships", "Managing change", "Benchmarking" and "Operational planning and management". *This program was funded by the Australian Government's Drought Communities Program, in conjunction with Federation Council.*

Irrigation Discussion Group meeting — An online meeting of the Riverine Plains Irrigated Discussion Group was held on 22 September, with 29 people attending. Rob Fisher (AgResults) discussed the economics of spring watering and outlined decision-making for a late-spring watering. Three summer irrigation scenarios were also tested using gross margins for corn, soybeans, grazing canola and irrigated lucerne. Local GRDC and FAR Australia maize agronomy trial results from 2019 — 20 were presented by Nick Poole (FAR Australia), while Andrew Cogswell (Lachlan Commodities) gave a maize market update for human consumption and feed grades. *The Riverine Plains Irrigation Discussion Group is part of a GRDC investment, led by Irrigated Cropping Council.*

The Irrigation Discussion Group met for a paddock walk at Yarrawonga during June.

2021 John Hanrahan and UNCLE TOBYS Scholarships — Applications for both the John Hanrahan and UNCLE TOBYS Scholarships closed on 30 September. Each scholarship provides a bursary of $5,000, as well as mentoring and networking opportunities, with the successful recipients to be announced during the first part of 2021.

Hyper Yielding Crop Walk — On 13 October, a GRDC Hyper Yielding Crop paddock walk was held at Rutherglen and Bungeet. The walk was led by Jon Midwood (Techcrop) and Kate Coffey (Riverine Plains) and attended by 12 people overall (numbers were severely limited by COVID restrictions). The day included visits to Andrew Russell's DS Bennett wheat crop at Rutherglen, Neil Fishers' DS Bennett wheat and Jock Binnie's Scepter wheat at Bungeet.

Rand Pulse Check Discussion Group Pre-harvest Meeting — An online meeting of the GRDC Northern Pulse Check Discussion Group was held on 14 October, attended by 16 people. The meeting addressed harvester set-up for pulses and other harvest-related issues, including windrowing faba beans and dessication and was attended by representatives from O'Connor's and Hutcheon and Pearce.

Dookie/Murchison East Pulse Check Discussion Group — A pre-harvest meeting of the GRDC Dookie/ Murchison East Pulse Check group was held online on Friday 16 October, attended by 20 people. Ben Morris (FAR Australia), discussed aspects of faba bean agronomy and lentil varieties, as well as acid tolerant rhizobia. John Fanning (Agriculture Victoria) also discussed new fungicide chemistry versus current practice in faba beans.

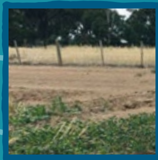
A GRDC Hyper Yielding Crops paddock walk was held at Bungeet during mid October.

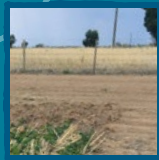
Research and extension project summary

During 2020, Riverine Plains concluded several research and extension projects. This included the Soil CRC projects, *Visualising Australasian Soils: A Soil CRC interoperable spatial knowledge system* and *Addressing barriers to adoption; Building farmer innovation capability.*

The trials component of the GRDC investment *Innovative approaches to managing subsoil acidity in the southern grain region*, funded by NSW Department of Primary Industries with financial support from GRDC, was also completed.

The successful *GRDC Pulse Check — local extension and communication for profitable pulse production in South East NSW* (Rand Pulse Check Discussion Group) project also officially concluded. During 2020, the group met twice for in-crop and pre-harvest discussions, with the project's final meeting held during March 2021.





A number of longer-term projects continued during 2020.

This included our delivery of the *Cool Soils Initiative* (formerly the *Australian Cool Farm Initiative*), funded by project partners Mars Petcare, Kellogg's Group, Manildra Group and Allied Pinnacle through the Sustainable Food Lab and Charles Sturt University (CSU), with additional funding through the Food Agility Cooperative Research Centre (CRC). This project aims to promote the long-term productivity and quality of cropping systems using practices that reduce on-farm greenhouse gas emissions and increase organic soil carbon. During 2020, 40 Riverine Plains region farmers were involved in soil testing, monitoring farm inputs and meetings, with the report presented on page 12.

The southern region *Riverine Plains Inc GRDC Pulse Check Discussion Group,* continued through the *Southern Pulse Extension Project*. The group, based in the Dookie and Murchison regions, met four times (online and in person) during 2020 to discuss pulse related research, production and marketing issues.

Demonstration trials for the GRDC investment *Increasing the effectiveness of nitrogen fixation in pulse crops through extension and communication of improved inoculation and crop management practices in the southern region* project were also sown at Murchison, with results reported on page 32 of this publication.

As part of the Co-Operative Research Centre for High Performing Soils (Soil CRC) suite of projects, trials were again established at Burramine as part of the five-year project *Plant based solutions to improve soil performance through rhizosphere modification*. The site was sown to a range of cover crop species, with the second-year winter crop phase results available on page 26.

Other Soil CRC projects that continued during 2020 included; *Improving the representation of soil productivity/ constraints in existing decision support systems and modelling platforms, Understanding adoptability of techniques and practices for improved soil management* and the *Mechanistic understanding of the mode to action of novel soil re-engineering methods for complex chemical and physical constraints*, as well as the *'Smart' soil sensors* project.

The GRDC Irrigation Discussion Group investment, *Facilitated Action Learning Groups to support profitable irrigated farming,* led by the Irrigated Cropping Council, also continued. Three meetings were held during 2020, with monitoring also continued for the irrigation focus paddock trial established in 2019 (looking at sub-soil manuring to improve soil structure and water holding capacity).

A *From the Ground Up* project, *Evaluating plant-based opportunities to increase soil carbon in cropping systems,* funded by the Australian Government's National Landcare Program and led by the Goulburn Broken Catchment Management Authority, also continued. The project involves a number of demonstrations established alongside the Soil CRC site in north east Victoria. A sub-project *Quantifying the carbon gains from mixed cropping systems*, and funded by the North East and Goulburn Broken Catchment Management Authorities, was completed during 2020, with the report on page 18.

Two new GRDC projects were established during 2020. This included *Machine learning to extract maximum value from soil and crop variability*, which involves providing soil and plant data from paddocks using precision agriculture to help further develop data management processes.

The GRDC *Hyper Yielding Crops* project, led by FAR Australia, also commenced in 2020, focussing on research and extension designed to push yield boundaries in wheat, barley and canola in the higher rainfall zone. As part of the project, Riverine Plains established three on-farm trials at Culcairn, Howlong and Gerogery during 2020 and held two meetings.

Acknowledgements

Our former Research Coordinator, Dr Cassandra Schefe, along with Project Officers Kate Coffey and Jane McInnes and the Research and Extension sub-committees, chaired by Melissa Brown and Adrian Clancy respectively, have been the driving force behind our project work and I'd like to congratulate them for continuing to bring high quality research and extension to our region. I'd also like to thank all of our farmer co-operators and event hosts for their ongoing work and support of our programs.

Funding partners

Riverine Plains partners with a number of organisations in delivering our research and extension programs. We recognise the ongoing support and investment made by our funding partners; the Grains Research & Development Corporation (GRDC), NSW DPI, *Cool Soil Initiative* project partners, the Soil CRC and the Australian Government's National Landcare Program, as well as the support provided by the Goulburn Broken Catchment Management Authority and the North East Catchment Management Authority.

Riverine Plains is involved in projects led by Birchip Cropping Group, Farmlink, Irrigated Cropping Council, Mallee Sustainable Farming, FAR Australia, as well as Southern Cross University, University of Southern Queensland, University of Tasmania, Charles Sturt University and Federation University. We thank these organisations for

their support and also recognise the support received by the large number of organisations collaborating on these projects, and who are individually acknowledged in each of the trial reports.

Sponsors

The sponsors of Riverine Plains deserve a special mention. With many events moved online, there were not the same opportunities for sponsors to attend events and to network and support the farming community during 2020. Riverine Plains greatly appreciates the ongoing support of all our sponsors and looks forward to providing more opportunities in 2021.

Through their financial support, the businesses that sponsor Riverine Plains play an important role in allowing us to deliver additional services to members. Our sponsors are also terrific supporters of our field days, seminars and other events and we sincerely value their contributions. Many of our sponsors have been with us for many years and we thank them for their continued support.

Staff

On behalf of the committee and our members I would also like to recognise the contributions made by Riverine Plains staff to the group's operation. Our CEO, Catherine Marriott; Chief Operating Officer, Fiona Hart; Finance and Project Officer, Kate Coffey; former Research Coordinator, Dr Cassandra Schefe; Communications Officer, Michelle Pardy; Project Officer, Jane McInnes and Casual Field Assistant, Sue Campbell, all make significant contributions to the organisation and are greatly appreciated.

Members

Sincere thanks to our loyal members for the continued support, involvement, feedback and encouragement. We really look forward to engaging more closely with you over the next 12 months to provide greater support and more opportunities.

Committee

Lastly, I'd like to thank the 2020 committee (John Bruce, Melissa Brown, Adrian Clancy, Barry Membrey, Jan Davis, Paul Gontier, Fiona Marshall, Daniel Moll, Eric Nankivell, Curt Severin and Brad Stillard) for their work and support throughout the year. Also thank you to Dale Grey (Agriculture Victoria) for providing executive support.

Research for the Riverine Plains

Finally, I wish to thank Michelle Pardy, for her work in collating and editing these articles and to Cassandra Schefe, Jane McInnes and Kate Coffey for contributing articles for this publication.

We trust you will enjoy the read and find value in the reports contained within. All the best for the 2021 season.

Ian Trevethan
Chairman

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2020 — the year in review

Adrian Smith
Senior Land Services Officer, Murray Local land Services, Deniliquin

What a difference a year can make! While 2019 was characterised by drought, fire, heat and frost, we fast-forward 12 months and the contrast could not be any more stark!

Producers warmly welcomed the return to more 'normal' rainfall across the Riverine Plain region during 2020. Whereas 2019 saw rainfall at around one-third to half of the annual long-term average, 2020 saw well-timed rainfall events occur throughout the season, with above-average rainfall generally experienced across the Riverine Plains (Figures 1, 3, 4 and 5).

For the calendar year, Yabba South recorded total rainfall of: 597mm, Rand 614mm and Culcairn 590mm. This compares with a long-term average rainfall at Corowa of 543mm (Figure 1).

After a hot and relatively dry finish to the 2019–20 summer, significant early autumn rainfall was experienced right across the Riverine Plains area, along with most of NSW. Combined with relatively mild temperatures, this meant crops and pastures emerged well and produced plenty of early biomass.

Rainfall during winter was slightly below average. Coupled with the relatively mild winter, this meant waterlogging was not a significant issue and resulted in excellent continued plant (and livestock) production throughout winter.

Heading into spring hopes were high, with the declared (moderate) La Nina event by the Bureau of Meteorology (BoM) and a positive Southern Oscillation Index (SOI), all pointing in the right direction. However, the region's recent history of failed spring rainfall and early heatwaves were still well and truly in the back of producers' minds.

In the end, 2020 turned out to be one of the best growing seasons for local producers in recent memory. Plentiful spring rainfall, coupled with relatively mild temperatures, a lack of significant frost events, and minimal disruptions to harvest and hay making, helped deliver high crop and pasture yields and excellent livestock growth.

Given the high livestock prices, and with grain (and hay) prices remaining firm despite the generally above-average harvest across eastern Australia, most producers would take a year like 2020 in a heartbeat (despite the challenges a global pandemic threw our way!).

The long-term average number of frost days recorded at Rand for July is 16, August is 12 and September is seven. Figure 2 shows the lower number of frost events experienced during the 2020 winter – spring period, with a total of 15 frost events occurring at Rand during July, 13 during August and four frost events experienced during September. There were no frost events recorded during October.

While frost damage can have major impacts on crop production, the relatively mild late-winter and early-spring conditions during 2020 resulted in minimal crop damage, with the region recording its lowest number of frost days (or more accurately, days below 2.2°C) for a number of years.

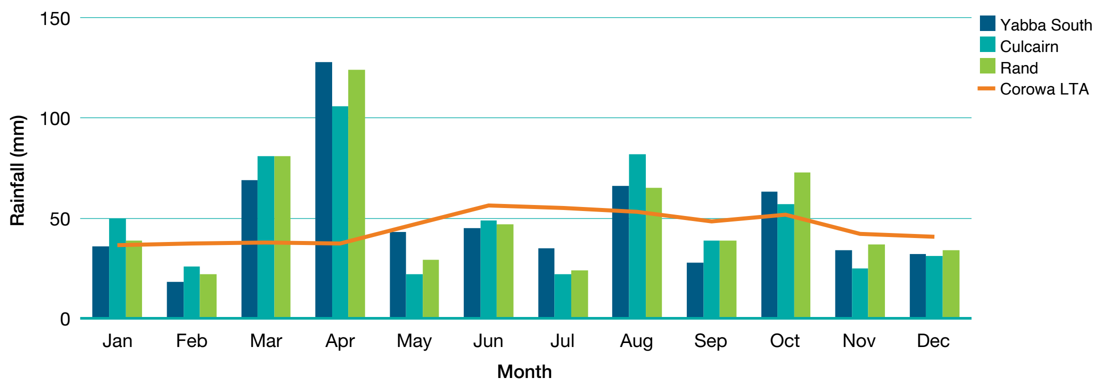

FIGURE 1 2020 monthly rainfall for Yabba South, Rand and Culcairn compared with the long-term average (LTA) for the Corowa Airport weather station (No. 74034)

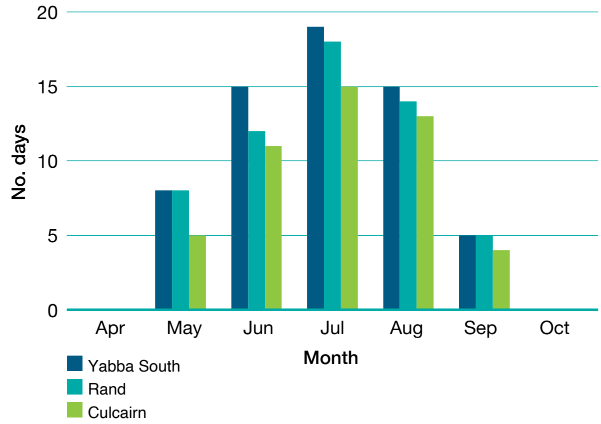

FIGURE 2 Number of frost days at Yabba South, Rand and Culcairn during the 2020 growing season (April – October)

Source: **www.riverineplains.org.au** and **www.bom.gov.au**

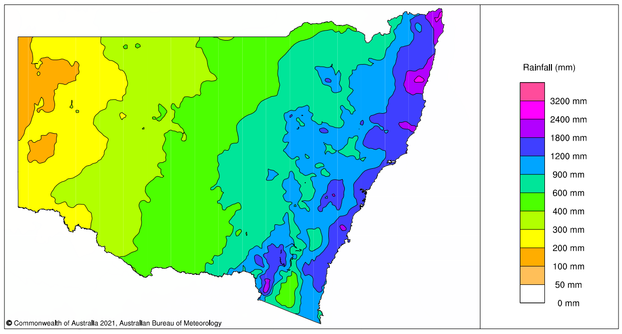

FIGURE 4 Total rainfall (mm) across NSW during 2020

Source: Australian Bureau of Meteorology, 2021. Australian gridded climate data, www.bom.gov.au/climate/maps/rainfall/

Australia experienced its warmest year on record during 2019 (1.5ºC above the long-term average), along with its driest year on record (rainfall was 40 per cent below the long-term average). Whilst 2020 was the fourth-warmest year on record, it had a nationally averaged rainfall 4 per cent above average (BoM, 2021).

For NSW, 2019 was also the warmest year on record (nearly 2ºC above the long-term average), with the state also experiencing its lowest annual rainfall on record (55% below the long-term average). While temperatures across NSW during 2020 were still above-average (0.91ºC above) (Figure 3), it was the coolest year since 2012. The real turnaround was in terms of rainfall (Figure 4), which was 14 per cent above-average across NSW as a whole, with the Riverine Plains region faring even better than that!

Figures 5 and 6 show how 2020 NSW annual rainfall fared against the long-term average. For much of NSW, rainfall was at decile 6 or above, with much of eastern NSW experiencing decile 10 rainfall (which represents the highest 10 per cent of years). For most of the Riverine Plains area of NSW, rainfall was decile 5 and above.

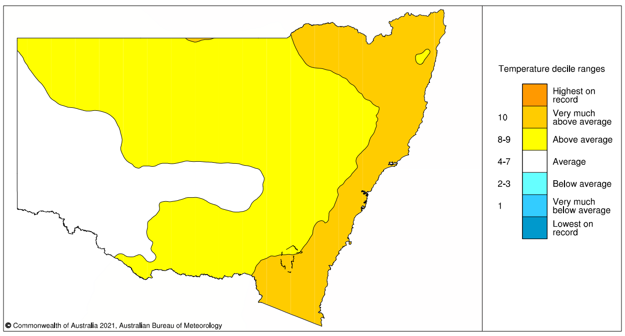

FIGURE 3 Mean temperature deciles across NSW during 2020

Source: Australian Bureau of Meteorology, 2021. Distribution based on gridded data, www.bom.gov.au/jsp/awap/temp/

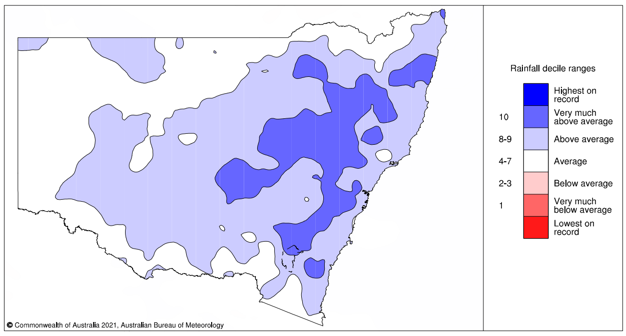

FIGURE 5 Rainfall deciles across NSW during 2020

Source: Australian Bureau of Meteorology, 2021. Australian gridded climate data, www.bom.gov.au/climate/maps/rainfall/

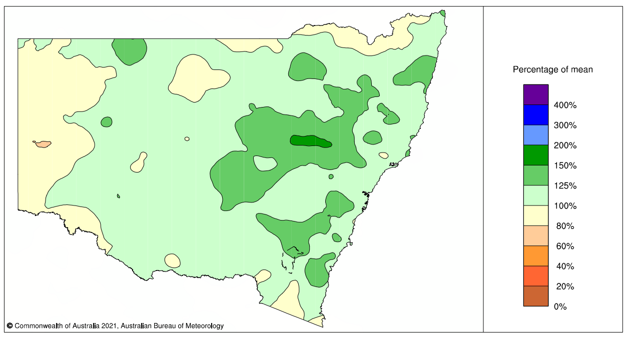

FIGURE 6 Rainfall (per cent of annual mean) across NSW during 2020

Source: Australian Bureau of Meteorology, 2021. Australian gridded climate data, www.bom.gov.au/climate/maps/rainfall/

Summary

The contrast between 2019 and 2020 could not have been any more stark. The turn-around in seasonal conditions was to the relief of all (city and country alike) and was especially welcomed by those on the land.

A hot and dry end to summer was quickly replaced by an exceptional autumn break, a mild winter, a relatively small number of frost events, and a wet and mild end to the growing season. A fairly dry harvest capped off, what was for many producers, an excellent year.

The high prices for most agricultural commodities, accompanied by some exceptional yields, means that most producers will look favourably upon 2020.

High rainfalls also meant water supplies were replenished, with many farm dams full for the first time in a long while. Even long-suffering general security irrigators ended up with a 50 per cent allocation in NSW (100 per cent for those with Victorian Murray high reliability water entitlements).

Who's to say what 2021 has in store for us, but at the time of writing, a good autumn break has already provided producers with some early weed control options and allowed pastures and forage crops to produce some early biomass before heading into winter.

No matter what the upcoming season holds, producers who have good plans in place and make early decisions based on objective data will be best placed to capitalise on any opportunities that may arise. Good plans and early decisions will also help minimise the impacts on farm businesses should things turn the other way.

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Elders

Cool Soils Initiative results and learnings from the Riverine Plains

Jane McInnes[1], Dr Cassandra Schefe[2]
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[2] AgriSci Pty Ltd

Key points

- Analysis of soil samples from 165 Riverine Plains paddocks participating in the *Cool Soils Initiative* project during 2020 showed soil organic carbon (SOC) levels ranging from 0.70–4.75 per cent.
- Analysis of 165 surface (0–10cm) soil samples taken as part of the project showed that pH ranged from 4.2–7.3 ($CaCl_2$).
- During 2020, greenhouse gas (GHG) emissions from paddocks in the Riverine Plains region ranged from -1134 to 1165kg CO_2e/t and between -3062 to 2636 kg CO_2e/ha.
- Further validation of greenhouse gas emission data is required.

Aim

The *Cool Soils Initiative* aims to increase the long-term sustainability and yield stability of the grain-producing regions of southern New South Wales and north-east Victoria, through the adoption of innovative agronomic strategies to increase soil health and related function.

Background

During 2018, Riverine Plains and Central West Farming Systems (CWFS) partnered with Mars Petcare to develop an industry program, the *Australian Cool Farm Initiative*, to quantify greenhouse gas emissions (GHG) from wheat production, as well as to identify avenues to support farmers in reducing emissions, with a focus on soil health. Technical support for this project was provided by the Sustainable Food Lab, an international agency with experience in supporting effective sustainability projects across supply chains.

The program was unique in Australia and has since evolved in response to local learnings and the desire to create more value for the farmers who have come on board.

During 2020, the project was recognised as an industry program of value, with Kellogg's, Manildra Group and Allied Pinnacle also joining the project, in partnership with Charles Sturt University (CSU) and the Food Agility Cooperative Research Centre (CRC). Farmer engagement also increased during 2020, with FarmLink joining Riverine Plains and Central West Farming Systems in delivering the project.

The program aims to create a platform for the food industry to support grain growers in reducing GHG emissions, leading to increased long-term sustainability and yield stability through the adoption of innovative agronomic strategies to increase soil health and related function.

Because soil health has been recognised as a key driver mitigating GHG emissions on farm, while supporting increased system resilience across variable seasonal conditions, the name of the program was also changed during 2020 to the *Cool Soils Initiative*.

Given the project partners' widespread use of wheat as a commodity, the emphasis of the program remains with wheat production, however the project will expand into the irrigated cropping sector during 2021, with a focus on corn production.

Method

During 2019, 30 growers from both the Riverine Plains and CWFS region participated in the project. During 2020, the number of growers participating across the project increased to 85, which includes new participants from the area managed by FarmLink. There were 40 participant growers from the Riverine Plains region during 2020, with data from the Riverine Plains region described in this report.

All participating growers identified up to five wheat paddocks each season to include in the project, with GPS-located soil tests (0–10cm) taken for each paddock. Figure 1 shows the locations of all samples taken from across the Riverine Plains during 2018, 2019 and 2020.

Each soil sample was air dried and analysed for a range of soil properties, including: soil pH ($CaCl_2$), soil organic carbon (SOC) percentage, cation exchange capacity (CEC) and nutrients. Soil samples were taken from specific locations in each paddock based on ease of access and the known location of representative soil types.

Anonymised soil test results, farm input data and yields were captured in a simple database and processed through the Cool Farm Tool (CFT), which generated predictions of GHG emissions for each paddock. Results were communicated to growers as they became available.

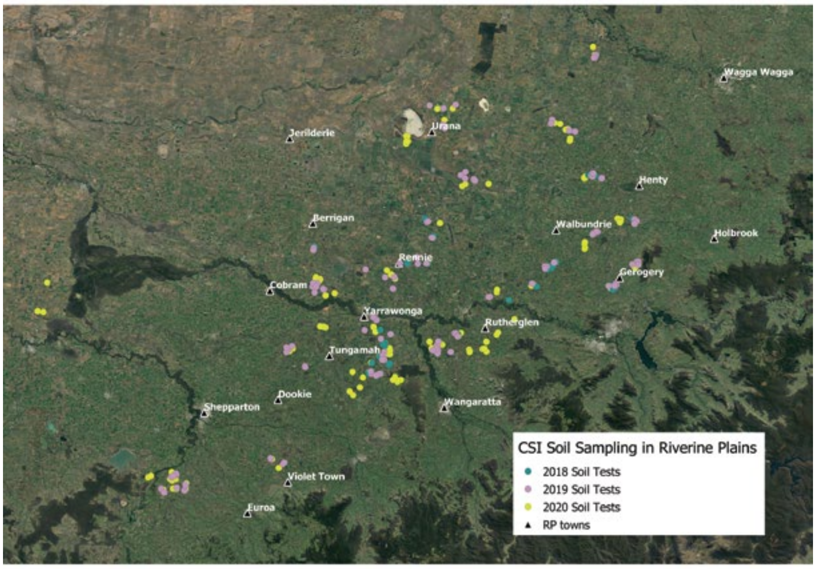

FIGURE 1 Location of paddocks across the Riverine Plains area participating in the CSI project, incorporating the use of the Cool Farm Tool (CFT), from 2018–20

All participating growers were encouraged to test an innovative farming practice, with additional soil sampling available, to follow specific paddocks through the rotation. Additional technical support was also available to support innovative practices, such as novel intercropping strategies in grazed winter wheat, growing new pulse crops, brown manuring and summer cover cropping.

The project will continue with existing and new participants during 2021.

Results

Rainfall

The 2020 growing season was generally excellent across the Riverine Plains region, with regular and timely rains contributing to high winter crop yields. During 2020, annual rainfall across the region ranged from 391mm to 801mm, while growing season rainfall (GSR) from April to October, ranged from 195–471 mm (Figure 2).

Soil organic carbon

During 2018, 67 GPS-referenced soil samples were taken from participating wheat paddocks, while 132 samples were collected during 2019. During winter 2020, 165 wheat paddocks were sampled, with 24 per cent of these having been previously sampled.

Analysis of the 2020 winter sampling results show that SOC values ranged from 0.7–4.75 per cent across the paddocks tested (Figure 3). The highest value (4.75 per cent) was recorded in a paddock new to cropping with a history of low inputs and high stocking rates. The distribution of SOC results from the 2020 samples was similar to those sampled during previous years and the median value of 1.5 has remained consistent from 2018–20.

Of the paddocks with low SOC levels, two had just been purchased and had a history of low inputs and subsurface constraints, while another paddock that returned a

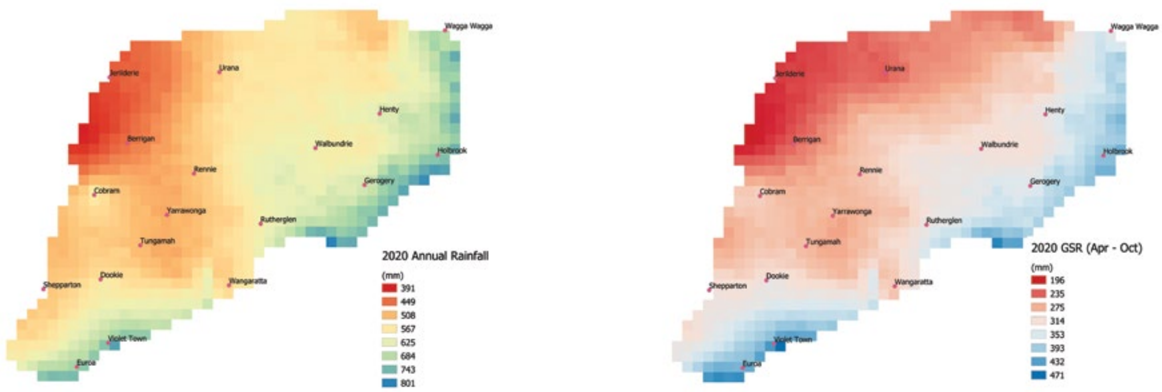

FIGURE 2 Annual rainfall and growing season rainfall for the Riverine Plains region during 2020

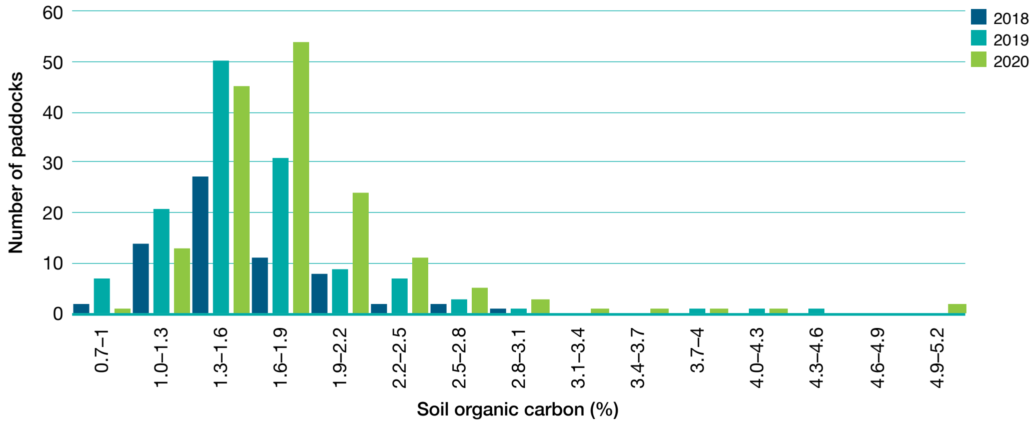

FIGURE 3 Soil organic carbon distribution across paddocks sampled as part of the ACFI 2018–19 summer sampling program, ACFI 2019 and CSI 2020 winter sampling program for the Riverine Plains region

0.8 per cent SOC has a history of average SOC values. From other studies, including the *Quantifying-in paddock variation* project (page 18), we know SOC can be highly variable across the paddock and the low value returned in this instance may not be representative of the paddock as a whole. Spatial variability within a paddock and identifying the most representative location in a paddock to sample is an area requiring further project research.

Across all project years (2018–20) there was no clear relationship between SOC levels and grain yield for the paddocks sampled in the Riverine Plains (Figure 4). During 2020, water was not a limiting factor in grain production and all crops were taken through to grain harvest. Several paddocks yielded less than 2t/ha due to the ongoing effects of transient flooding at the start of the season.

Soil pH ($CaCl_2$)

The Riverine Plains region has a diverse range of soil types. This is reflected in the pH values seen across the area, with soils ranging from naturally acid to alkaline. Soil pH values higher than pH 5.2 are ideal to ensure nutrient availability is not limited, while being high enough to ensure aluminium (Al) toxicity is not an issue.

The soil pH in the surface (0–10cm) soil samples taken during 2020 ranged from pH 4.2–7.3 (Figure 5). While the three years of results (2018–20) show a similar distribution of soil pH, detailed analysis of paddock history and management data collected as part of the project (data not presented) suggests the range of pH values also reflects the use of amendment practices, such as applying lime, which can take a long time to show a response in the soil profile.

Aluminium toxicity

Figure 6 shows the relationship between aluminium and pH for the sampling conducted during 2020. Similar to the 2019 data, 2020 data shows that as soil pH values decrease, aluminium solubility increased for the soil samples collected, with an increasing contribution of aluminium into the CEC. This response is highly predictable within each soil type, with the exact relationship depending on clay mineralogy. Plant toxicity effects due to increased aluminium solubility are generally seen when the aluminium saturation of cation exchange sites exceeds six per cent, although different plant species have differing tolerance to aluminium. Aluminium saturation was above six per cent in 12 per cent of paddocks sampled as part of this project.

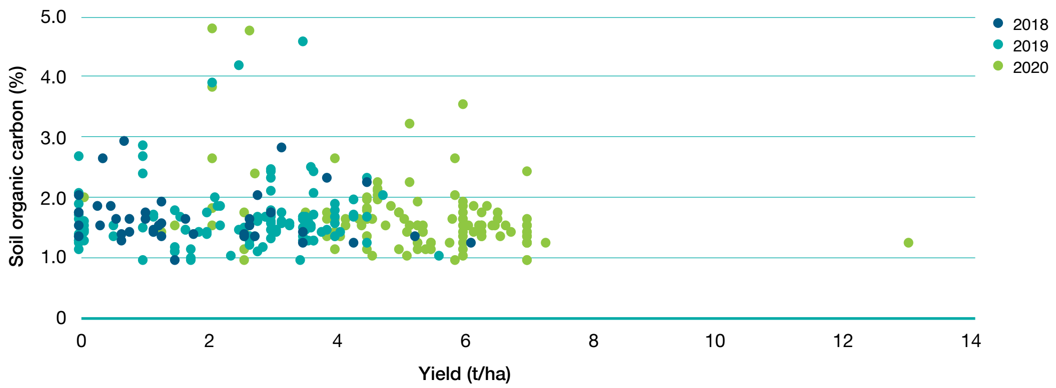

FIGURE 4 Relationship between soil organic carbon percentage and yield across paddocks sampled as part of the as part of the ACFI project 2018– 19 and 2020 CSI project

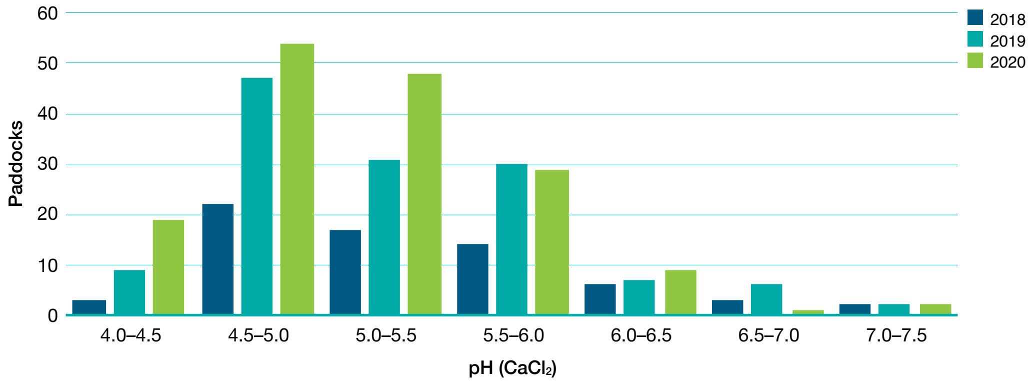

FIGURE 5 pH ($CaCl_2$) distribution across Riverine Plains region paddocks sampled as part of the ACFI project 2018–19 and 2020 CSI project

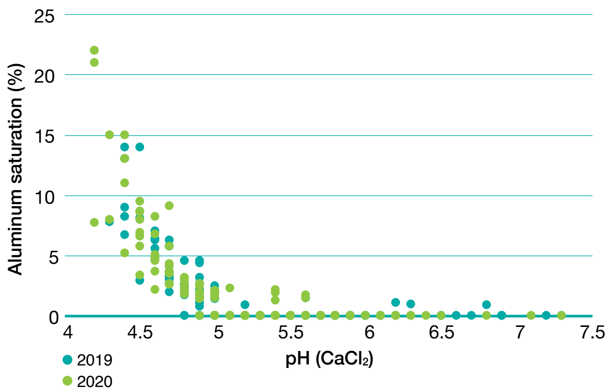

FIGURE 6 Relationship between aluminium saturation and soil pH ($CaCl_2$) for samples taken from the Riverine Plains as part of the ACFI project 2019 and 2020 CSI project

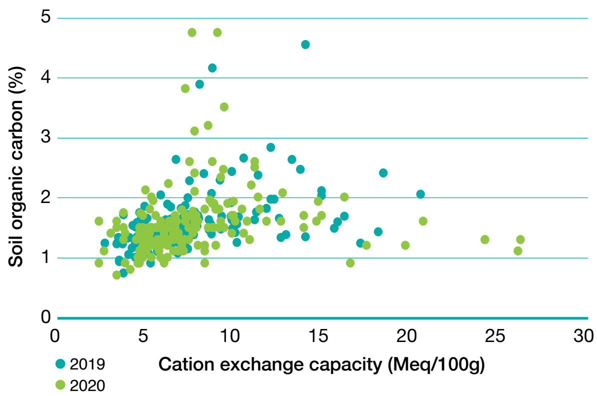

FIGURE 7 The relationship between soil organic carbon percentage and the cation exchange capacity for Riverine Plains paddocks sampled as part of the ACFI project (2019) and CSI project (2020)

Cation exchange capacity

The CEC of a soil is an estimate of the soil's ability to attract, retain and exchange cation elements, with a higher CEC tending to be indicative of higher clay content within a soil. Figure 7 shows the relationship between SOC percentage and CEC for the soil samples analysed during 2019–20 as part of the project, with a non-significant trend for carbon values to increase with CEC. This is due to the fact that SOC (through organic matter) binds to clay particles because clay has a greater ability to attract cations than sandy soils (due to their high negative charge). Clay soils therefore tend to have higher CEC values than sandy soils and have a higher capacity to retain SOC. This explains why it is easier to build carbon levels on clay soils than sandy soils.

Greenhouse gas emissions

Data from each paddock was also analysed to determine the GHG emissions per hectare (kg CO_2e/ha) as well as greenhouse emissions per tonne of grain produced (kg CO_2e/tonne wheat).

Figures 8 and 9 show that paddocks one and two both have negative GHG emissions. These paddocks both returned unusually high SOC values for a cropping paddock, possibly because the paddocks are both new to cropping and have residually high SOC levels from the previous pasture phase.

The paddocks shown in Figure 8 are ranked according to increasing emissions per tonne of wheat produced, with emissions ranging from -1134 to 1165kg CO_2e/t. Figure 9 shows emissions per hectare, ranked in the same order as Figure 8 (i.e. by emissions/tonne), with a much greater range in emissions of between -3062 to 2636 kg CO_2e/ha.

Results from this and previous analyses has highlighted that further work is required to validate the emission calculations made by the tool for Australian conditions. Further validation of the CFT will be conducted during 2021 through the broader *Cool Soils Initiative* project.

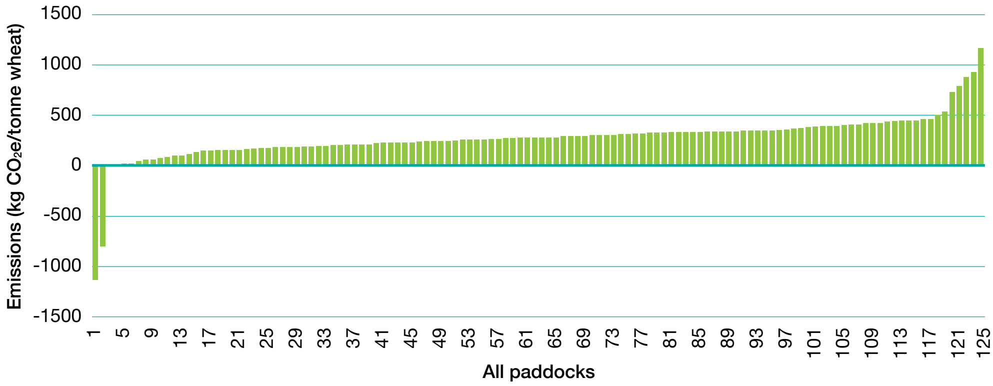

FIGURE 8 Greenhouse gas emissions per tonne of grain produced from Riverine Plains 2020 sample paddocks (ranked from lowest to highest)

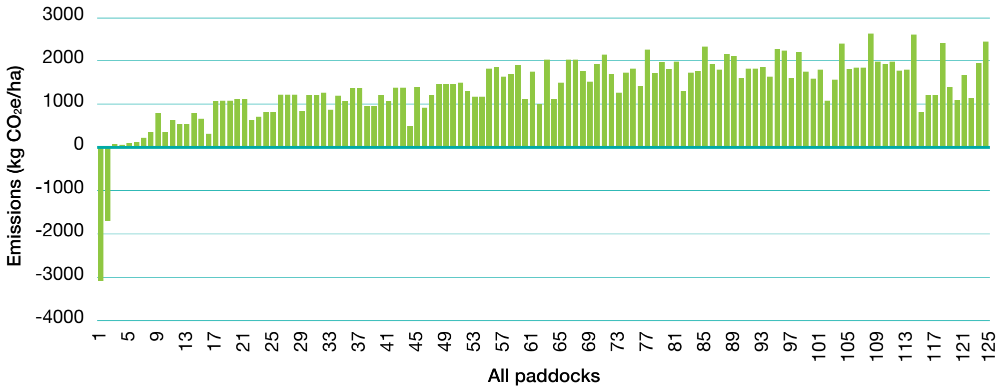

FIGURE 9 Greenhouse gas emissions per hectare from Riverine Plains 2020 sample paddocks (ranked from lowest to highest paddock emissions/tonne wheat and in the same order as Figure 8)

Observations and comments

During 2020, the *Cool Soils Initiative* project in the Riverine Plains area involved 40 participants, who collectively managed an area of more than 120,000 hectares.

Analysis of 165 surface (0–10cm) soil samples, taken as part of the project, showed that pH ranged from 4.2–7.3 ($CaCl_2$), while SOC levels ranged from 0.70–4.75 per cent. This suggests SOC values within the region are staying constant and the methodology to capture in-paddock spatial variability needs to be further developed. Subsoil acidity is becoming a more pronounced limitation in the region, with 5cm incremental sampling to 20cm now recommended as standard practice. While liming is generally practiced across the region, incorporation and the use of higher liming rates to target problem areas needs to receive a greater focus.

Increasing SOC has been globally recognised as a key driver in reducing emissions, through sequestration of atmospheric carbon dioxide (CO_2). It can also increase system resilience through increased water storage and nutrient cycling, potentially contributing to increased sustainability and yield stability. Therefore, this project has a focus on the adoption of on-farm practices that may increase soil carbon while maintaining production and profitability.

The *Cool Soils Initiative* continues to evolve, with associated research projects working through specific issues to support the larger program. These include better access and interpretation of paddock-scale spatial data, review of the GHG emission calculators, and understanding the economic value of practice changes to increase soil health. Results from a sub-project *Quantifying in-paddock variation of soil organic carbon and pH in north-east Victoria*, are reported on page 18 of this publication.

Acknowledgements

Riverine Plains acknowledges the investment by Mars Petcare, Kelloggs', the Manildra Group, Allied Pinnacle, Charles Sturt University and Food Agility CRC, as well as the project support from the Sustainable Food Lab (SFL). Thank you also to all our farmer co-operators, whose support for this project is greatly appreciated. ✓

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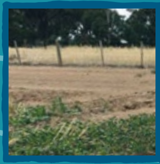

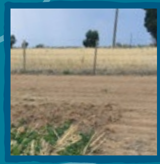

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Quantifying in-paddock variation of soil organic carbon and pH in north-east Victoria

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Key points

- Soil pH varied significantly across the four pasture and four cropping project paddocks, with some areas showing areas of high soil acidity, both in the topsoil and the subsoil.
- Soil organic carbon (SOC) per cent varied within each of the paddocks, with surface (0–10cm) values ranging from 0.5–3.3 per cent. These results suggest that within this climatic zone and these soil types, there may be capacity to increase SOC values, based on an understanding of what is driving the differences in high versus low SOC zones.
- Regular soil testing to a depth of at least 20cm, using GPS-located sample points, based on available spatial data (including yield maps, EM surveys, NDVI images or radiometric maps) will offer a clear picture of the chemical profile and associated health of the soil and changes in that profile over time.
- Estimates of SOC stocks (t/ha) were completed and used to calculate values for the Federal Government's Emission Reduction Fund and it was found that an increase of 0.5 per cent SOC at the 0–10cm soil layer may equate to about $55/ha (as measured after the first five-year sampling period). Calculations did not account for reductions in this value due to on-farm emissions (both historically and within the sampling period), or the costs of sampling, auditing and reporting.
- Comprehensive baseline soil pH and SOC information was collected from eight paddocks in north-east Victoria. Monitoring these paddocks over time will provide valuable information on the rate of change in soil pH and SOC occurring under cropping systems, and the change in soil pH and SOC upon converting pasture paddocks into cropping paddocks.

Project background

In north-east Victoria and southern NSW, two soil properties influence soil health and productivity in a significant way — soil pH and soil organic carbon (SOC).

Soil pH plays an important role in governing the chemical environment in the soil. While some soils in north-east Victoria and southern NSW are naturally acidic, due to their parent material, others are becoming more acidic due to agricultural production. The ongoing use of nitrogen (N) and the off-farm export of agricultural produce (all of which extract calcium (Ca), magnesium (Mg) and other cations from the soil), result in net soil acidification.

Soil organic carbon (SOC) is a key component of soil organic matter (SOM) and plays many important roles in maintaining soil health, including supporting microbial activity, nutrient cycling, improved infiltration and water holding capacity, as well as maintaining soil structure.

With soil pH and SOC being critical to soil health and productivity, regular soil testing is critical to establish accurate soil pH and SOC values and understand how they change over time.

While 0–10cm transect sampling has traditionally been the preferred method for soil sampling (where soil samples are collected along a line through a paddock, with all samples combined into the one sample for analysis), this approach is likely to mask any in-paddock soil pH and SOC variability. For this reason, incremented GPS-referenced soil sampling was used in this project to provide a more comprehensive understanding of paddock conditions and to enable these conditions to be monitored over time.

Soil organic carbon contributes much to our soil and farming systems and mechanisms are now in place, through the Federal Government Emission Reduction Fund, to pay farmers to maintain an increase in SOC, via the *Carbon Farming Initiative* (a voluntary carbon offsets scheme that allows land managers to earn carbon credits by changing land use or management practices to store carbon or reduce greenhouse gas emissions). This project sought to provide further information for growers looking to understand more about this process.

Aims

The project aimed to quantify the baseline variance in soil pH and SOC across four cropping paddocks and four pasture paddocks in north-east Victoria, in order to understand the degree to which these parameters may vary in paddocks that appear relatively uniform.

Because the calculation of carbon stocks (for carbon trading) is more difficult in practice than in theory, and because there is a lack of regionally relevant reference data available for growers, the collection of soil samples using protocols from the *Carbon Farming Initiative* also aimed to provide a regionally relevant example of how to conduct this work, as well as a guide to likely local SOC stocks.

The project also aimed to calculate the benefit that could be ascribed to an SOC increase of 0.5% (within a 25-year contracted period), using data collected for one of the project paddocks.

Method

Eight paddocks were selected across north-east Victoria, consisting of four paddock 'pairs'. Each pair included a paddock with a long-term cropping history and a paddock about to transition from pasture to crop production. These pairs are referred to as the "Yarrawonga 1", "Yarrawonga 2", "Springhurst" and "Violet Town" paddock pairs (Figure 1).

The four pasture paddocks were soil sampled (GPS referenced) immediately before being prepared for the cropping phase, with future soil sampling to be completed in order to track SOC and soil pH values. This will provide long-term information for both the continuous cropping and pasture-to-cropping paddocks to help understand the impact of practice change on SOC and soil pH.

Groundcover on the cropped paddocks at the time of sampling comprised retained stubble and volunteer species, while groundcover on the pasture paddocks ranged from annual grasses and broadleaf species, through to high-quality perennial ryegrass pastures.

As per the *Carbon Farming Initiative* methods, 20 GPS-located sampling points were selected in each paddock (by a Latin Hypercube analysis of spatial variance in satellite-derived radiometric data). Each paddock was assigned into polygons (sub-areas of similar properties) to enable carbon stocks to be calculated within each sub-area.

All soil sampling was carried out during March, 2020. While 0–10cm is the traditional depth for SOC and soil pH

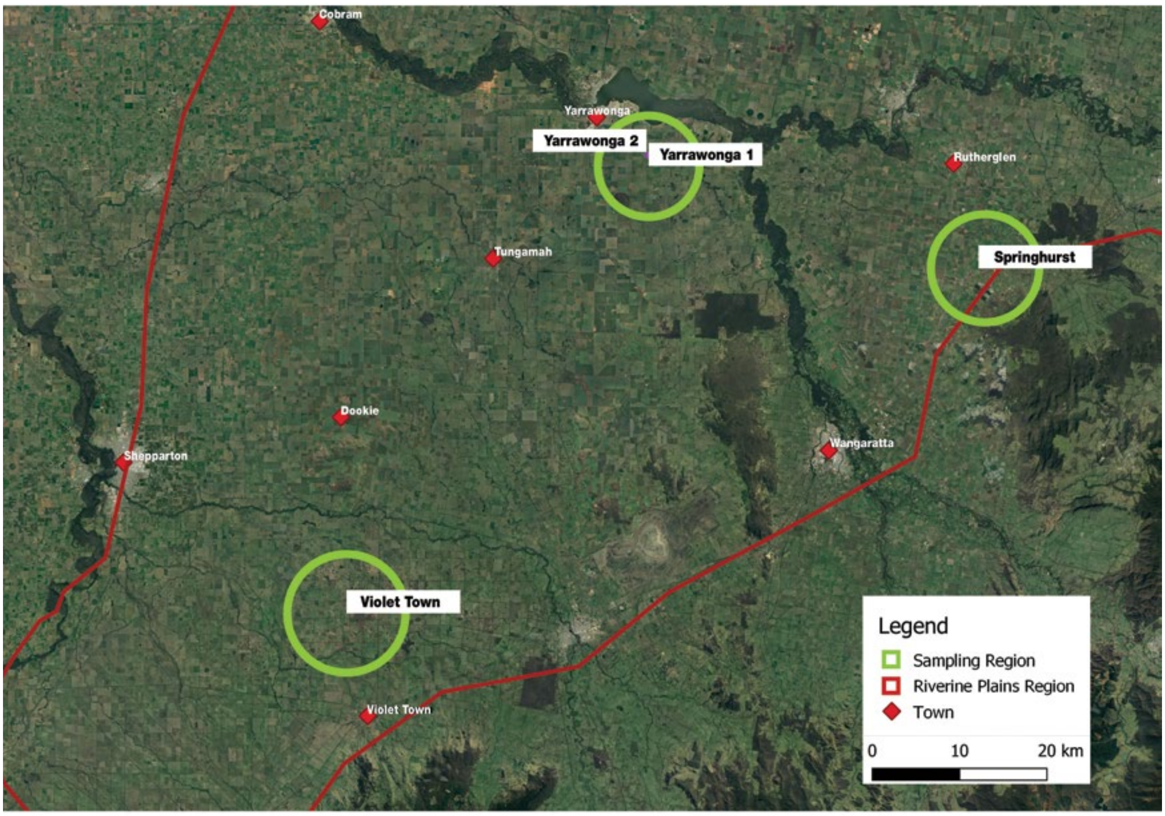


FIGURE 1 General location of each paddock pair, with a pair consisting of a paddock with a long-term cropping history and a paddock transitioning from pasture to crop production

sampling, the likely presence of subsoil acidification and the need to quantify SOC stocks down to 30cm means soil cores were taken to a depth of 30cm, incremented at 0–10cm, 10–20cm and 20–30cm.

The *Carbon Farming Initiative* methods specify one soil core per sampling point with an inner cutting diameter of 3.8cm, however this was not available in the region. Therefore, two soil cores with an inner cutting diameter of 2.6cm were collected at each sampling point and bulked.

Soil cores were analysed for soil carbon (as per *Carbon Farming Initiative* methods, including bulk density and gravel determination) and soil pH ($CaCl_2$) at Environmental Analysis Laboratory, Southern Cross University.

Determination of carbon stocks (reported as tonnes of soil organic carbon per hectare [t C/ha]) was done according to the calculations described in the Carbon Credits Methodology Determination 2018 (*Carbon Farming Initiative — Measurement of Soil Carbon Sequestration in Agricultural Systems*), and the Supplement version 1.0 — January 2018.

Carbon stocks (t C/ha) were calculated from SOC% and other parameters as follows;

Carbon stock calculations:

SOC (%) adjusted for gravel = SOC (%) – [SOC x (% gravel ÷ 100)]

SOC (t/ha) per depth = ((SOC% adjusted for gravel x 10) x total soil mass (kg/ha)) ÷ 1,000,000

Total SOC stocks (0–30cm) (t/ha) = SOC (0–10cm) + SOC (10–20cm) + SOC (20–30cm)

Total SOC stocks (0–30cm) were assigned to each polygon based on area.

Results and discussion

Soil organic carbon

Calculation of SOC stocks from SOC% and other soil parameters showed the SOC stocks (t C/ha) across the eight paddocks were relatively similar, ranging from 27–45t C/ha (Figure 2). However, there was large in-paddock variation, which reflected changes in soil type, clay content and cation exchange capacity (CEC) within individual paddocks.

The total SOC stocks measured (0–30cm) were similar between the pasture and cropping paddocks, with the Violet Town paddocks in the higher rainfall zone having the highest values (43.77–44.9t C/ha) (Figure 2). Generally, most of the SOC in these soils was present in the top 10cm (up to 79%), however, at some of the sites with lower SOC values, the proportion present in the top 10cm dropped to as low as 20%. The relationship between SOC stocks (t C/ha) and SOC% is presented in Figure 4, which shows a SOC stock value of 45t/ha may equate to 2.2% SOC (0–10cm). This, along with the other results, indicates the possible range of SOC stocks for soils in north-east Victoria (keeping in mind this relationship changes if there is greater SOC accumulation below 10cm depth).

For the cropped paddocks, average SOC values within the 0–10cm increment ranged from 1.2% in the Yarrawonga 2 paddock to 2.2% in the Violet Town paddock (Figure 3). While average values of 1.2% would be considered quite acceptable for cropped paddocks, spatial sampling also showed the upper values of SOC measured in those paddocks ranged between 1.6% (Yarrawonga 2) to 3.3% (Violet Town paddock).

Individual SOC results varied significantly within each paddock, with the greatest variation in the Violet Town pasture paddock, where sampling points ranged from

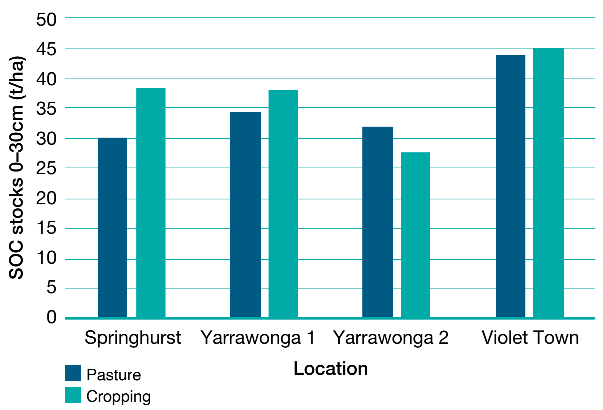


FIGURE 2 Weighted average SOC stocks at the 0–30cm depth for each paddock pair, from 20 sample sites per paddock and accounting for the different area in each polygon

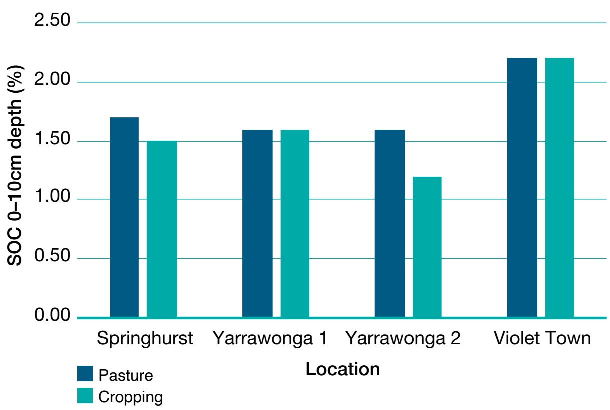
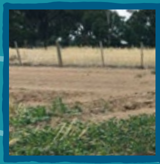
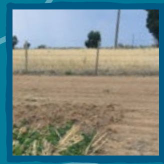


FIGURE 3 Average SOC % for the 0–10cm depth increment for each paddock pair, sampled from 20 sites per paddock*

*Note: SOC% (as described in a normal soil test) is used to calculate SOC stocks (t C/ha); the SOC% presented in Figure 3 (0–10cm) may relate to the SOC stocks (0–30cm) presented in Figure 4.





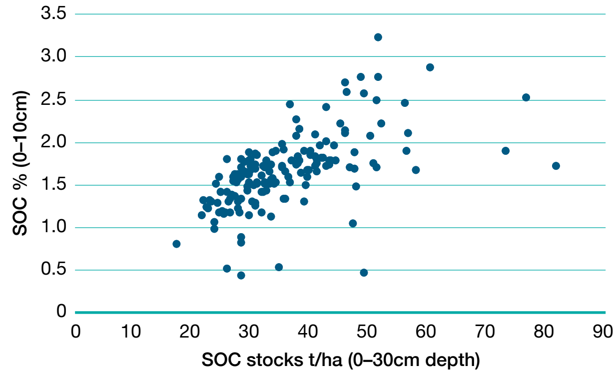


FIGURE 4 The relationship between commonly measured SOC % at 0–10cm and what this looks like in regards to SOC stocks at 0–30cm (quantified as t C/ha)

0.5–3.2% SOC (0–10cm). If a conventional transect method had been used for the Violet Town paddock (with all samples bulked together), the SOC would have been 2.2%, with the in-paddock variance acting to dilute, or mask, the impact of any changes in SOC over time. As such, when looking to monitor the SOC value over time to determine the impact of paddock management on SOC values, a more detailed GPS-located sampling approach (in increments to a depth of at least 20cm), is recommended.

While the GPS-located approach may not reflect the full range in SOC across the entire paddock, even if only 1–2 sampling points are used over time, any changes in SOC at these sampling points should be able to be measured more easily.

As the range in SOC values corresponds well to other readily available satellite imagery (including satellite-derived radiometrics [gamma-ray spectrometric methods], NDVI [greenness index] and other datasets including EM surveys and yield monitor data), one of the first steps towards increasing SOC in paddock may include identifying the likely high and low SOC locations in the paddock. This could be done using remote sensing methods or EM or yield monitor information, and by then sampling these points for a range of soil chemistry attributes to help identify the factors responsible for the difference. This would help in whole-paddock management to support an increase in those factors of value.

The four pasture paddocks were sampled just before being cultivated prior to cropping, with a high potential for SOC loss during this transition through soil disturbance and associated carbon mineralisation (loss to the atmosphere as CO_2). Therefore, the baseline soil sampling and follow-up monitoring over the next 12–24 months (and potentially longer) will be of high value in understanding the flux of SOC over this time.

Soil pH ($CaCl_2$)

Soil pH values varied significantly across each paddock, both on the surface and at depth (Figure 5). Figure 5 also indicates soil acidity is a significant problem in the paddocks, with results as low as pH 4.61 in the 0–10cm increment and pH 4.84 in the 10–20cm increment (Violet Town cropping). Generally, soil pH was higher (more alkaline) in the pasture paddocks than in the long-term cropping paddocks. The images in Figure 6 (page 22) indicate the presence of some highly acid soils in the monitored paddocks.

The greatest range in 0–10cm pH values was in the Yarrawonga 1 cropping paddock, where values ranged from pH 4.55–6.56. While low pH values were most common in the surface samples, there were also several highly acid (pH 4.8–5.1) 10–20cm depth samples, with the Springhurst cropping paddock also being more acid at the 10–20cm than 0–10cm.

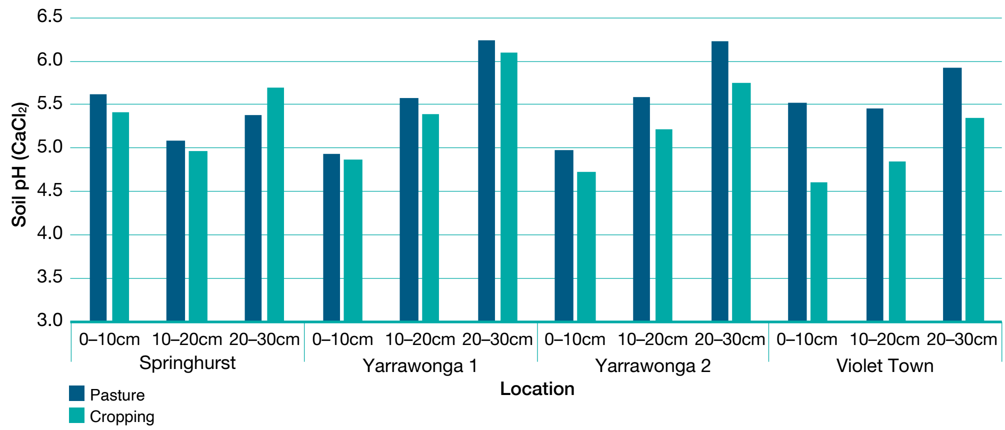


FIGURE 5 Average soil pH_{Ca} values at depths of 0–10, 10–20 and 20–30cm for long-term cropping and pasture-to-cropping paddocks at each location

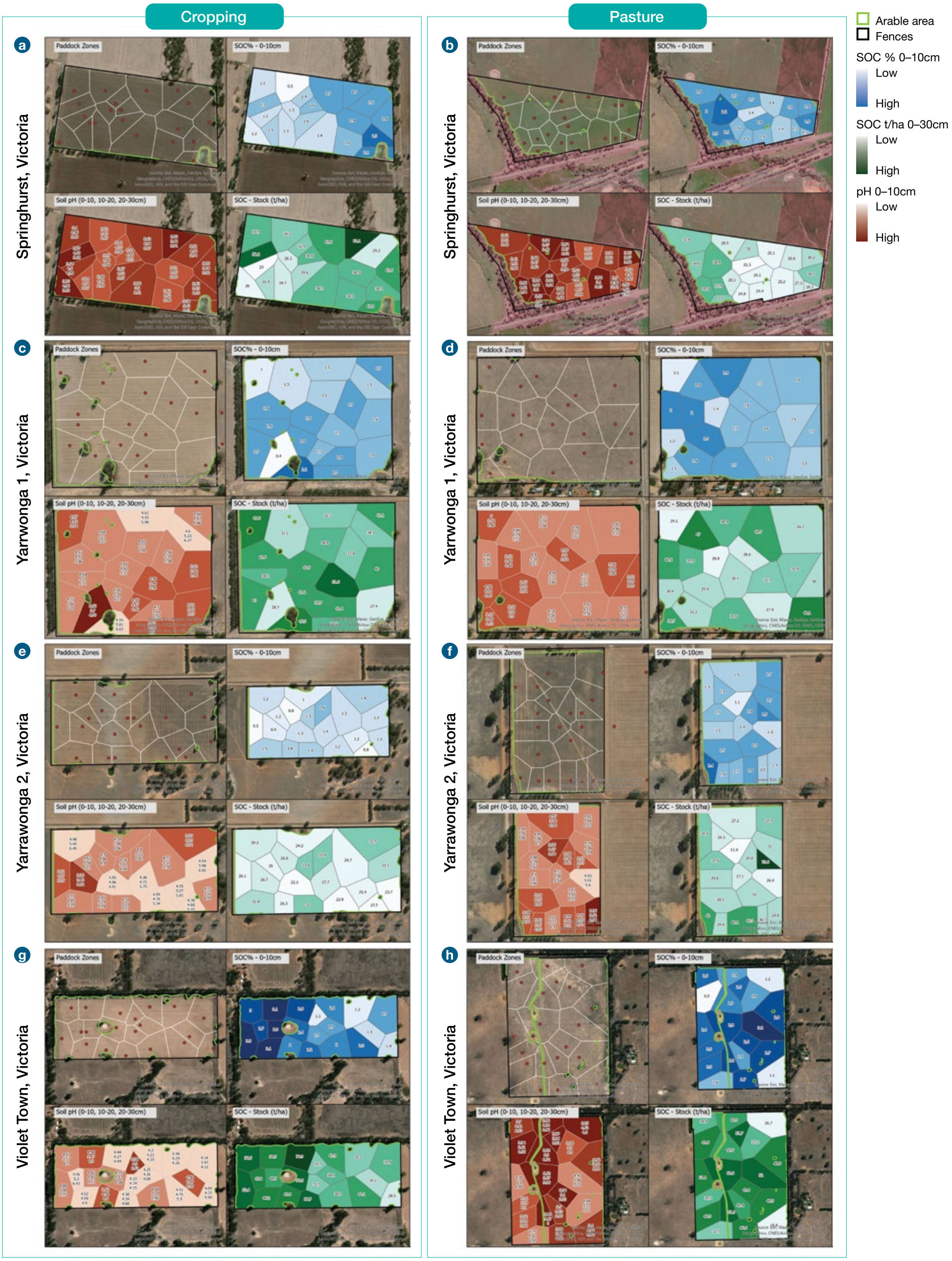
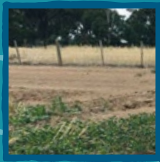
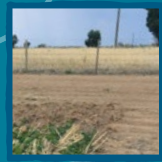


FIGURE 6 A–H demonstrate the variance in SOC and pH within and between each paddock pair

Note images on the left are cropping paddocks, images on the right are pasture paddocks about to transition to cropping.





While the average soil pH values shown in Figure 5 indicate a number of paddocks with pH values higher than 5.0 (and which would be considered acceptable for agricultural use), the range in pH values measured across the paddocks include highly acid locations, which would be limiting productivity.

To help identify regions of low productivity in a paddock, as well as to measure soil pH variance, remotely sensed data (satellite NDVI etc) and yield maps could be used to select GPS located sampling sites. Additionally, soil sampling in 10cm increments to a depth of at least 20cm will provide a clearer picture of the soil's chemical profile at depth. For paddocks with a history of broadcast lime application with no incorporation, sampling at 0–5, 5–10 and 10–20cm increments will provide a clearer picture of how far down the profile the lime has moved.

When the range of soil pH values is known, appropriate rates of lime can be applied to offset both surface and subsurface acidity, with some incorporation required; the depth of which will depend on soil conditions.

Interaction between SOC and soil pH

The interactions between SOC and soil pH are relatively complex, with soil pH being a key parameter driving the soil's capacity to increase SOC.

As illustrated in the Violet Town cropping paddock (where SOC was 2.2% despite pH 4.6–4.8 in the 0–10 and 10–20cm depth increments), SOC can be retained under acidifying conditions. However, the ability to increase SOC under such acid conditions is limited because microbial activity and function is reduced (bacteria prefer conditions between pH 5–9, with optimum activity at pH 7). Reduced microbial function in acid soils also affects the bacterial legume inoculants (*Rhizobium* species) and is a key reason why legumes do not persist well under acidic conditions. Fungal activity is also important for increasing SOC, and while some fungi can function down to pH $2_{(CaCl_2)}$, optimum activity occurs at pH 5.

It follows that if soil microbes cannot function well under acid conditions, they cannot efficiently convert plant residues into SOM. This means more of this material is inefficiently converted into carbon dioxide (CO_2) gas and lost to the atmosphere.

Many plant species cannot grow well under acid conditions. In a pasture system, this means productive, deep-rooted perennials, such as phalaris (which can deposit significant levels of carbon through their root systems at depth) and clovers (which improve soil fertility) are outcompeted by annual grasses and broadleaf weeds. Annual grasses and broadleaf weeds are of little productive value and also produce less residue for recycling into SOM.

In cropping systems, areas of low pH can produce low-vigour crops with reduced biomass and yield. Acidic soils can also increase abiotic stresses on sensitive crops, which can lead to the crop being outcompeted by weed species or subject to increased pest and disease pressure. This can further reduce biomass turnover on top of the limits already imposed by reduced microbial activity.

Maintaining soil pH values above pH 5 (and preferably 5.2), will improve the productivity of the system while also improving the microbial function of the soil, both of which are important in increasing SOC values.

Carbon sequestration: The process and calculation

A key part of this project was to understand the practicalities of sampling for SOC using *Carbon Farming Initiative* approved methods and the estimated Australian Carbon Credit Unit (ACCU) value of any increase in SOC.

In order to be eligible for consideration for ACCUs through the Australian Emission Reduction Fund program, the following actions are required;

1. Initial baseline soil sampling to 30cm depth is to be carried out, according to approved sampling designs, with qualified contractors (subject to commercial arrangement).
2. An independent contractor is to be engaged to develop a land management plan, to demonstrate 'additionality' (i.e. not be something that you would do anyway).
3. A third-party audit of the land management plan is carried out.
4. The practice change is to be set up (i.e. the 'new' change or practice that will lead to carbon sequestration).
5. Soils are to be resampled after five years (first sampling period) and an independent audit of the results paid for.
6. Where a measurable increase in SOC is observed, land owners/managers may then apply for consideration into the Emission Reduction Fund (ERF) auction. They can choose to hold onto ACCUs, or cash them in at current auction price.
7. A carbon broker can also be engaged to assist in registering baseline sampling results and going through the ACCU auction process.

The following scenario covers the key cost points of applying for ACCUs, based on publicly available information (as at December, 2020):

Financial benefit calculation for a 0.5% increase in SOC over a 25-year period (contracts available for either 25 or 100-year periods)

Using the Springhurst pasture paddock as an example (which had a baseline starting SOC of 1.7% and carbon stock of 30t C/ha), and maintaining all gravel and bulk density calculations, increasing the 0–10cm depth soil carbon value by 0.5% resulted in an extra **6.18t C/ha over an initial five-year sampling period, within a 25-year contract.**

Using this starting figure, the financial benefit of applying for ACCUs (carbon credits) after the first five years (first monitoring period) can be described by the following process:

1. ACCUs are based on carbon dioxide equivalents (CO_2e values), not on SOC values. Therefore, the **6.18t C/ha *is equivalent* to 22.63 t CO_2e/ha**.
2. An estimation should be made of baseline emissions over the 10 years leading up to the baseline sampling including: methane (CH_4) from livestock, nitrogen (N) fertiliser, fuel, lime and other input emissions. The starting CO_2e value is therefore **22.63t CO_2e/ha *less emissions from the previous 10 years***. (Not calculated in this example, therefore this CO_2e value is higher than it should be.)
3. Discount of 5% (applied to all projects considered for ACCUs to account for uncertainty) = **21.50t CO_2e/ha**
4. Discount of 25% applied for a 25-year contract (NB not discounted for 100-year contracts) = **15.84t CO_2e/ha**
5. Discount of further 50% applied as all soil carbon projects have a 50% deferral from the first monitoring period (five years after baseline) and the second period = **4.53t CO_2e/ha**
6. Assuming an average ACCU value of **$16.14** (as per the Emission Reduction Fund auction on 25/26 March 2020 — Auction #10) = **73.06 ACCUs/ha (= $73/ha at current pricing)**
7. Emissions over the five-year monitoring period also need to be considered, so growers need to assume the value of **$73/ha** will decrease further due to emissions that offset any carbon gains.
8. Based on current pricing, a carbon broker may charge 25% of the total ACCU value, which further decreases the value to **$54.8/ha. This is equivalent to $11/ha/year for the first five-year monitoring period. (Note: this value does not take into account any further discounts due to estimated emissions during the sampling period, which would further reduce any carbon value).**

While the above calculations provide an example financial return from carbon trading on a local soil, it is important to also consider that all soils have a threshold of soil carbon, based on their climate, soil type and management. Therefore, it is highly likely the rate of carbon increase over the second five-year sampling period will be considerably less than the first five-year period (due to the law of diminishing returns).

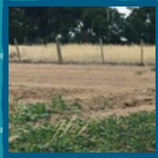
Also, if anything happens to the land during the 25-year ACCU contract period that results in a net loss of carbon (i.e. due to drought, flood, fire, pest animals etc), the farmer will need to pay back the loss.

Finally, if the land is sold during the contracted 25-year period, the new owner must either sign up to the committed contract, or pay it out.

Conclusion

Given the importance of soil pH and SOC on soil health and productivity, it is important to soil test regularly to measure soil pH and SOC values and better understand how they change over time, with incremented GPS-located sampling being the preferred method for sampling.

Soil pH can affect a soil's ability to increase SOC and the results from this project suggest that within the climatic zone and soil types of north-east Victoria, there may be capacity to use remote sensing data to understand differences in high versus low SOC areas. This could then be used to increase SOC values by identifying the factors responsible for the difference and managing the whole paddock to support an increase in those factors of value.



Measuring carbon stocks for trading using the ACCU and the Australian Government's Emissions Reduction Fund may be of interest to some local growers. While such a program appears highly attractive, it relies on detailed soil sampling protocols to understand baseline carbon stock values, with further sampling also required over time to measure any increase in carbon stocks. The method for calculating carbon stocks, as indicated by the *Carbon Farming Initiative,* is somewhat complex and may present challenges to those seeking to understand what it involves, and the relative gains to be made.

Further monitoring of the paddock pairs over time will provide valuable information on the rate of change in soil pH and SOC occurring under cropping systems, and the change in soil pH and SOC occurring upon the conversion of pasture paddocks into cropping.

Acknowledgements

This project was completed within the Cool Soil Initiative, with contributions from; Dr Cassandra Schefe (AgriSci), Jane McInnes (Riverine Plains), Jonathan Medway (Charles Sturt University) and Patrick Lawrence (Sustainable Food Laboratory).

The project team would like to thank the participating growers for their willingness to contribute to this work.

Cool Soil Initiative partners include: Mars Petcare, Kellogg's, Manildra Group and Allied Pinnacle, through the Sustainable Food Lab and Charles Sturt University (CSU), with additional funding through the Food Agility Cooperative Research Centre (CRC).

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Increasing plant species diversity in cropping systems

Jane McInnes[1], Terry Rose[2], Shahnaj Parvin[2], Jason Condon[3]
[1] Riverine Plains
[2] Southern Cross University
[3] Charles Sturt University

Key points

- During 2019, nine crop treatments were established using a range of winter crops (including wheat, field peas for grain and brown manure, as well as a brown-manure mix) at Burramine, Victoria, as part of a larger, long-term project looking at increased plant species diversity in cropping systems.
- A number of plots from this trial were sown to summer crop mixes during January 2020 and this impacted on water availability (when canola was sown over the treatment plots during May 2020) and levels of some diseases in the soil. During 2020, canola and peola were sown over the treatments established during 2019.
- The use of a pulse in the rotation, or inclusion of a brown-manure crop, substantially increased mineral nitrogen (N) at sowing of the subsequent canola crop.
- There was no difference in biomass production or yield between the control and the pulse rotation treatments or the control and increased diversity treatments.
- Cover crops sown during 2021 were affected by poor summer rainfall

Background

Cropping systems in Australia can have limited species diversity, exacerbated by declining legume use in cropping systems during the past decade. Increases in plant diversity, either in time or space, are more likely to enhance the species richness of soil biota by providing more diverse litter deposition, exudates, rooting patterns and plant associations. Diversification of crop rotations, compared with monoculture or minimal break crops and/or the integration of green manures (including cover crops), into crop rotations have positive benefits for soil health.

To help address a lack of species diversity across the region, Riverine Plains has established a long-term (five-year) trial site at Burramine, Victoria as part of a national Cooperative Research Centre for High Performance Soils (Soil CRC) project, led by Southern Cross University. The trial is assessing the viability of integrating diverse species into the farming system, as either winter rotation crops (or green/brown manures) or as summer cover crops, within the constraints of soil water and weed pressures. These trials will investigate a range of rotation options for improving soil function and, ultimately, grain yields and farm profitability. Soil function will be assessed in terms of measuring soil microbial communities, structure and their extracellular enzyme activities as well as mineralisation rate of nutrients (carbon [C], nitrogen [N] and phosphorus [P]) through decomposition of litters, root debris and soil organic matter (SOM) over the time.

Further, the Burramine trial evaluates how green manure crops, cover crops (crops grown over summer primarily for the benefit of the soil rather than for yield), intercrops (where multiple species of crop are grown at the same time and are all taken through to harvest) and companion crops (where multiple crops are sown, but only one is taken to harvest) can affect soil functionality through modulating a suite of soil health assays.

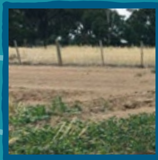
Aim

Although the cereal–oilseed crop–legume rotation offers advantages in terms of disease control, microbial abundance and nutrient transformation, there is little incentive for growers in southern cropping systems to increase plant diversity by growing alternative winter crops. This project aims to investigate other options to increase plant diversity, such as summer cover cropping, intercropping or companion cropping, and to examine their impacts on soil function and winter crop yields.

Method

A field trial spanning four growing seasons (winter-summer-winter-summer) was established at Burramine, Victoria, during autumn 2019. A total of nine different rotational treatments were established based around the core wheat–canola rotation growers in the area typically employ (Table 1).

On 13 May, 2020, the entire trial site was sown to either canola (cv Bonito) or 'peola' (a canola (cv Bonito) and field pea (cv Morgan) intercrop), representing the second (canola) phase of the wheat–canola rotation. The canola-only treatments were sown into soil moisture following a significant rainfall event during early May, at a rate of 3kg/ha with 80kg/ha of MAP and 50kg/ha of GranAM below the



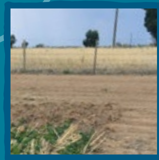


TABLE 1 Treatments and crop rotations for the *Increasing crop diversity trial* for four growing seasons (winter 2019, summer 2020, winter 2020 and summer 2021), Burramine, Victoria

	Treatments	2019 winter crop	2020 summer cover crop	2020 winter crop	2021 summer cover crop
1	Control (wheat/ canola/wheat)	Wheat (cv Trojan)	-	Canola (cv Bonito)	-
2	Pulse/canola/ wheat	Field peas (cv Morgan)	-	Canola (cv Bonito)	-
3	Pulse (brown manure)/canola/ wheat	Field pea (cv Morgan)	-	Canola (cv Bonito)	-
4	Brown manure (mix)/canola/ wheat	Field pea (cv Morgan) + tillage radish (cv Tillage Radish)	-	Canola (cv Bonito)	-
5	Intercrop (wheat/ peola/wheat)	Wheat (cv Trojan)	-	Canola (cv Bonito) + Field Pea (cv Morgan) (peola)	-
6	Companion crop (wheat undersown with subclover/ canola/wheat)	Wheat (cv Trojan) + sub-clover (cv Riverina)	-	Canola (cv Bonito)	-
7	Cover crop mix 1	Wheat (cv Trojan)	Medic and buckwheat	Canola (cv Bonito)	Medic and buckwheat
8	Cover crop mix 2	Wheat (cv Trojan)	Sorghum (cv Crown), millet (cv Shirohie), forage rape (cv Greenland) and oilseed radish (cv Tillage Radish)	Canola (cv Bonito)	Sorghum (cv Crown), millet (cv Shirohie), forage rape (cv Greenland) and oilseed radish (cv Tillage Radish)
9	Maximum diversity	Wheat (cv Trojan)	Sorghum (cv Crown), millet (cv Shirohie), forage rape (cv Greenland) and oilseed radish (cv Tillage Radish)	Canola (cv Bonito) + Field Pea (cv Morgan) (peola)	Sorghum (cv Crown), millet (cv Shirohie), forage rape (cv Greenland) and oilseed radish (cv Tillage Radish)

Note: The 2021 cover crops (treatments 7 and 8) and maximum diversity plots (treatment 9) were sown into the same 2020 summer cover crop and maximum diversity treatment plots and have grown two summer and two winter crops to date.

seed. The 'peola' mix was sown using a canola rate of 3kg/ha and a field pea rate of 100kg/ha, with fertiliser applied at the same rate as the canola-only treatments.

A range of measurements, including soil moisture, soil nitrogen and disease status, as well as crop establishment, biomass and yield, were taken during 2020 to determine the effect of the summer and winter crop treatments, established during 2019, on the yield of the canola and 'peola'. Additional soil measurements were also taken to investigate whether summer cover crops provide more benefit if the summer cover crop species are from different plant families than the winter crops grown in the rotation (results were not available in time for publication). Statistical analysis was undertaken separately for the rotation treatments and the increased diversity treatments using $P < 0.1$. Data from the peola treatments was not statistically analysed due to the difficulty comparing treatments.

On 28 January 2021, summer cover crops were sown into the same plots as the 2020 summer cover crops. The same mixes were used during 2021 as during 2020; these

Peola (peas and canola) sown together in the maximum diversity plot (Photo taken 2 September 2020).

included cover crop mix 1 (CC mix 1: medic and buckwheat) and cover crop mix 2 (CC mix 2: sorghum, millet, forage rape and oilseed radish (tillage radish), while the maximum diversity treatment was sown to CC mix 2.

The cover crops emerged well, having received 30mm of rainfall during the 10 days following sowing, however they subsequently struggled due to the lack of rainfall from sowing until late March. The cover crops were terminated with glyphosate on 1 April, 2021 to prepare for the 2021 winter crop.

During winter 2021, the site will revert to the cereal phase of the rotation, with selected plots sown to treatments with greater diversity. Actual species determination for the remaining years of the trial will be subject to crop performance and with consideration to the specific range of weeds, pests or diseases that require active management.

Delays associated with soil analysis means not all soil function results were available in time for publication of this article.

Results and comments

2020 summer cover crop treatments

Summer cover crops emerged following a rainfall event during January 2020 and produced 0.6–0.7t/ha dry matter (DM) biomass before being sprayed out with glyphosate on 18 March 2020 (see report in Research for the Riverine Plains, 2020, p33).

A range of soil measurements, including available soil water, was taken for the plots sown to canola during 2020 by soil coring at a depth of up to 1m when the winter crop (canola) was sown on 13 May, 2020. The peola plots (Treatments 5 and 9) were excluded from statistical analysis due to difficulty in comparing treatments.

Impact of crop rotation on soil function and soil water at sowing

Plots sown to pulse treatments during 2019 (field peas for grain, field peas for brown manure or mixed-species brown manure) were sampled for soil moisture and compared against the control (wheat) during May 2020. There was no difference between soil moisture overall in the (bulked) 0–90cm increment (Table 2), however, there was significantly more moisture available in the control (Treatment 1) for the 0–10cm increment compared with the other pulse rotation treatments (Figure 1). For the 60–90cm depth increment, there was significantly less moisture available in the control (wheat) and field pea for grain treatments compared with the brown-manure treatments and this difference likely reflects late-season water use at depth during 2019 in crops grown for grain compared with those terminated in spring by brown manuring.

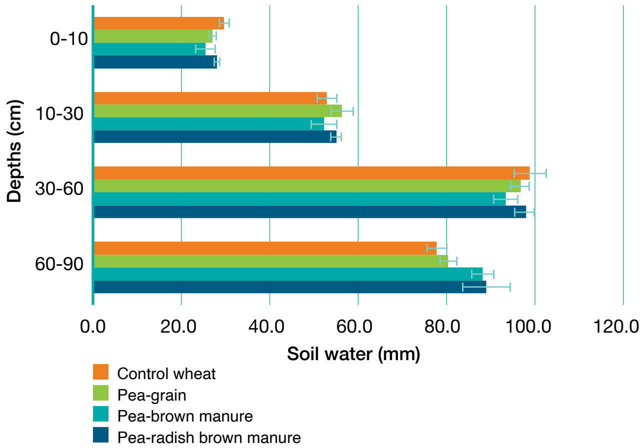
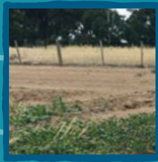
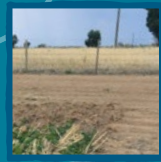


FIGURE 1 Effect of 2019 winter control and pulse treatments (pulse crop – field pea, brown manure – field pea, brown manure mix – field pea plus tillage radish) on available soil water on 13 May, 2020

Cover crop treatments before being sprayed out with glyphosate on 1 April, 2021. a) Cover crop mix 1; b) Cover crop mix 2 at Burramine, Victoria.





When moisture availability was compared between the wheat and increased diversity treatments (Table 3), there was significantly less moisture available overall in the plots sown to wheat plus mixed species cover crop (CC mix 2) at sampling, compared with the control and wheat undersown with sub-clover treatments. This may be related to the increased rooting depth and rooting patterns of the different species in CC mix 2.

For the rotation treatments sown to pulses during 2019, mineral nitrogen at sowing was significantly lower in the control (119kg/ha) and mixed brown-manure treatments (field peas and tillage radish, 128kg/ha) than the field peas for grain (179kg/ha) and field peas for brown-manure treatments (223kg/ha). This likely reflects the higher rate of decomposition and release of nitrogen in the field pea treatments compared with the wheat and mixed-species brown-manure treatments.

There was no statistical difference in mineralised soil nitrogen between the increased diversity (wheat and summer cover crop or undersown treatment plots) when measured during May 2020.

Predicta B testing in the wheat and increased diversity treatments showed that pythium and take-all were significantly higher in the wheat plus summer CC mix 2 treatment compared with the undersown wheat and wheat plus CC mix 2 treatments. The reason for this difference is currently unclear.

2020 winter crop treatments

Emergence and biomass at flowering

Plentiful opening rains during autumn 2020 meant that for plots in the wheat (2019) – canola (2020) rotation canola establishment rates and canola biomass at flowering was not significantly different to the other treatments (Table 2).

TABLE 2 Effect of rotation on water use, soil nitrogen at sowing, emergence, DM and yield for plots sown to canola in 2020 at Burramine, Victoria

	Rotation treatments			
Treatment reference	1	2	3	4
Rotation	Control (2019: wheat, 2020: canola)	Pulse for grain (2019: field pea, 2020: canola)	Pulse brown manure (2019: field pea, 2020: canola)	Brown manure mix (2019 field pea/ tillage radish, 2020 canola)
Water at sowing (mm)	261^{a}	262^{a}	260^{a}	271^{a}
Mineral N at sowing (kg N/ha)	119^{a}	179^{b}	223^{c}	128^{a}
Emergence (plants/m²)	24^{a}	30^{a}	29^{a}	31^{a}
Canola biomass at flowering (t/ha)	4.5^{a}	5.6^{a}	7.7^{a}	5.3^{a}
Canola yield (t/ha)	1.76^{a}	1.86^{a}	2.05^{a}	2.11^{a}

TABLE 3 Effect of integrating plant species within the wheat – canola rotation as summer cover crops or wheat undersown with clover treatments on water use, soil nitrogen at sowing, disease levels, emergence, DM production and yield at Burramine, Victoria, 2020

Integrated plant species treatments within the wheat/canola rotation				
Treatment reference	1	6	7	8
Rotation	Control (2019: wheat, 2020: canola)	Intercrop – undersown wheat (2019: wheat undersown with sub-clover, 2020: canola)	Cover crop mix 1 (2019: wheat, 2020 CC mix 1, 2020: canola, 2021 CC mix 1)	Cover crop mix 2 (2019: wheat, 2020 CC mix 2, 2020: canola, 2021 CC mix 2)
Water at sowing (mm) (P = 0.07)	261^{b}	257^{b}	245^{ab}	225^{a}
Mineral N at sowing (kg N/ha)	119^{a}	137^{a}	124^{a}	105^{a}
Pythium	41^{ab}	16^{a}	16^{a}	77^{b}
Take all (0.07)	0^{a}	0^{a}	0^{a}	0.4^{b}
Emergence (plants/m²)	24^{a}	27^{a}	26^{a}	21^{a}
Canola biomass at flowering (t/ha)	4.5^{a}	4.5^{a}	5.7^{a}	3.1^{a}
Canola yield (t/ha)	1.76^{a}	1.74^{a}	1.85^{a}	1.48^{a}

* Pythium and take all disease levels measured by Predicta B testing.

There was also no significant difference in canola emergence for treatments that used summer crops or wheat undersown with sub-clover to increase diversity in the rotation (Table 3). However, the canola sown into the CC mix 1 plots emerged somewhat poorly relative to the other treatments and was affected by high levels of volunteer buckwheat. Similarly, poorer canola emergence was observed in the plots sown to CC mix 2, due to the later-than-ideal chemical termination of summer crops, which resulted in seed set.

Canola biomass accumulation was measured as DM at flowering for all treatments. The highest biomass production was measured in the brown manure treatment (7.7t/ha), however this was not significantly different to the wheat plus CC 2 mix, which produced the lowest biomass at flowering (3.1t/ha)

Yield

There was no difference in canola yield between the control and the pulse rotation treatments (Table 2).

For the increased diversity through summer cropping or undersowing treatments, canola yield was highest in the wheat plus summer CC mix 1 treatment (1.85t/a), however this was not significantly different to any other treatment, including the control, which represented a summer fallow (1.76t/ha) (Table 3). The additional water used by the wheat plus 2020 summer CC mix 2, reduced canola yield by 10 per cent (1.48t/ha), however this was not significantly different to the yield of the other treatments.

The two peola treatments yielded similarly during 2020, with the intercropped peola (2019: wheat, 2020: peola) treatment yielding 1.97t/ha and the maximum diversity (2019: wheat, 2020 CC mix 1, 2020: peola, 2021 CC mix 1) yielding 1.92t/ha. The peola yield represents both the canola and pea yields combined together.

2021 summer cover crop

Dry matter production

Due to a lack of rainfall, the summer cover crop treatments were not sown until late January 2021. The late sowing, combined with poor follow-up summer rainfall received after crop emergence, affected cover crop biomass production. There were approximately eight weeks of growth from the time of cover crop emergence until crop termination on 1 April, 2020, with no significant differences in biomass production observed between the two treatments (Figure 2).

Following the termination of the summer cover crops, soil function samples were taken from the control and cover crop plots. There was a noticeable difference in the ground conditions observed at sampling, with the control plots being much harder and it was more difficult to insert the probe into the ground.

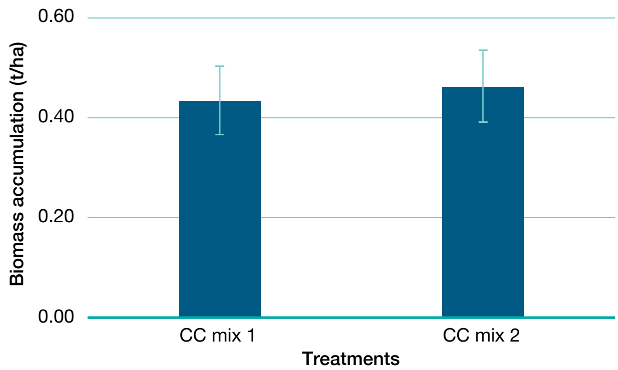


FIGURE 2 Biomass accumulation of summer cover crop treatments (CC mix1: medic and buckwheat and CC mix 2: sorghum, millet, forage rape and oilseed radish (tillage radish)) after eight weeks of growth, before being sprayed out with glyphosate on 1 April 2021 at Burramine, Victoria

Observations and comments

The use of a pulse in the rotation, or inclusion of a brown manure crop, substantially increased mineral nitrogen at the sowing of the subsequent canola crop, but the economic benefits of these alternatives are yet to be explored.

Summer cover crops can be incorporated into the system, but biomass production to date has been low due to low summer rainfall and hot summer conditions. The summer cover crops sown during 2020 impacted on water availability at 2020 winter crop sowing, as well as levels of some diseases in the soil, but no significant impact on canola grain yields was observed.

Soil function and winter grain yields will be monitored during upcoming seasons to determine whether impacts of summer cover crops become apparent over the longer term.

Acknowledgements

This trial is part of the *Plant-based solutions to improve soil performance through rhizosphere modification* project, led by Southern Cross University. The project is supported by the Cooperative Research Centre for High Performance Soils whose activities are funded by the Australian Government's Cooperative Research Centre Program. The project is also supported by the Goulburn Broken Catchment Management Authority's 'From the Ground Up' program through funding from the Australian Government's National Landcare Program.

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Demonstrating opportunities for improved pulse production and nitrogen fixation

Kate Coffey
Riverine Plains

Key messages

- Sowing rate, rather than inoculation, was the main determinant of faba bean dry matter (DM) production.
- It was estimated the faba beans in this demonstration trial fixed between 101–129 kilograms of nitrogen (N) per hectare based on above-ground DM production.
- High harvest indices (HI) in the trial (48.8–64.09%) indicated a considerable amount of the nitrogen fixed was removed in the grain.
- A new DNA test available to measure Group E and F rhizobia in soil accurately predicted the moderate levels of nodulation measured in the trial.
- Inoculation responses are more likely in soils with lower pH (<pH_{ca} 5.0). Where faba beans are sown into acidic layers at depth, the likelihood of inoculation responses will further increase.

Background and aim

As well as generating income, pulses provide significant benefits to farming systems, with nitrogen (N) fixation boosting the supply of this critical nutrient to subsequent crops. However, not all pulses are adequately nodulated, rendering them unable to reach their nitrogen-producing potential, especially on acidic soils.

The demonstration trials in this report were sown as part of a GRDC investment aiming to improve the nitrogen fixation of winter pulse crops and to promote their wider adaptation and adoption. This is the second year of the project, which focussed on the impacts of soil acidity on nitrogen fixation. The project also aims to promote effective inoculation and pulse management practices, and raise awareness and knowledge around pulse nodulation and nitrogen fixation.

A number of organisations across the GRDC Southern Region are involved in the project including: Mallee Sustainable Farming (lead organisation), the South Australian Research and Development Institute (SARDI), AgCommunicators, Bates Ag, Rural Directions, Southern Farming Systems, Birchip Cropping Group, Ryder Ryan Research Pty Ltd, Moodie Agronomy, Riverine Plains Inc, Southern Pulse Extension, SARDI and Trengove Consulting.

In order to demonstrate best-practice inoculation in pulse crops on acid soils in northern Victoria, a demonstration site at Murchison was sown to faba beans. Inoculant treatments were decided in consultation with the host farmer and the nitrogen-fixation project research team.

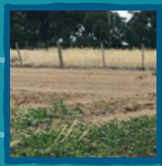
The results from the site have been promoted through the GRDC southern pulse extension project.

Method

The range of inoculation and nutrient treatments are shown in Table 1.

Two sowing rates (140 and 160kg/ha) were also tested to see if there would be any effect on nitrogen fixation or yield. The site was soil sampled on 28 February, 2020, (0–10cm depth) and samples were sent to SARDI for pH and background rhizobia level testing. Background rhizobia level tests were carried out using a plant trap method in pots and using DNA testing to estimate rhizobia number per gram of soil. Soil samples were also collected at 5cm increments down to 20cm to identify the location and extent of any acid soil layers.

Two spray passes (2 x 28m) of sodium molybdate (75g/ha) were applied to a section of the trial, across all treatments by boom spray after sowing, to see if there was any response to molybdenum applied to the soil rather than to the seed. The demonstration trial (un-replicated) was sown at Murchison on 17 May, 2020, using the host farmers' sowing equipment. Nodulation was assessed on 11 August, 2020. Six plants per treatment were dug out from six positions, soaked and rinsed, nodules counted and ascribed a score using the method described in Table 2. Dry matter samples and pod counts were taken on the 21 October 2020 at mid pod fill. Four samples were taken from each treatment, weighed, dried and averaged. Results from the demonstration trial were analysed via simple linear regression using Statistix 8.0. A subsample from the DM cuts will be used to determine the amount of nitrogen in the shoots from symbiotic nitrogen fixation in a process called Nitrogen 15 analysis. This will show how much nitrogen in the faba bean plant came from the atmosphere (i.e. fixed) and how much came from the soil (results not available at the time of publication).



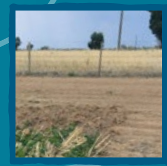


TABLE 1 Site information, soil type, pH, background rhizobia and details of experimental treatments for the faba bean demonstration trial at Murchison, Victoria, 2020

	Demonstration 1		
Pulse crop	Faba beans		
Location	Murchison, Victoria		
Cultivar	Samira		
Soil type	Mixed		
Soil pH ($CaCl_2$) 0–10cm	5.5		
Soil nitrogen (0–60cm)*	140kgN/ha		
Background rhizobia levels	Low levels lentil/faba* bean rhizobia; ~ 284/g soil		
	Treatment	**Sowing rate (kg/ha)**	**Plot size (m)**
	Nil inoculation	140	18m x 660 (1.18ha)
	Acid-tolerant peat inoculant (strain SRDI-969)	140	18m x 660 (1.18ha)
	TagTeam® peat inoculant and molybdenum-treated seed (Mo 250P™ @ 0.7L/t)	140	18m x 660 (1.18ha)
	TagTeam peat inoculant 1	140	18m x 660 (1.18ha)
	TagTeam peat inoculant 2	165	18m x 660 (1.18ha)

* Soil samples were collected for soil nitrogen testing during late May, 2020, from the paddock where the trial was located (Note: samples were not taken from the actual trial site).

TABLE 2 Nodulation scorecard used to assess the number and distribution of nodules from plants collected across the demonstration treatments

Nodule score	Distribution of effective nodules	
	Crown (top 5cm)	>5cm from tap root
0	0	0
0.5	0	1–4
1.0	0	5–9
1.5	0	>10
2.0	<10	0
2.5	<10	<10
2.75	<10	>10
3.0	>10	0
4.0	>10	<10
5.0	>10	>10

Source: Brockwell and Gault (1977) in AGrow, Final technical report, 2018, southern NSW Trials, Improving nitrogen fixation in lentils.

The plots were harvested using the farmer's header, using a 12m wide section harvested from the middle and along the full length of each treatment.

Results

The paddock at Murchison had a continuous cropping and liming history spanning more than 10 years. Lime was applied at a rate of 2.5t/ha during 2012 and again during 2017. Pulse crops have not previously been grown in the paddock, however sub-clover would have been present prior to 2010. Although the 0–10cm soil test indicated a pH of 5.5, soil pH decreased to 4.4 at the 5–15cm depth, with aluminium (Al) percentage increasing to potentially damaging levels (Figure 1). This indicated the previously applied lime had not moved through the profile into the root zone.

Although faba beans had not previously been grown at the site, pre-sowing tests indicated low background levels of rhizobia in the soil (284 rhizobia/g soil, 0–10cm), which was possibly due the presence of a species that hosts Group E or F rhizobia in the paddock prior to 2010. A moderate level of nodulation (score 2.3) was measured in the uninoculated treatment (Table 3). Nodulation scores for the remaining

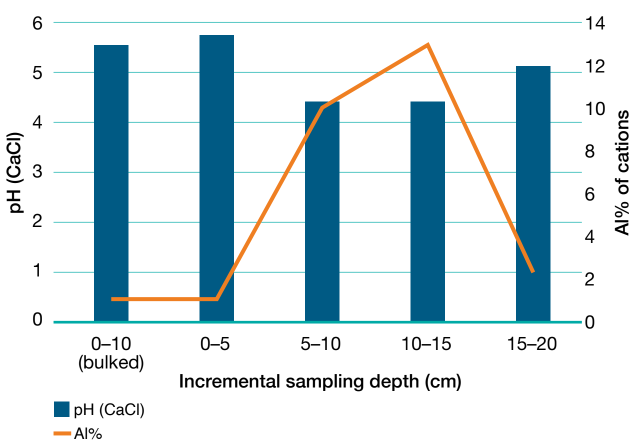


FIGURE 1 Soil test results for the Murchison demonstration paddock showing soil pH and aluminium percentage at different depth increments

Note: The bulked 0–10cm sample shows different pH and aluminium results compared to when the sample was divided into 5cm increments (0–5 and 5–10cm). This is due to lime being concentrated in the top few centimetres of soil and not having moved down the soil profile.

TABLE 3 Faba bean plant density, nodulation score, dry matter production, pod count, yield, estimated nitrogen fixation and harvest index for the faba bean demonstration trial at Murchison, Victoria, 2020

Treatment	Plant density (plants/m²)	Nodule score (1–5)	Dry matter (t/ha)	Pod count (pods/m²)	Yield (t/ha)	Estimate of nitrogen fixed (kg N/ha)#	Harvest index (%)
Nil inoculation	15	2.3	8.07	273	3.94*	129	48.88
Acid-tolerant inoculant (strain SRDI-969)	20	3.8	7.58	231	4.35	121	57.39
TagTeam peat inoculant and molybdenum treated seed (Mo 250P)	20	0.8	7.47	281	4.34	120	58.09
TagTeam peat inoculant 1 (sowing rate 140kg/ha)	27	1.7	6.32	243	4.03*	101	63.76
TagTeam peat inoculant 2 (sowing rate 165kg/ha)	25	2.2	6.99	236	4.48	112	64.09

* Both the nil inoculation and TagTeam peat inoculation 1 (sowing rate 140kg/ha) treatments had wheel tracks (from a spray boom), which would have reduced harvested yield.

Estimated nitrogen fixation based on 16kg nitrogen per tonne of DM produced.

treatments ranged from 3.8 (rhizobia strain SRDI-969 treatment), to less than 1.8 for the TagTeam peat and molybdenum seed treatments.

Plant densities approximated targeted figures of 20 plants/m² for sowing rates of 140kg/ha and 25 plants/m² for the sowing rate of 165kg/ha. Plant density was lowest in the uninoculated treatment, but was not significantly correlated with nodulation overall.

Dry matter production ranged from 6.32–8.07t/ha and was significantly and inversely correlated with plant density (R^2=0.96, P=<0.01), but not nodulation. Grain yield was not significantly correlated with either density or nodulation.

There were no observed differences in yield or DM from applying molybdenum to either seed (Table 3) or as a post-sowing spray (based on visual paddock assessments).

Observations and comments

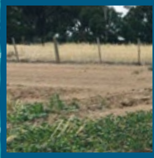
There was a significant inverse relationship between plant density and maximum DM production, which was unexpected. Disease levels were low in the paddock and the reduction in DM production with higher plant density in this trial may have been due to soil type variability across the paddock as the treatments moved from east to west, rather than a result of plant density *per se*.

Nitrogen 15 isotope analysis of the faba beans and a reference plant (lupin) was not completed before publishing. As a result, the rate of nitrogen fixation was estimated based on 16kg N/tonne of above-ground DM (Glover *et al*, 2013). The estimated amount of nitrogen fixed in treatments ranged from 101–129kg N/ha (with actual results to be confirmed using nitrogen 15 analysis). The high harvest indices in the demonstration trial indicated a considerable amount of nitrogen fixed was removed in the grain.

Molybdenum is an important micronutrient in the nitrogen fixation process and it is less available in acid soils. The seed-applied molybdenum treatment had the lowest nodule count, which raised questions about the compatibility of the form of molybdenum applied and the rhizobia. Further investigation is needed, as this is a common practice in the region.

While there was some variation in nodulation across treatments, the demonstration trial showed that there was no benefit during 2020 from applying rhizobia (pending nitrogen fixation results) because there was no significant correlation between nodulation and DM or yield. In part, this was due to the presence of a low background level of rhizobia, which resulted in moderate nodulation in the untreated control. In this trial, the level of nodulation and levels of background rhizobia were sufficient to support faba bean growth, but this is unlikely to be the case at lower pH and rhizobia levels as found in other trials (see below). Available soil deep soil nitrogen (0–60cm) also may have moderated any symbiotic responses, as research indicates plants will access easy-to-source nitrogen before fixing nitrogen.

Acid-tolerant rhizobia (Group F for faba beans and lentils) are being trialled to verify their performance across a range of environments before they are released to pulse growers. Although the acid-tolerant rhizobia used in this demonstration resulted in effective nodulation, they did not increase yield, but have done so in other trials where background rhizobia are absent and where average soil pH in the top 10cm is below pH 5.0.



Soil testing for E and F rhizobia number in soil is now available through SARDI. In both years of demonstration trials (2019 and 2020), background soil testing corresponded well to actual nodulation results observed in the field and this indicates background rhizobia testing could provide growers and advisors with accurate information regarding the requirement for inoculation. The test may also have application in understanding how acid layers, such as those measured in this trial at a depth of 5–15cm, affect rhizobia number and subsequent nodulation. Where beans are sown and germinate in the acidic layer, inoculation is more likely to be beneficial.

References

Glover *et al*, 2013, *Break crops in cropping systems: impacts on income, nitrogen and weeds in Research for the Riverine Plains*, 2013.

Acknowledgements

Increasing the effectiveness of nitrogen fixation in pulse crops through extension and communication of improved inoculation and crop management practices in the southern region is a GRDC investment led by Mallee Sustainable Farming Systems. The author also wishes to acknowledge the technical assistance provided by Ross Ballard and Liz Farquharson (SARDI). Thank you to our farmer co-operators, the Menhennett family (Murchison).

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Southern Pulse Agronomy 2019 trial overview (faba beans, lentils and chickpeas) — Dookie

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Background

Pulses are an important part of many productive, profitable and sustainable farming systems across southern Australia. During recent seasons, there has been rapid and successful uptake of new pulse varieties with improved adaptability and novel management traits. In addition, pulses are expanding into the low rainfall zone (LRZ) and high rainfall zone (HRZ) where they have traditionally been less adapted.

Building on previous projects, through targeted research and development activities, the project *'Understanding the implications of new traits on adaptation, crop physiology and management of pulses in the southern region'* will contribute to the broader understanding of pulse growth and performance under changing environmental and management conditions. This knowledge will lead to improved yield and yield stability of pulses, ultimately leading to increased profitability and increased adoption of new varieties by growers.

Project objectives

This overarching project delivers research and development activities across South Australia and Victoria to assess new traits for modern farming systems including:

- herbicide tolerance and weed ecology
- disease management
- canopy management (biomass and architecture)
- harvest quality.

From these activities, the project will develop variety specific agronomy packages (VSAP), addressing major and expanding production zones in alignment with GRDC's agroecological zones including: SA Mid-North, Yorke Peninsula and Lower Eyre Peninsula; SA Bordertown and the Victorian Wimmera; SA and Victoria's Mallee, including Upper Eyre Peninsula and the Victorian high rainfall zone.

As part of this overarching project, four trials were sown at Dookie during 2019 — a faba bean variety x sowing rate trial, a faba bean disease management trial, and lentil and chickpea trials. The results of these trials are presented in this report.

Select trials were repeated during 2020, however the 2020 reports were not available in time for inclusion in this publication.

Aim

To determine the best faba bean varieties, sowing rates and disease management strategies for north-east Victoria.

To identify the yield potential of chickpeas and lentils grown in north-east Victoria.

Seasonal conditions

The Dookie Southern Pulse Agronomy trials were sown into a dry seedbed and emerged after a rainfall event on 3 May, 2019. Establishment was very good across all trials.

Monthly rainfall for 2019 was average-above average from May – July, however it was extremely low from August — November for north-east Victoria. Dookie experienced a decile 2 season (Figure 1). The late rainfall events during October ensured most crops were harvestable, while low temperatures though spring, and the ability of the crops to grow sufficient canopies through winter, improved grain yields. During the reproductive phase, conditions were generally cool, however there were some frosts, which affected pod set across all crop types. There were no major heat events through October, while maximum temperatures were 2 degrees higher than the long-term average.

Table 1 describes the results of soil testing carried out at the trial site.

Faba beans were evaluated in the 2019 Dookie Southern Pulse Agronomy trial.

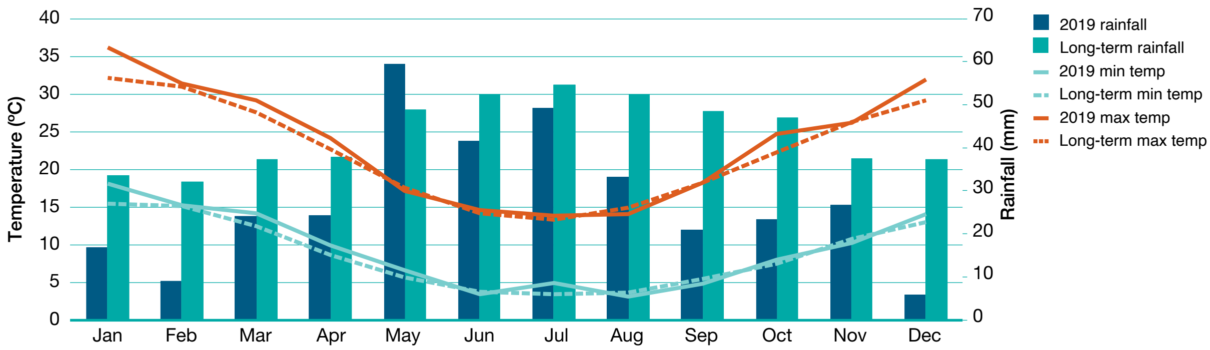


FIGURE 1 Average monthly rainfall, average monthly maximum and minimum temperatures and absolute maximum or minimum at the at the Dookie trial site (MRZ, Victoria) in 2019 compared with the long-term average for Dookie

TABLE 1 Soil characteristics of the Dookie trial site in 2019

Depth (cm)	NH_4-N	NO_3-N	P	K	S	EC (dS/ m)
	(mg/ kg)					
0–10	5.00	41.5	81	302.5	21.68	0.14
10–20	1.75	12.0				0.09
20–40	1.50	9.0				0.10
40–60	1.50	4.5				0.34
60–80	1.50	2.0				0.32
80–100	1.25	2.0				0.36
100–120	1.00	2.0				0.45

Depth (cm)	OC	Total N	Total C	pH		Clay	Coarse sand	Fine sand	Sand	Silt
	(%)			($CaCl_2$)	(H_2O)	(%)				
0–10	1.41	0.14	1.87	5.35	6.15	36	19	27	46	18
10–20				5.80	7.02	62	6	24	30	8
20–40				6.62	7.70	74	5	11	15	10
40–60				7.40	8.47	66	6	15	21	13
60–80				8.08	9.10	68	4	16	20	12
80–100				8.05	9.15	65	5	13	18	18
100–120				8.10	9.12	61	6	22	28	11

Trial 1: Dookie faba bean fungicide strategy x plant density and fungicide strategy trials (2019)

Michael Straight, Kat Fuhrman and Aaron Vague
FAR Australia

Sowing information

Sowing date: 29 April, 2019
Stubble height: 30cm
Row spacing: 22.5cm
Fertiliser: 50kg/ha as MAP

Key points

- In a season with little disease pressure, there were small varietal differences in chocolate spot symptoms throughout the season, although they did not manifest into yield differences.
- Sowing rate was critical to maximising yield during 2019. Lower sowing rates produced significantly lower yields when compared with higher rates.
- Sowing rate had a major effect on crop architecture, with lower sowing rate treatments podding over a larger portion of the stem, with a higher pod number, but lower overall dry matter (DM) harvest than the higher sowing rates.
- During 2019, grain yields were high (3.36 and 2.96t/ha) considering the dry finish to the season.
- Slower-maturing varieties held a green canopy for longer, but could not convert the green leaf area into yield due to the dry spring conditions.
- Varietal selection is the key to minimising disease, however, in low disease-pressure situations less disease doesn't automatically mean higher yields.

Aim

To investigate the adaptability of a range of faba bean varieties and breeding lines to different plant densities and fungicide programs.

Treatments

Varieties: See tables 2 and 3
Plant densities: See tables 2 and 3
Fungicide strategies: See tables 4 and 5

TABLE 2 Seed weight and estimated sowing rate to achieve target plant densities for each of the varieties sown in the fungicide strategy x plant density trial at Dookie, Victoria, 2019

Variety	Seed weight (g/100 seeds)	Target plant density (plants/m²)		
		15	25	35
		Estimated sowing rates (kg/ha)		
PBA Samira	77	138	223	315
PBA Zahra	72	109	181	253
Farah	55	82	137	191
PBA Amberley (AF11023)	60	107	173	245

TABLE 3 Seed weight and estimated sowing rate to achieve the target plant density sown in the fungicide strategy trial at Dookie, Victoria, 2019

Variety	Seed weight (g/100 seeds)	Target plant density (plants/m²)
		20
		Estimated sowing rates (kg/ha)
PBA Samira	77	177
PBA Bendoc	59	135
PBA Zahra	72	145
Farah	55	109
Fiesta VF	64	128
PBA Amberley (AF11023)	60	137

Results and discussion — fungicide strategy x plant density trial

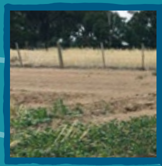
i. Establishment

Average faba bean establishment was slightly below target for the 25 and 35 plants/m² treatments, at 21 and 28 plants/m² respectively. There was no interaction between sowing rate and variety. PBA Samira had the lowest average establishment (19 plants/m²) across the sowing rate treatments, while Farah had the highest (22 plants/m²) (Table 6).

ii. Disease

Interactions between disease and variety or fungicide strategy were insignificant (Table 7).

PBA Amberley, Farah and PBA Zahra had significantly less leaf area infected with chocolate spot in the top part of the canopy than PBA Samira at both 10 and 25 September (Table 8). Green leaf retention (GLR) on 25 September was at least 9.6 per cent higher in Amberley (61.7 per cent) than any other variety.



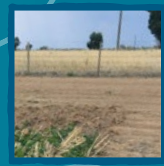


TABLE 4 Treatments and rates in the fungicide strategy x plant density trial at Dookie, Victoria, 2019

	Early (6/8 node)	Early flowering	Mid-late flowering	Post flower
Nil fungicide	Nil	Nil	Nil	Nil
Best practice	Tebuconazole 150 ml	Carbendazim 500ml	Carbendazim 500ml	Carbendazim 500ml
Complete control	Veritas 1L	Aviator 600ml	Carbendazim 500ml	

TABLE 5 Treatments and rates in the fungicide strategy trial at Dookie, Victoria, 2019

	Early (6/8 node)	Early flowering	Mid-late flowering	Post flower
Nil fungicide	Nil	Nil	Nil	Nil
Best practice	Tebuconazole 150 ml	Carbendazim 500ml	Carbendazim 500ml	Carbendazim 500ml
Complete control	Veritas 1L	Aviator 600ml	Carbendazim 500ml	
Old chemistry	Mancozeb 1.5kg	Mancozeb 1.5kg	Mancozeb 1.5kg	Mancozeb 1.5kg
New chemistry	Veritas 1L	Aviator 600ml	Aviator 600ml	

TABLE 6 Establishment of faba bean varieties sown at different rates on 22 May, 2019 in the fungicide strategy x plant density trial at Dookie, Victoria, 2019

Target plant density (plants/m^2)	Actual plant density (plants/m^2)				
	PBA Samira	PBA Zahra	Farah	PBA Amberley	Average
15	13	14	15	14	14
25	18	21	23	20	21
35	26	27	28	29	28
Average	**19**	**21**	**22**	**21**	

LSD (P<0.05) sowing rate x variety = ns; sowing rate = 2; variety = 2.

TABLE 7 Chocolate spot disease score* and green leaf retention of various fungicide strategies in the fungicide strategy x plant density trial at Dookie, Victoria, September 2019

	Chocolate spot (% LAI)			GLR (%)
	10 September		25 September	25 September
Fungicide strategy	Top	Bottom	Top	Bottom
Untreated	0.4	1.1	2.5	60
Best practice	0.1	0.9	2.1	48
Complete control	0.5	0.9	2.4	50
LSD (P<0.05)	**ns**	**ns**	**ns**	**ns**

* 0 – no disease; 100 – dead.

TABLE 8 Chocolate spot disease score* and green leaf retention of different varieties in the fungicide strategy x plant density trial at Dookie, Victoria, September 2019

	Chocolate spot (% LAI)			GLR (%)
	10 September		25 September	25 September
Variety	Top	Bottom	Top	Bottom
PBA Samira	0.5	1.2	2.9	50
PBA Zahra	0.3	1.0	2.1	52
Farah	0.3	1.1	2.4	47
PBA Amberley (AF11023)	0.2	0.6	2.0	62
LSD (P<0.05)	**0.2**	**0.25**	**0.48**	**6.73**

* 0 – no disease; 100 – dead.

iii. Crop architecture

Plant height increased with sowing rate. The tallest variety was PBA Samira (94.5cm), in the 35 plants/m^2 treatment (Table 9). For both PBA Samira and PBA Amberley, the height of the bottom-most pod was lowest in the 15 plants/m^2 treatment. Although pod number and seed weight were highest in the 15 plants/m^2 treatment for both PBA Amberley and PBA Samira, harvested DM was lowest in these treatments. This suggests harvest index (HI) in treatments with lower plant populations (15 plants/m^2) was significantly higher (around 55 per cent) than the HI observed in the treatments with higher plant populations (around 40 per cent).

iv. Grain yield and quality

Grain yields were very good, averaging 2.79t/ha across the trial despite the dry spring. Farah had the lowest seed weight (65g per 100 seeds) but produced the highest yield (3t/ha) (Figures 2 and 3).

There were significant differences in yield between plant density treatments, with the 15 plants/m^2 treatment (2.58t/ha) yielding significantly less than the 25 plants/m^2 treatment (2.85t/ha) and 35 plants/m^2 (2.94t/ha) treatments. Plant densities lower than 25 plants/m^2 resulted in a yield penalty (Figure 3).

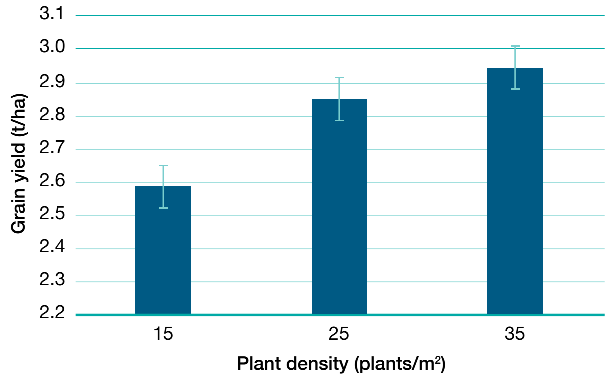


FIGURE 3 Grain yield of faba beans in the fungicide strategy x plant density trial at Dookie, Victoria, 2019

Error bars are a measure of LSD. LSD = 0.13.

Farah had the highest average yield (2.97t/ha), yielding significantly more than PBA Zahra (2.85t/ha), PBA Samira (2.75t/ha) and PBA Amberley (AF11023) (2.6t/ha) (Figure 4).

TABLE 9 Faba bean phenology of new and existing faba bean varieties, and plant population in the fungicide strategy x plant density trial at Dookie, Victoria, 2019

Variety	Plant density (plants/m^2)	Plant height (cm)	Bottom pod height (cm)	Stem length between bottom and top pod (cm)	Pod number	Branches per plant	Dry matter harvest (t/ha)	Seed weight (g/100 seeds)
PBA Samira	15	92.4	36.3	25.8	6.8	3.8	4.26	62
	25	90.2	48.2	16.9	3.9	3.0	6.73	62
	35	94.5	51.5	17.8	4.7	3.3	6.88	61
PBA Amberley (AF11023)	15	83.8	37.3	21.5	6.3	4.3	4.53	60
	25	91.8	45.6	17.8	4.5	3.8	5.19	62
	35	94.3	53.7	13.7	3.9	3.1	6.03	61
LSD (P<0.05)		**6.1**	**8.2**	**7.2**	**1.8**	**0.6**	**1.74**	**ns**

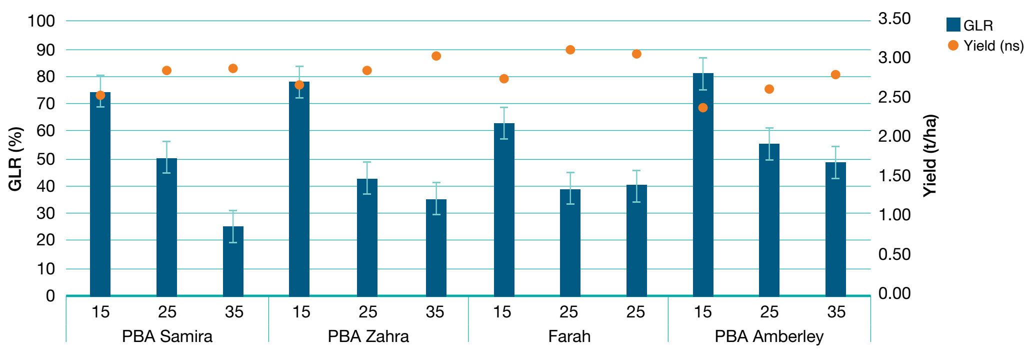


FIGURE 2 Effect of variety* and plant population on green leaf retention (assessed 25 September) and grain yield in the fungicide strategy x plant density trial at Dookie, Victoria, 2019

Error bars are a measure of LSD. LSD GLR = 11.65.

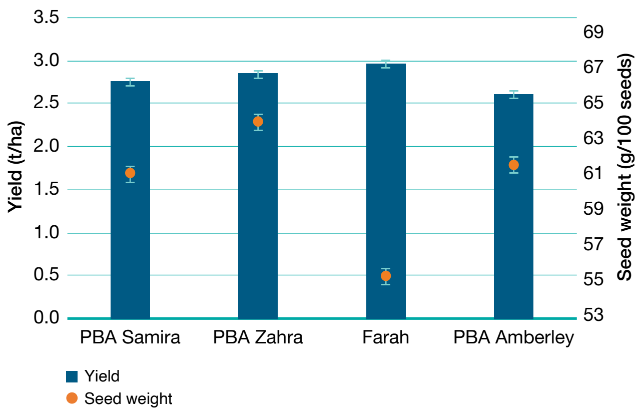


FIGURE 4 Grain yield and seed weight of faba bean varieties* in the fungicide strategy x plant density trial at Dookie, Victoria, 2019

Error bars are a measure of LSD. LSD Yield= 0.08: LSD seed weight = 8.7.

v. Green leaf retention (GLR)

Green leaf retention was closely linked with plant population. Lower plant populations had higher GLR due to lower plant biomass and delayed water use (Figure 2).

There were differences in GLR between varieties, however this did not affect yield. Amberley had the highest GLR, but due to the dry spring, could not convert the late green leaf into yield.

Results and discussion — fungicide strategy trial

i. Establishment

Establishment was reasonably even and reached the target plant densities (Table 10). Although differences between varieties were small, Fiesta (21.7 plants/m²) had significantly higher plant establishment than PBA Amberley (18.3 plants/m²) and PBA Samira (17.9 plants/m²)

ii. Disease

Diseases levels were very low in the trial (Tables 11 and 12) and fungicide strategy had no effect.

TABLE 10 Faba bean establishment on 22 May 2019 in the fungicide strategy trial at Dookie, Victoria

Variety	Establishment (plants/m²)[1]
PBA Samira	18
PBA Bendoc	20
PBA Zahra	20
Farah	20
Fiesta VF	22
PBA Amberley	18
LSD (P<0.05)	**2.1**

[1] Target plant population was 20 plants/m²

TABLE 11 Chocolate spot disease scores* for different faba bean varieties in the fungicide strategy trial at Dookie, Victoria, during September 2019

	Chocolate spot (% LAI)			
	10 September		25 September	
Variety	Top	Bottom	Top	Bottom
PBA Samira	0.5	1.2	0.8	2.1
PBA Bendoc	0.4	1.4	0.7	1.9
PBA Zahra	0.4	1.3	0.3	2.0
Farah	0.3	1.7	0.4	1.8
Fiesta VF	0.6	1.8	0.6	2.4
PBA Amberley	0.1	0.9	0.3	1.3
LSD (P<0.05)	**0.3**	**0.4**	**0.4**	**0.4**

* 0 – no disease; 100 – dead.

TABLE 12 Cercospora disease scores* for different faba bean varieties in the fungicide strategy trial at Dookie, Victoria, during September 2019

	Cercospora (% LAI)		
	10 September	25 September	
Variety	Bottom	Top	Bottom
PBA Samira	1.4	0.2	1.8
PBA Bendoc	1.3	0.1	1.2
PBA Zahra	1.1	0	0.9
Farah	1.6	0.2	1.6
Fiesta VF	2	0.2	1.9
PBA Amberley	0.4	0.1	1.0
LSD (P<0.05)	**0.5**	**0.25**	**0.68**

* 0 – no disease; 100 – dead.

iii. Yield and quality

Fiesta VF yielded significantly more (3.36t/ha) than PBA Samira (3.13t/ha), PBA Zahra (3.08t/ha) and Amberley (2.96t/ha), yielding 0.4t/ha more than PBA Amberley, while having around twice the disease levels.

Seed weight was highest in varieties where yield was lowest. This was because varieties such as PBA Samira, PBA Zahra and PBA Amberley produced significantly less grain, but the grain was significantly heavier — by up to 10g per 100 seeds (Figure 5).

Conclusion

Grain yield in faba beans at Dookie during 2019 averaged around 3t/ha, which was very good given the reasonable start to the season was followed by a harsh, dry finish. The dry seasonal conditions meant fungicide management strategies had no impact on final yields.

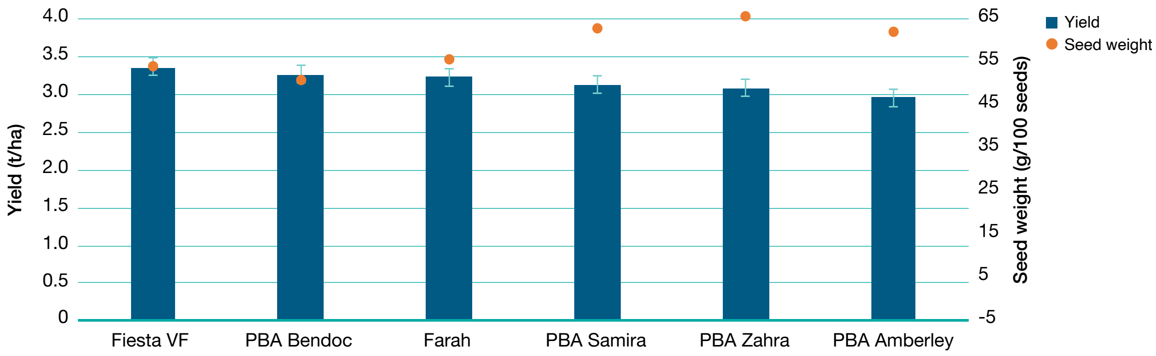


FIGURE 5 Grain yield and seed weight of different faba bean varieties in the fungicide strategy trial at Dookie, Victoria, 2019

Error bars are a measure of LSD. LSD yield = 0.12: LSD seed weight = 1.18.

Trial 2: Dookie lentil germplasm trials (2019)

Michael Straight, Kat Fuhrman and Aaron Vague
FAR Australia

Key points

- Older lentil varieties, such as PBA Jumbo and PBA Jumbo2, were the top yielding varieties in a region where lentils are not traditionally grown.
- Yields were high (1.21–1.97t/ha), considering the dry finish at Dookie during 2019.

Aim

To investigate the adaptability of a range of lentil varieties and breeding lines, specifically on the more acidic soils of the north-east high rainfall zone (HRZ) at Dookie.

Treatments

Varieties: See Table 13.

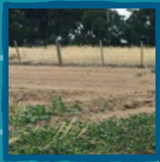
Sowing information

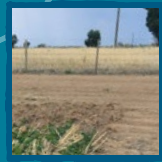
Sowing date: 29 April, 2019
Stubble height: 30cm
Row spacing: 22.5cm
Fertiliser: 50kg/ha MAP

All varieties were sown at 120 seeds/m^2. Treflan was applied as a pre-emergent herbicide and clethodim was applied as a post-emergent herbicide.

TABLE 13 Disease scores on 10 September, harvest index, seed weight, and grain yield of lentils at Dookie, Victoria, 2019

Variety	(% LAI)	Seed weight (g/100 seeds)	Harvest index (%)	Yield (t/ha)
PBA Jumbo		4.5	37	1.97
PBA Jumbo2	2.3	4.9	42	1.96
CIPAL1801	4.7	3.8	42	1.89
PBA Flash	3.7	4.4	35	1.85
PBA Bolt	2.3	4.1	32	1.81
CIPAL1721	2.3	4.2	38	1.80
PBA Hallmark XT	1.7	3.5	37	1.60
PBA Greenfield	1.3	4.8	30	1.47
CIPAL1504	1.3	3.9	26	1.42
PBA Hurricane XT	1.7	3.3	29	1.38
PBA Ace	2.0	4.2	30	1.37
PBA Giant	1.3	5.8	22	1.21
LSD (P<0.05)	**1.8**	**0.3**	**10**	**0.41**





Results and discussion

i. Disease

The percentage of leaf area infected (LAI) by disease were scored on 10 September, with overall disease levels being low (Table 13).

ii. Grain yield and quality

The average seed weight was consistent with market classes for each of the varieties (Table 13).

PBA Jumbo, PBA Jumbo2, CIPAL1801, PBA Flash, PBA Bolt and CIPAL1721 yielded the highest, ranging between 1.80–1.97t/ha (Table 13).

iii. Harvest index

Harvest index decreased with yield across all varieties. This highlights the superior ability of the higher yielding varieties to convert their winter biomass into grain. These factors, combined with a mild spring with few frost events, resulted in high yields across the trial.

Conclusion

Lentils can yield well, despite seasonal factors, in north-east Victoria. Vigorous growth through winter combined with low background disease levels, showed that even in dry conditions lentils are a viable option for growers across the region if prices and rotations are favourable. It is worth noting waterlogging could be a significant issue during wetter seasons. In low a disease-pressure situation, such as was experienced during 2019, PBA Jumbo and PBA Jumbo2 yielded the highest.

Trial 3: Dookie chickpea germplasm trial (2019)

Michael Straight, Kat Fuhrman and Aaron Vague
FAR Australia

Key points

- Desi varieties were among top three highest yielding varieties at Dookie during 2019.
- Grain yields were high (0.90–1.53t/ha) considering the dry finish at Dookie during 2019.

Aim

To investigate the adaptability of a range of chickpea varieties and breeding lines to the acidic soils of the high rainfall zone (HRZ) in north-east Victoria (Dookie).

Treatments

Varieties: See Table 14.

Sowing information

Sowing date: 29 April, 2019
Stubble height: 30cm
Row spacing: 22.5 cm
Fertiliser: 50kg/ha MAP

All varieties were sown at a rate of 35 seeds/m^2. Pre-emergent treflan and post emergent clethodim was applied for grass weed control.

TABLE 14 Dry matter production at maturity, seed weight, grain yield and harvest index of chickpeas at Dookie, Victoria, 2019

Variety	Type	DM production (t/ha)	Seed weight (g/100 seeds)	Yield (t/ha)	HI (%)
CICA1454	Kabuli	6.04	23	1.53	25
Neelam	Desi	3.61	15	1.41	40
Howzat	Desi	3.58	15	1.40	38
CICA1521	Desi	5.32	17	1.36	25
Genesis Kalkee	Kabuli	4.79	29	1.29	27
CICA1352	Kabuli	4.78	27	1.18	28
D11022>F101>13F3TMWR2005	Desi	4.56	16	1.16	23
PBA Striker	Desi	5.10	17	1.14	22
Genesis090	Kabuli	3.96	21	1.13	23
PBA Monarch	Kabuli	4.17	27	1.05	29
PBA Maiden	Desi	4.12	16	0.92	23
D12084>14F3TMWR2AB008	Desi	3.77	15	0.90	25
LSD (P<0.05)		**1.42**	**1.6**	**0.22**	**8.3**

Results and discussion

i. Dry matter production at harvest

Dry matter production (t DM/ha) varied across seed types and varieties. The Kabuli variety CICA1454 produced almost twice as much DM (6.04t DM/ha) at harvest than the highest-yielding Desi variety, Neelam (3.61t DM/ha) (Table 14). Despite large differences in biomass production, both varieties achieved similar grain yields and were the highest yielding for each chickpea type.

ii. Grain yield and grain quality

Neelam, Howzat and CICA1521 were the highest yielding Desi varieties, with yields ranging from 1.40–1.36/ha. Of the Kabuli varieties, CICA1454 (1.53t/ha) yielded 18% more than Genesis Kalkee (1.29t/ha) (Table 14). As expected, Kabuli varieties had higher seed weights than Desi varieties. Genesis Kalkee had the highest seed weight 29g/100 seeds whereas the Desi variety Howzat had a seed weight of 15g/100 seeds.

iii. Harvest Index

Harvest indices were higher in the Desi varieties, Neelam and Howzat than all other varieties. There is a correlation between HI and yield in Desi chickpea varieties.

Conclusions

Chickpeas were a viable crop for the north-east region of Victoria during 2019, despite the dry spring. Low background disease pressure and the dry finish meant little-to-no yield penalty occurred as a result of disease. The large canopies produced by some Kabuli types caused some of these varieties to experience water stress from flowering until maturity; resulting in yield loss.

Acknowledgments

The research undertaken as part of the GRDC-funded Southern Pulse Agronomy project is made possible by the significant contributions of growers through both trial cooperation and the support of the GRDC. The authors would like to thank these growers for their continued support. The authors would also like to gratefully acknowledge SARDI Plant Pathology and Soil Biology groups for their scientific input and assistance, as well as advisors and grower groups involved in the project.

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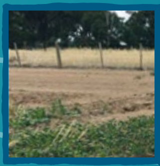

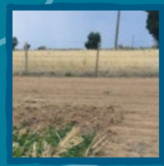

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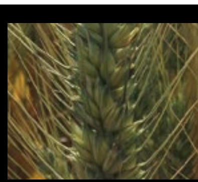

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Hyper-yielding crops: disease management and germplasm interactions

Tom Price and Nick Poole
FAR Australia

The following article is based on results from the southern NSW hyper-yielding crops research program, which is a national GRDC investment taking place across the higher yielding regions of southern Australia. The research is taking place at Wallendbeen, NSW, at an altitude of 540m, which naturally creates a generally cooler, longer-season environment for growing high-yielding crops. At this altitude, disease infection can be delayed until later in the season compared with lower altitudes in the Riverine Plains region. Please note these are first-year results.

Key points

- In seasons that favour higher yield potential, disease management is one of the most important management factors for growing high-yielding cereal crops.
- Irrespective of the fungicide strategy applied in this trial, the feed winter wheats RGT Accroc and Anapurna significantly out-yielded all other cultivars and achieved more than 10t/ha with fungicide input.
- There was a significant interaction between cultivar and fungicide management strategy, with the stripe-rust-susceptible cultivars, LRPB Trojan and DS Bennett, yielding an additional 5.27t/ha and 3.07t/ha, respectively, when fungicide was applied at flag leaf emergence (GS39). This compared to a response of less than 1t/ha with most other less susceptible cultivars.
- Septoria tritici blotch (STB) was the principal disease observed in untreated crops of Scepter and Beckom, while stripe rust was the main disease in LRPB Trojan, DS Bennett, Coolah, RGT Accroc and Catapult. Other cultivars were subject to low levels of both stripe rust and STB disease pressure.
- LRPB Trojan, Catapult, Coolah and DS Bennett yielded significantly more when four units of fungicide were applied (seed treatment and three foliar fungicides), compared with a single spray at flag leaf emergence (GS39).
- Where genetic resistance in a wheat cultivar is not sufficient to enable fungicide decisions to be delayed until flag leaf emergence (GS39), look to target the following key timings for fungicide intervention: first node (GS31), flag leaf emergence (GS39), with an optional third application at head emergence (GS59).
- Avoid repeated use of the same fungicide active ingredients. In the case of the newer Group 11 strobilurins (QoIs) and Group 7 succinate dehydrogenase inhibitors (SDHIs), restrict application (where possible) to just one per season in order to slow and prevent the selection of resistant strains.

Aim

This trial aims to develop profitable and sustainable approaches to disease management for high yielding wheat varieties grown in regions with higher yielding potential.

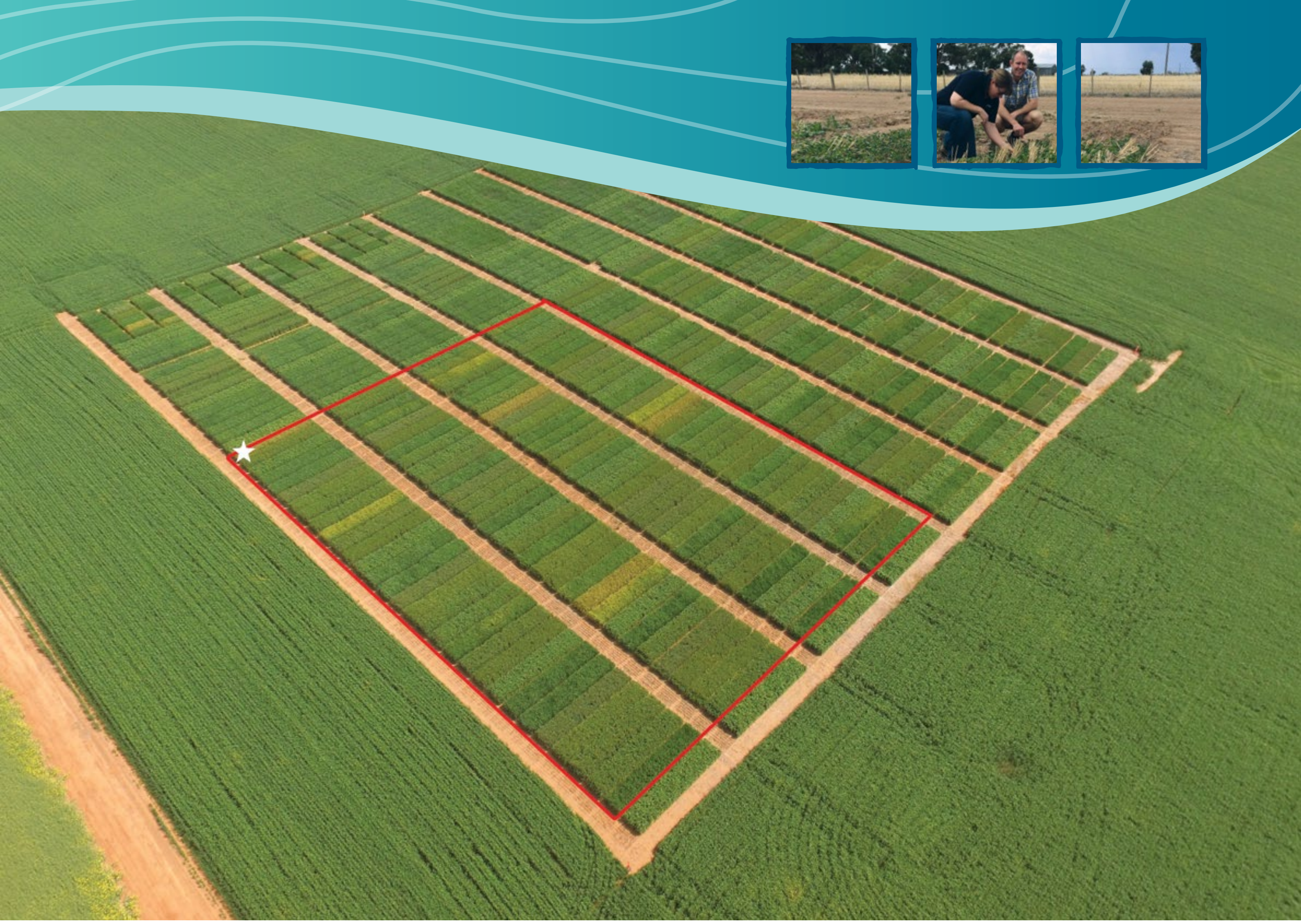
Method

During 2020, a replicated small plot trial was established at the NSW Hyper-yielding crops research site at Wallendbeen, New South Wales, as part of the national GRDC funded Hyper-yielding crops (HYC) project, led by FAR Australia.

This trial, sown 21 April, 2020, assessed the performance of 10 wheat cultivars (five of which were sown across all HYC sites nationally, with the remaining five cultivars selected specifically for their adaptation to the region). Both winter and spring germplasm was evaluated, with cultivars having a variety of disease ratings to fully assess the yield potential of these cultivars under different disease management strategies (Table 1).

Each cultivar was exposed to three different levels of disease management: an untreated control, a single fungicide spray and a full fungicide control package, with details of each treatment presented in Table 2. Other than fungicide application, all other management applications were standardised across the trial to maximise yield potential as per the seasonal conditions.

Sowing date: 21 April, 2020
Harvested: 14 December, 2020
Rotation position: First cereal after canola (2019)
Rainfall: GSR 587mm (April – October)
Soil mineral nitrogen: (10 June, 2020)
0–60cm: 68.5kg N/ha



Outline of Wallendbeen trial, 8 October 2020, white star denotes first plot.

TABLE 1 Cultivar, type and disease ratings of wheat cultivars sown at Wallendbeen, NSW, 2020

Cultivar	Type	Disease rating		
		Stripe rust	Septoria tritici blotch	Yellow leaf spot
LRPB Trojan	Mid – slow spring	S-VS	MS	MS-S
Scepter	Mid spring	MS-S	S	MR-MS
LRPB Nighthawk	Slow spring	MR	MS-S	MR-MS
Anapurna	Slow winter	R-MR	MR-MS	MR-MS
RGT Accroc	Slow winter	R-MR	MR-MS	MR-MS
Beckom	Mid spring	MR-MS	S	MS-S
Catapult	Mid – slow spring	MR-MS/S-VS	MS-S	MR-MS
EGA Gregory*	Mid – slow spring	MR	MS-S	S
Coolah*	Mid – slow spring	R-MR	MS-S	MS-S
DS Bennett	Mid winter	S	MS-S	MR-MS

Note: The first five cultivars listed were standard to all sites across the HYC project nationally, with the remaining five cultivars chosen for their adaptation to the region.
VS = Very susceptible, S = Susceptible MS = Moderately susceptible, MR = Moderately resistant, R = Resistant.
Ratings from most recent data source: Cereal disease guide Victoria 2021.
* Rating from Winter crop variety sowing guide NSW 2020.

TABLE 2 Fungicide treatment of wheat cultivar trials sown at Wallendbeen, NSW, 2020

Crop stage	Unsprayed	Single spray	Three spray (complete control)
Seed treatment	Vibrance/Gaucho	Vibrance/Gaucho	Vibrance/Gaucho + Systiva
GS31	–	–	Prosaro 300ml
GS39	–	Amistar Xtra 800ml	Amistar Xtra 800ml
GS 59–61	–	–	Opus 500ml

Note: All fungicide treatments received a seed dressing for smuts/bunts and insecticide as Gaucho.

Results

i. Phenology

For the spring cultivars, there was little difference in the time to reach the start of stem elongation (first node — GS31) with the fastest spring Scepter and Beckom being the earliest varieties to reach GS31 (12 July). The winter varieties reached GS31 significantly later, with the earliest being RGT Accroc and DS Bennett on 11 August, followed by Anapurna on 15 August.

Similarly, the spring-type varieties started to flower at about the same time (25 September), while the winter varieties started flowering much later. RGT Accroc was the first winter type to start flowering (12 October) and DS Bennett was the last (17 October).

The slow spring cultivar, LRPB Nighthawk, has a greater photoperiod requirement than the other spring cultivars and had the longest time period between stem elongation (GS31) and flowering (GS61) at 87 days (Figure 1). LRPB Nighthawk started stem elongation at the same time as the spring-type varieties (15 July) but began flowering at a similar time to the winter varieties (10 October) (Table 3).

TABLE 3 Approximate dates of critical growth stages of stem elongation (GS31) and start of flowering (GS61) in wheat cultivars sown at Wallendbeen, NSW, 2020

Cultivar	GS31	GS61
Scepter	12 July	25 September
Beckom	12 July	25 September
LRPB Trojan	15 July	25 September
LRPB Nighthawk	15 July	10 October
Catapult	15 July	25 September
EGA Gregory	15 July	25 September
Coolah	15 July	25 September
RGT Accroc	11 August	12 October
DS Bennett	11 August	17 October
Anapurna	15 August	15 October

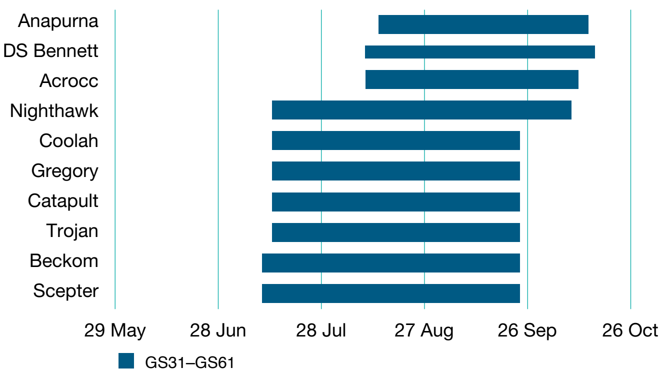


FIGURE 1 Duration of the development period between first node (GS31) and flowering (GS61) (calendar days) in wheat cultivars sown at Wallendbeen, NSW, 2020

ii. Disease assessment

The 2020 growing season generated high disease pressure across a number of susceptible varieties. Full disease assessments were conducted after flag leaf emergence (GS39) and during grain fill (GS75–80), however only the results from the grain fill assessment are presented here.

There were significant levels of stripe rust in the unsprayed treatments. The highest levels of stripe rust were observed in LRPB Trojan, DS Bennett and Catapult, with lower disease levels observed in Coolah, RGT Accroc, and Scepter (Figure 2). LRPB Trojan had the highest levels of infection with 80 per cent of the flag leaf and 68 per cent of the flag-1 infected by stripe rust. In varieties that were significantly infected by stripe rust, a single fungicide application at GS39 significantly reduced the levels of infection and provided over 90 per cent control in all varieties except Catapult (which provided 78 per cent control of stripe rust). The application of three in-crop fungicide sprays as part of the complete control treatment provided 100 per cent control in Scepter and RGT Accroc and over 97 per cent control in all other varieties.

Septoria tritici blotch, caused by the pathogen *Zymoseptoria tritici*, was much less prevalent at the site, with only Scepter showing high levels of infection (Figure 3) at 15 per cent of the leaf area of the flag leaf and 28 per cent of the flag-1 leaf area affected. Yellow leaf spot, leaf rust and wheat powdery mildew also were present at the site at low levels.

Untreated, single spray and multiple fungicide control treatments in Coolah wheat at GS75–80 (3 November, 2020).

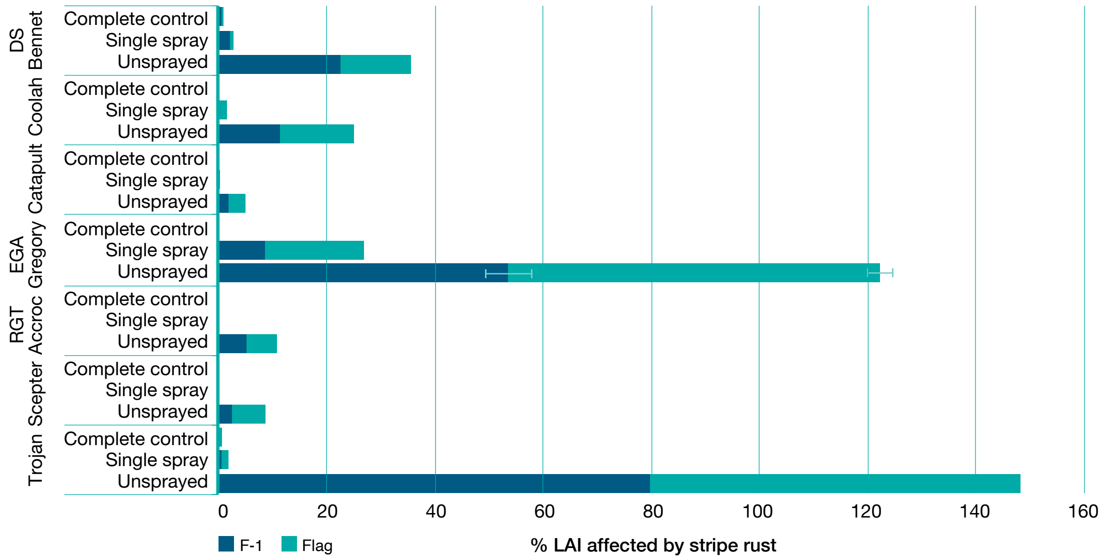


FIGURE 2 Stripe rust infection at grain fill (GS75–80), 3 November, in wheat cultivars sown at Wallendbeen, NSW, 2020

Note: This figure only shows varieties with significant infection levels. F-1 P= <0.001, LSD= 8.4. Flag P=<0.001, LSD= 4.6. Error bars represent LSD.

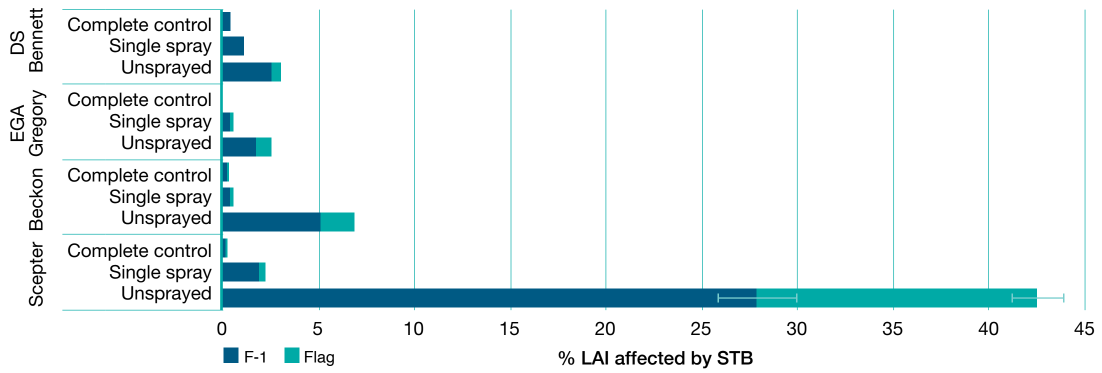


FIGURE 3 Septoria tritici blotch infection at grain fill (GS75–80), 3 November, in wheat cultivars sown at Wallendbeen, NSW, 2020

Note: This figure only shows varieties with significant infection levels. F-1 P= <0.001, LSD= 2.6. Flag P=<0.001, LSD= 4.2. Error bars represent LSD.

iii. Normalised difference vegetative index (NDVI)

Crop reflectance measurements taken with a Greenseeker™ and recorded as NDVI showed differences in crop canopy greenness that can mostly be attributed to the presence of disease (Figure 4). When measured on 23 September and 1 November, the untreated LRPB Trojan plots had significantly lower NDVI than all other treatments as a result of high levels of stripe rust infection. On 1 November, the disease-susceptible varieties LRPB Trojan, DS Bennett (Stripe rust susceptible, Figure 2) and Scepter (STB susceptible, Figure 3) had significantly lower NDVI values in the untreated plots when compared to the complete control plots. However, Anapurna, with its improved disease resistance, showed no significant difference in NDVI value between the untreated and complete control plots, highlighting the value of genetic resistance in maintaining green leaf area.

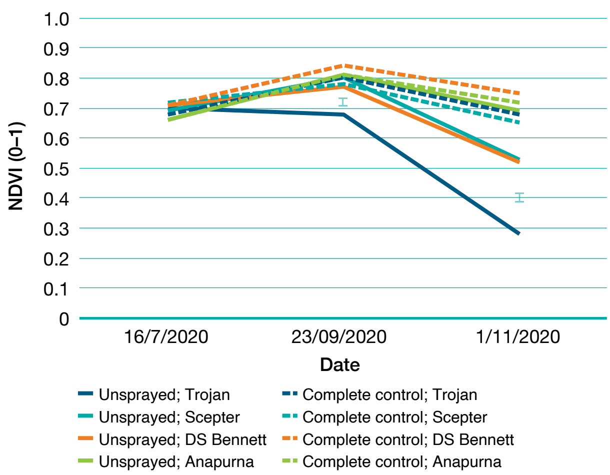


FIGURE 4 NDVI readings (0–1 scale) of the unsprayed and complete control treatments on 16 July, 23 September and 1 November in selected wheat cultivars sown at Wallendbeen, NSW, 2020

Error bars represent LSD where P<0.05.

iv. Lodging index

Lodging index scores were calculated by assessing the percentage of the plot lodged multiplied by the severity of the lodging. Lodging was assessed pre-harvest (9 December) and was accompanied by a measure of crop height, assessed at the same time. The most susceptible variety to lodging, EGA Gregory, gave the highest lodging score, while the more resistant LRPB Nighthawk was relatively unaffected (Figure 5).

v. Grain yield and quality

The trial was harvested on 14 December 2020 with an average yield of 8.2t/ha. The highest yields were recorded in the complete control treatments for RGT Accroc (10.8t/ha) and Anapurna (10.5t/ha). As a result of high disease pressure at the site, there was a significant interaction for grain yield between fungicide management strategy and cultivar (Table 4). All varieties showed a yield response to a single flag leaf spray compared with the unsprayed control. However, only four varieties gave a significant yield response to the multiple fungicide applications in the complete control treatment compared with the single fungicide application.

Grain protein varied significantly between varieties. EGA Gregory and Scepter had the highest proteins of 11.9 per cent and 11.8 per cent respectively, while RGT Accroc and DS Bennett had the lowest proteins with 10.3 per cent and 10.4 per cent respectively.

TABLE 4 The effect of fungicide management and cultivar on grain yield at harvest, 14 December in wheat cultivars sown at Wallendbeen, NSW, 2020

	Fungicide management			
	Unsprayed	Single spray	Three-spray (complete control)	Mean
Cultivar	Yield (t/ha)	Yield (t/ha)	Yield (t/ha)	Yield (t/ha)
LRPB Trojan	2.28^{n}	7.55^{hij}	8.13^{efg}	**5.98**
Scepter	7.07^{kl}	8.60^{d}	8.55^{de}	**8.07**
LRPB Nighthawk	7.98^{gh}	8.47^{def}	8.54^{de}	**8.33**
Anapurna	9.69^{c}	10.22^{b}	10.46^{ab}	**10.12**
RGT Accroc	9.72^{c}	10.86^{a}	10.83^{a}	**10.47**
Beckom	7.75^{ghi}	8.46^{def}	8.66^{d}	**8.29**
Catapult	6.06^{m}	7.84^{ghi}	8.46^{def}	**7.45**
EGA Gregory	6.75^{l}	7.15^{jkl}	7.40^{ijk}	**7.10**
Coolah	7.26^{jk}	8.07^{fg}	8.75^{d}	**8.03**
DS Bennett	5.68^{m}	8.75^{d}	9.48^{c}	**7.97**
Mean	**7.02**	**8.60**	**8.93**	
LSD Cultivar p = 0.05				
LSD Management p=0.05				
LSD Cultivar x management P=0.05				

Figures followed by different letters are regarded as statistically significant.

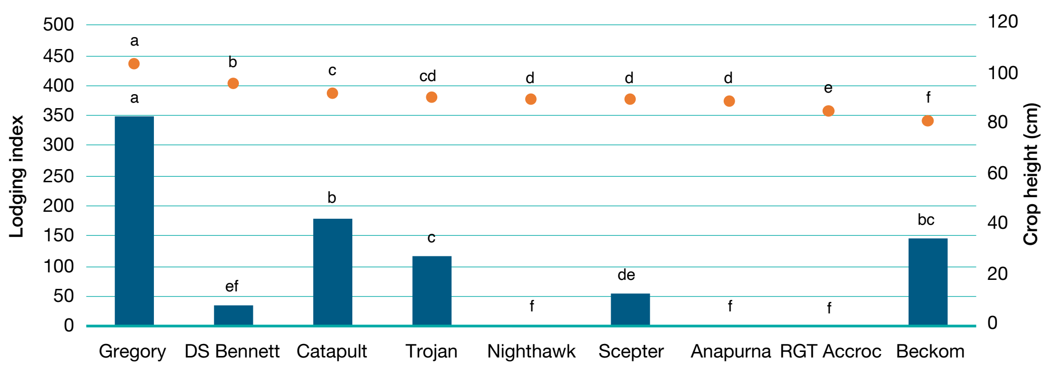
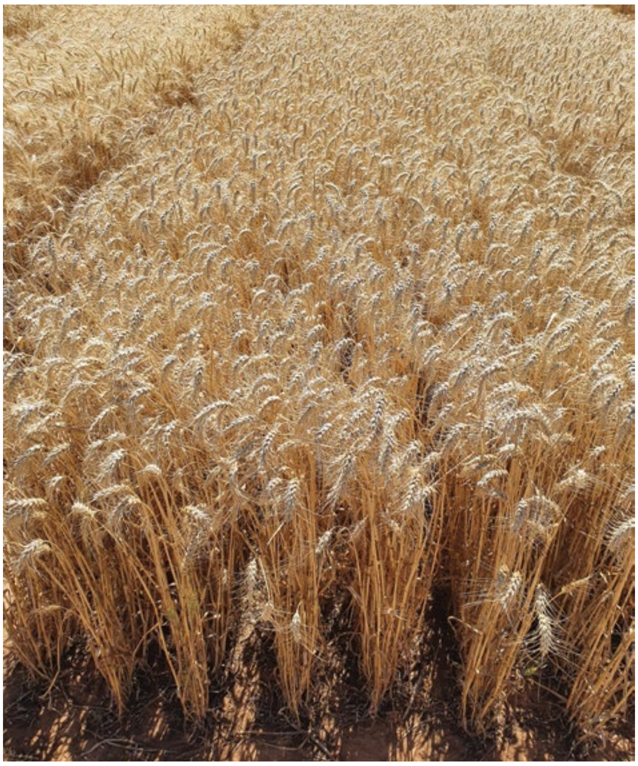


FIGURE 5 Lodging index (0–500 scale) and crop height at crop maturity in wheat cultivars sown at Wallendbeen, NSW, 2020

Lodging P= <0.001, LSD= 35. Crop height P= <0.001, LSD= 2.2.
Points labelled with different letters are considered to be statistically different.



Untreated LRPB Trojan vs untreated Anapurna pre harvest (9 December, 2020).

Conclusion

The first year of Hyper Yielding Crops research reaffirms that in seasons that favour higher yield potential, disease management is one of the most important management factors in growing high-yielding cereal crops.

Stripe rust infection in untreated LRPB Trojan (22 September, 2020).

The Wallendbeen site had high yield potential (greater than 10t/ha) during the 2020 season and the ability to achieve high yields depended on disease control. Disease pressure was high, with disease management strategies increasing yield by up to 5.27t/ha in the most susceptible cultivars. This compares to yield responses of less than 1t/ha for the more disease-resistant cultivars and highlights the critical importance of genetic resistance to disease.

In a season with higher yield potential and higher disease pressure (primarily stripe rust pathotypes 198 E16 A+ J+ T+ 17+, septoria tritici blotch and lower levels of leaf rust, powdery mildew and yellow leaf spot), all wheat cultivars gave a significant yield response to fungicide application. Where cultivars had greater genetic resistance there was no statistical yield difference between a single application of fungicide at flag leaf (GS39) (based on a full rate azoxystrobin/epoxiconazole mixture [Radial® 840mL/ha]) and the application of Systiva and three in-crop fungicide sprays.

Acknowledgements

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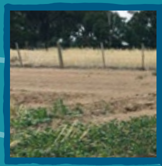
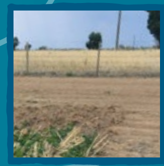




Intercropping to utilise rainfall for profit

Dr Meredith Mitchell, Brendan Christy, Kerry Stott, Dr Uttam Khanal and Dr Garry O'Leary
Agriculture Victoria

Key points

- Four dual-species mixes (field pea/canola, faba bean/canola, faba bean/wheat and barley/canola) were sown at different ratios at Rutherglen, Burramine and Caniambo during 2020.
- At all three sites, seasonal conditions during 2020 were exceptional, with excellent growing season rainfall (GSR) resulting in high yields across the trials.
- At the Rutherglen site, all the dual-species combinations resulted in positive yield benefits compared with the monoculture crops.
- At the Burramine and Caniambo sites, 75% of the dual-species combinations resulted in positive yield benefits compared with the monoculture crops.
- To achieve a superior economic return, when compared to a monoculture of either species, the intercrop land equivalent ration (LER) needed to be greater than 1.1.

Introduction

Intercropping involves sowing and growing two (or more) crop species together in the same paddock. This approach can increase the use of total available solar radiation and water per unit of land, offers an opportunity to diversify grain production and increase total grain yields and profit.

Traditionally, intercropping has been widely practiced on small-sized holdings and cropping systems in developing countries, however there is evidence of farmers adopting the practice in developed countries like Canada, particularly with field pea/canola mixtures. In Australia, intercropping is not widely practiced, possibly due to the additional labour requirements and the additional management complexity.

Aim

To determine if two crop species sown together (intercropping) could provide an opportunity to increase total grain yield compared to monocultures, diversify grain production and increase yield and profit in the Riverine Plains region.

Method

Four dual-species mixtures (field pea/canola, faba bean/wheat, faba bean/canola and barley/canola) were sown during 2020 at three experimental sites (Rutherglen, Caniambo and Burramine, Victoria) to compare the performance of cereals, legumes and oilseeds when grown as intercrops and monocultures (Figure 1).

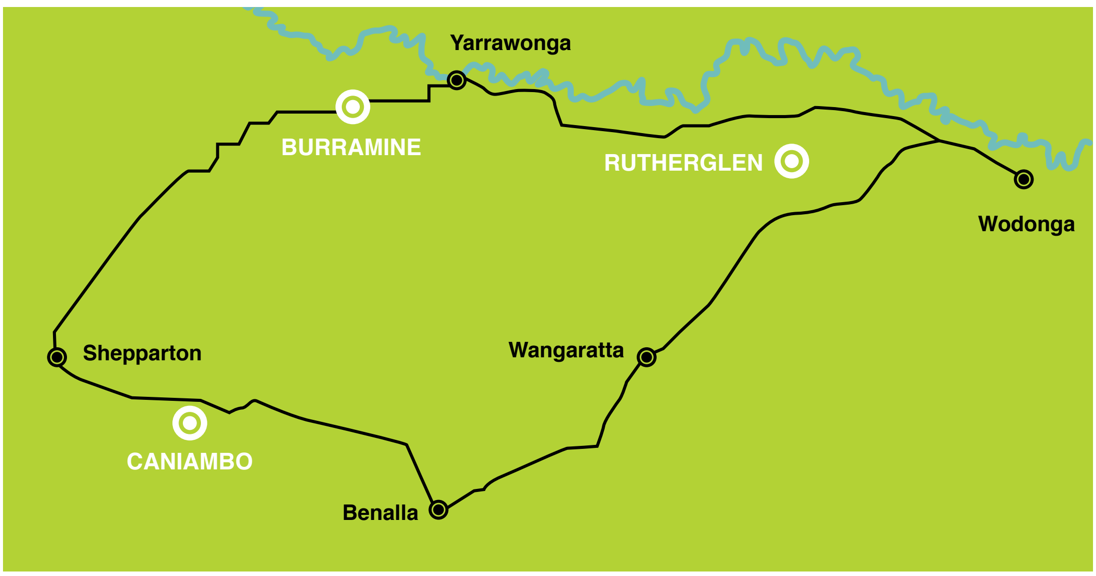


FIGURE 1 Location of the three experimental sites, Rutherglen, Burramine and Caniambo

Faba bean/canola 50:50 skip row plots (alternating two rows of each crop) at Rutherglen, 2020.

Experimental layout at Rutherglen, 2020, showing the blocked design of the intercropping experiment.

At the Rutherglen site, the dual-species mixtures were sown at different species ratio targets of 25:75 per cent, 75:25 per cent, 50:50 per cent, skip row (alternating two rows of each crop) and each species was also grown as a monoculture. The 50:50 per cent and the skip-row treatments were not sown at the Burramine and Caniambo sites.

Experimental sites were sown on 7 May, 13 May and 29 May, 2020, at Rutherglen, Caniambo and Burramine respectively. Cultivar selection was based on crops with a similar phenology and, except for field pea, herbicide tolerance, including: imidazoline tolerance (CL) or triazine and imidazoline tolerance (CT). Cultivars were obtained commercially, with seed treated to protect against pests and disease (Table 1).

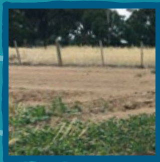
At Rutherglen, seed was sown on 25cm row spacings and plot size was 4.5 x 20m, giving a total plot area of 90m^2. At Caniambo and Burramine, seed was sown at 23cm row spacings and plot size was 1.4 x 10m, giving a total plot area of 14m^2. There were four replicates of each treatment at each site.

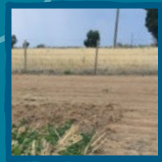
During early August (3 and 5 August), 100kg/ha urea was applied to half the area of each plot to allow a comparison of 'with' and 'without' nitrogen (N) to be made for each treatment.

At the Rutherglen site, the field pea/canola plots were sprayed with 40g/ha Raptor® herbicide on 8 July, 2020, with the faba bean/canola, faba bean/wheat and barley/canola plots sprayed with 600mL/ha Intercept (Intervix) on 30 June, 2020. The main weeds being targeted at the site were wireweed, shepherd's purse and annual ryegrass. Ryegrass in the barley/canola treatments was effectively suppressed by crop competition, so was not problematic.

TABLE 1 Crops, cultivars and herbicide treatments for the intercropping experiments at Rutherglen, Burramine and Caniambo, 2020

Sowing fertiliser	100kg/ha of MAP	
Pre-sowing herbicides:	Terbyne® (0.85kg/ha), trifluralin (1.5L/ha), Hammer® (30mL/ha), and glyphosate (1.5L/ha)	
In-crop insecticides:	Pyrinex	
Crop	**Cultivar**	**Herbicide tolerance**
Barley	Spartacus CL	Imidazolinone
Canola	Hyola® 580 CT	Triazine and imidazolinone
Faba bean	PBA Bendoc	Imidazolinone
Field pea	PBA Butler	Nil
Wheat	Sheriff CL	Imidazolinone





Plant establishment was recorded as plants per square metre, from random areas within the plots seven weeks after sowing, with establishment rates close to the target populations. Both species in each dual-species mixture were harvested together with a header, with grain separated post-harvest using a small-scale seed grader.

Rainfall during 2020 was slightly above the long-term average at all three sites (Table 2). Plentiful rainfall during early April, combined with high rainfall totals during August, helped to maintain yield potential above what would be expected given the dry spring conditions following mid-October across all sites.

Results

Assessing the relative advantage of intercrops is more complex than for monocultures, with several approaches available. The most commonly used approach is the land equivalent ratio (LER), which describes the additional land needed to grow the same quantity of both species if they were grown as monocultures, rather than as dual-species crops. The LER calculation is as follows;

$$LER = (Y1_c \div Y1_m) + (Y2_c \div Y2_m)$$

Where $Y1_c$ or $Y2_c$ = yield of crop 1 or 2 as an intercrop

$Y1_m$ or $Y2_m$ = Yield of crop 1 or 2 as a monoculture

The LER values for this trial were calculated using grain yield at harvest. An LER value greater than 1.0 means there is an advantage to growing the crops in a mixture compared to a monoculture (referred to as 'over-yielding').

The extent of the economic advantage (taking into account absolute yields, the proportion of each crop in the mix, crop prices and variable costs) was calculated using the net gross margin (net GM), as follows;

$$\text{Net gross margin (net GM)} = GM_c - GM_m$$

$$GM_c = [(Y_{1c}{*}P_1 + Y_{2c}{*}P_2) - C_3]$$

$$GM_m = [Z_{1c}{*}(Y_{1m}{*}P_1 - C_1) + Z2_c{*}(Y_{2m}{*}P_2 - C_2)]$$

Y_{1c} or Y_{2c} = yield of crop 1 or 2 as an intercrop

Y_{1m} or Y_{2m} = yield of crop 1 or 2 as a monoculture

Z_{1c} and Z_{2c} = proportional sown area of crops 1 and 2 in the intercrop

P_1 and P_2 are the five-year average of prices for crops 1 and 2

C_1, C_2 and C_3 are the variable costs of production for crop 1, crop 2 and the intercrop plots respectively

GM_c = Gross margin from intercropping

GM_m = Gross margin from monoculture with same enterprise mix as in the mixture.

The five-year average (2016–20) real prices per tonne of barley, canola, faba beans, field pea and wheat were assumed to be: $301, $569, $553, $486 and $302 respectively. The on-farm variable costs of producing a hectare of monoculture barley, canola, faba beans, field pea and wheat were assumed to be: $388, $545, $419, $371 and $406 respectively. The cost of separating grains for the mixture after harvest was taken as $24/t.

TABLE 2 Rainfall at Rutherglen, Burramine and Caniambo during 2020 compared with the long-term average

	Rutherglen		Burramine		Caniambo	
Month	2020 rainfall (mm)	Long-term average rainfall (mm)	2020 rainfall (mm)	Long-term average rainfall (mm)	2020 rainfall (mm)	Long-term average rainfall (mm)
January	29	37	46	33	38	34
February	18	39	31	31	19	32
March	104	39	75	31	64	34
April	136	42	97	33	123	38
May	30	50	28	45	42	46
June	41	56	32	41	45	50
July	16	63	34	48	34	55
August	73	60	58	44	65	54
September	39	54	30	42	28	49
October	67	57	40	41	64	44
November	22	46	25	39	31	41
December	25	45	18	38	33	39
Total	**600**	**588**	**514**	**466**	**585**	**515**
GSR (Apr – Oct)	**403**	**382**	**319**	**294**	**400**	**334**

i. Barley/canola intercrop

At the Rutherglen site, total grain yield expressed as the LER was between 1.11 and 1.15 in the barley/canola intercrop mix compared with the monoculture yields when no in-crop nitrogen was applied, showing a superior crop yield outcome with intercropping.

In terms of additional dollar return, the most profitable option was when barley formed 25% of the barley/canola crop mixture, returning an extra $182/ha when grown as an intercrop compared with a monoculture of barley (Table 3).

When in-crop nitrogen was added, the 75:25 and 25:75 intercrop mixes of barley and canola returned a negative GM. This was due to improved canola growth, which impacted barley yield in these mixtures. The 50:50 barley and canola skip-row mix benefited from nitrogen application, increasing the GM from $90/ha, when no nitrogen was added, to $161/ha with nitrogen.

At Burramine, combining barley and canola resulted in a negative LER, demonstrating crop losses due to growing in an intercrop system (Table 4). The crop loss was due to barley out-competing canola, which may have been caused by the later sowing advantaging the barley at that site. The addition of nitrogen improved the canola yield when grown in a dual-species mix.

At Caniambo, the positive LER of the barley/canola mix (between 1.04 and 1.07) showed benefits of intercropping with barley and canola when no in-crop nitrogen was added.

TABLE 3 Barley/canola intercrop treatment results for grain yield, land equivalent ratios (LER) and average net gross margin, Rutherglen, 2020

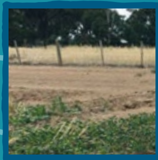
Planting ratio	Mono-culture	75:25		50:50		50:50 Skip row		25:75		Mono-culture
Species mix	Barley (100%)	Barley (75%)	Canola (25%)	Barley (50%)	Canola (50%)	Barley (50%)	Canola (50%)	Barley (25%)	Canola (75%)	Canola (100%)
No in-crop nitrogen										
Grain yield (t/ha)	8.6	7.6	0.8	5.3	1.7	3.8	2.5	3.4	2.5	3.4
LER*	1	1.12		1.11		1.15		1.14		1
Average Net GM# ($/ha)	0	66		83		90		182		0
100kg/ha urea applied										
Grain yield (t/ha)	8.6	7.4	0.8	5.8	1.9	3.8	3.1	3.1	2.8	4.4
LER*	1	1.04		1.12		1.16		1.02		1
Average Net GM# ($/ha)	0	-124		76		161		-128		0

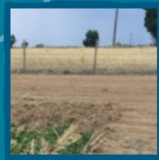
* LER is a measure of crop yield when grown as an intercrop compared with that same crop grown as a monoculture.
# Average Net GM is the change in gross margin of growing crops as an intercrop system compared with a monoculture.

TABLE 4 Barley/canola intercrop treatment results for grain yield and land equivalent ratios (LER), Burramine and Caniambo, 2020

	Burramine						Caniambo					
Planting ratio	Mono-culture	75:25		25:75		Mono-culture	Mono-culture	75:25		25:75		Mono-culture
Species mix	Barley (100%)	Barley (75%)	Canola (25%)	Barley (25%)	Canola (75%)	Canola (100%)	Barley (100%)	Barley (75%)	Canola (25%)	Barley (25%)	Canola (75%)	Canola (100%)
No in-crop nitrogen												
Grain yield (t/ha)	6.5	5.3	0.09	4.7	0.3	2.0	4.7	4.6	0.2	3.5	0.7	2.4
LER*	1	0.87		0.89		1	1	1.07		1.04		1
100kg/ha urea applied												
Grain yield (t/ha)	6.6	6.5	0.12	5.2	0.4	2.1	6.3	5.4	0.4	3.6	1.2	2.9
LER*	1	1.04		0.97		1	1	1.01		0.99		1

* LER is a measure of crop yield when grown as an intercrop compared with that same crop grown as a monoculture.





ii. Faba bean/canola intercrop

At the Rutherglen site, total grain yield (LER) was between 1.09 and 1.21 in the faba bean/canola intercrop mix compared with their monoculture yields when no in-crop nitrogen was applied, showing a positive yield outcome with intercropping (Table 5). The net gross margin compares the costs and benefits of the intercrop to the monocultures when grown on the same proportional area, with the 25 per cent faba bean crop mixture being the most profitable option, returning an extra $599/ha.

The addition of in-crop nitrogen greatly increased both the LER and the averaged net GM for all crop mixtures during 2020, with the additional dollar returns ranging between $365/ha to $604/ha (Table 5).

At Burramine, there was a positive crop response based on LER when the intercrop mix was 25% faba bean and 75% canola (Table 6). When the mix was reversed, the LER response was negative, due to canola being outcompeted by the faba beans, possibly due to late planting at that site.

At Caniambo, the intercrop response was all positive, with in-crop nitrogen increasing yield and LER over the nil-nitrogen treatments.

iii. Field pea/canola intercrop

At the Rutherglen site, grain yield LER was between 1.01–1.21 for the field pea/canola intercrop mix compared with the monoculture yields when no in-crop nitrogen

TABLE 5 Faba bean/canola intercrop treatment results for grain yield, land equivalent ratios (LER) and average net gross margin, Rutherglen, 2020

Planting ratio	Mono-culture	75:25		50:50		50:50 Skip row		25:75		Mono-culture
Species mix	Faba bean (100%)	Faba bean (75%)	Canola (25%)	Faba bean (50%)	Canola (50%)	Faba bean (50%)	Canola (50%)	Faba bean (25%)	Canola (75%)	Canola (100%)
					No in-crop nitrogen					
Grain yield (t/ha)	5.7	4.6	1.1	3.8	1.5	3.9	1.6	3.4	2.4	3.8
LER*	1	1.09		1.07		1.10		1.21		1
Average Net GM# ($/ha)	0	78		144		236		599		0
					100kg/ha urea applied					
Grain yield (t/ha)	7.3	6.3	1.1	4.6	1.9	4.4	2.1	3.4	2.6	3.6
LER*	1	1.18		1.16		1.19		1.18		1
Average Net GM# ($/ha)	0	365		412		393		604		0

* LER is a measure of crop yield when grown as an intercrop compared with that same crop grown as a monoculture.
# Average Net GM is the change in gross margin of growing crops as an intercrop system compared with a monoculture.

TABLE 6 Faba bean/canola intercrop treatment results for grain yield and land equivalent ratios (LER), Burramine and Caniambo, 2020

	Burramine						Caniambo					
Planting ratio	Mono-culture	75:25		25:75		Mono-culture	Mono-culture	75:25		25:75		Mono-culture
Species mix	Faba bean (100%)	Faba bean (75%)	Canola (25%)	Faba bean (25%)	Canola (75%)	Canola (100%)	Faba bean (100%)	Faba bean (75%)	Canola (25%)	Faba bean (25%)	Canola (75%)	Canola (100%)
						No in-crop nitrogen						
Grain yield (t/ha)	4.3	3.0	0.4	1.3	1.6	2.0	5.9	4.1	0.8	1.7	1.8	2.3
LER*	1	0.95		1.11		1	1	1.05		1.05		1
						100kg/ha urea applied						
Grain yield (t/ha)	4.7	3.2	0.5	1.5	1.6	2.2	6.1	4.7	0.9	2.4	1.9	2.9
LER*	1	0.92		1.06		1	1	1.10		1.06		1

* LER is a measure of crop yield when grown as an intercrop compared with that same crop grown as a monoculture.

was applied, indicating a positive yield outcome with intercropping (Table 7). Growing field peas and canola in skip-rows (alternating two rows of each crop) resulted in a strong negative field pea yield. This negative response was caused when the field peas lost the trellising connection to the neighbouring canola plants post-flowering, which resulted in the field peas collapsing to ground level and falling under heavy shade from the canola. In the other intercrop mixes, the field peas could trellis up the canola plants, with the field pea plants growing to the same, or similar, height as the canola. In each of the intercrop mixes, field pea yield was lower compared with its monoculture, however the extra yield achieved by the canola in the intercrop mixes led to a high yield overall. In terms of extra dollars returned due to intercropping, excepting the skip-row intercrop, the addition of in-crop nitrogen resulted in extra returns of $256/ha (75% field pea, 25% canola) to $452/ha (50% field pea, 50% canola) compared with growing crops as monocultures.

At Burramine, there was a positive LER when the intercrop mix was 25% field pea and 75% canola (Table 8). When the mix was reversed to 75% field pea and 25% canola, the LER response was negative, possibly due to the canola being out competed by the field peas as a result of the late planting.

At Caniambo, the intercrop response was all positive, with increased yield and LER when in-crop nitrogen was applied.

TABLE 7 Field pea/canola intercrop treatment results for grain yield, land equivalent ratios (LER) and average net gross margin, Rutherglen, 2020

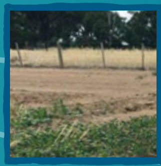
Planting ratio	Mono-culture	75:25		50:50		50:50 Skip row		25:75		Mono-culture
Species mix	Field pea (100%)	Field pea (75%)	Canola (25%)	Field pea (50%)	Canola (50%)	Field pea (50%)	Canola (50%)	Field pea (25%)	Canola (75%)	Canola (100%)
					No in-crop nitrogen					
Grain yield (t/ha)	5.8	3.4	2.4	2.9	2.8	1.4	3.1	1.7	3.1	4.2
LER*	1	1.18		1.21		1.01		1.08		1
Average Net GM# ($/ha)	0	170		264		-244		-4		0
					100kg/ha urea applied					
Grain yield (t/ha)	6.6	4.2	2.5	3.4	3.3	1.2	3.8	2.3	3.8	4.4
LER*	1	1.22		1.28		1.10		1.23		1
Average Net GM# ($/ha)	0	256		452		-198		377		0

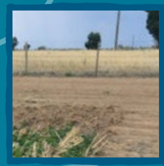
* LER is a measure of crop yield when grown as an intercrop compared with that same crop grown as a monoculture.
# Average Net GM is the change in gross margin of growing crops as an intercrop system compared with a monoculture.

TABLE 8 Field pea/canola intercrop treatment results for grain yield and land equivalent ratios (LER), Burramine and Caniambo, 2020

	Burramine						Caniambo					
Planting ratio	Mono-culture	75:25		25:75		Mono-culture	Mono-culture	75:25		25:75		Mono-culture
Species mix	Field pea (100%)	Field pea (75%)	Canola (25%)	Field pea (25%)	Canola (75%)	Canola (100%)	Field pea (100%)	Field pea (75%)	Canola (25%)	Field pea (25%)	Canola (75%)	Canola (100%)
						No in-crop nitrogen						
Grain yield (t/ha)	3.5	2.4	0.4	1.6	1.0	1.7	6.1	4.4	0.8	3.1	1.6	2.5
LER*	1	0.89		1.13		1	1	1.08		1.17		1
						100kg/ha urea applied						
Grain yield (t/ha)	4.3	3.1	0.7	2.0	1.1	2.2	5.5	5.0	0.9	2.1	2.6	2.7
LER*	1	0.94		1.07		1	1	1.17		1.34		1

* LER is a measure of crop yield when grown as an intercrop compared with that same crop grown as a monoculture.





iv. Faba bean/wheat intercrop

Total grain yield LER, at the Rutherglen site, was between 1.16–1.28 for the faba bean/wheat intercrop mixes compared with their monoculture yields when no in-crop nitrogen was applied (Table 9). This showed a positive crop yield outcome with intercropping. For these treatments, there were large returns of $363–644/ha, compared with growing crops as monocultures.

When in-crop nitrogen was added, the increase in wheat yield was offset by a larger decrease in faba bean yield, resulting in much lower (negative) returns.

The wheat/faba bean intercrops measured a positive yield response at both Burramine and Caniambo, with the best response at Caniambo without the addition of in-crop nitrogen (Table 10). In general, the addition of in-crop nitrogen improved wheat yield, but decreased faba bean yield at these sites, leading to a decreased LER.

Observations and comments

This research demonstrates that intercropping with mixtures has the potential to increase productivity and profits across the cropping regions of southern Australia. These results are based on mean responses from the 2020 harvest, however full statistical analyses have not yet been completed.

TABLE 9 Faba bean/wheat intercrop treatment results for grain yield, land equivalent ratios (LER) and average net gross margin, Rutherglen, 2020

Planting ratio	Mono-culture	75:25		50:50		50:50 Skip row		25:75		Mono-culture
Species mix	Faba bean (100%)	Faba bean (75%)	Wheat (25%)	Faba bean (50%)	Wheat (50%)	Faba bean (50%)	Wheat (50%)	Faba bean (25%)	Wheat (75%)	Wheat (100%)
No in-crop nitrogen										
Grain yield (t/ha)	5.7	5.9	1.4	4.5	3.9	4.9	2.3	2.4	6.1	7.9
LER*	1	1.22		1.28		1.16		1.20		1
Average Net GM# ($/ha)	0	502		644		446		363		0
100kg/ha urea applied										
Grain yield (t/ha)	7.4	6.0	1.8	4.9	3.8	4.2	2.6	2.3	6.3	8.5
LER*	1	1.03		1.10		0.87		1.07		1
Average Net GM# ($/ha)	0	-58		265		-367		-3		0

* LER is a measure of crop yield when grown as an intercrop compared with that same crop grown as a monoculture.
# Average Net GM is the change in gross margin of growing crops as an intercrop system compared with a monoculture.

TABLE 10 Faba bean/wheat intercrop treatment results for grain yield and land equivalent ratios (LER), Burramine and Caniambo, 2020

	Burramine						Caniambo					
Planting ratio	Mono-culture	75:25		25:75		Mono-culture	Mono-culture	75:25		25:75		Mono-culture
Species mix	Faba bean (100%)	Faba bean (75%)	Wheat (25%)	Faba bean (25%)	Wheat (75%)	Wheat (100%)	Faba bean (100%)	Faba bean (75%)	Wheat (25%)	Faba bean (25%)	Wheat (75%)	Wheat (100%)
No in-crop nitrogen												
Grain yield (t/ha)	4.7	1.4	3.6	0.3	4.9	5.0	6.1	5.0	1.8	2.0	3.8	4.9
LER*	1	1.01		1.05		1	1	1.21		1.13		1
100kg/ha urea applied												
Grain yield (t/ha)	4.2	1.6	3.9	0.5	5.4	5.9	6.7	4.0	2.9	1.4	5.6	6.5
LER*	1	1.05		1.04		1	1	1.03		1.09		1

* LER is a measure of crop yield when grown as an intercrop compared with that same crop grown as a monoculture.

Results demonstrate that growing a pulse with canola as a dual-species mix can produce positive benefits in terms of yield and profit. The exception to this was when canola and field pea were grown in a skip-row configuration (where the field pea did not climb into the canola stand). The addition of in-crop nitrogen to these mixes enhanced both the LER and the net GM.

When wheat or barley were part of an intercrop system, the yield benefits occurred only when there was no additional nitrogen applied. The application of nitrogen to these systems led to wheat and barley outcompeting their pulse or oilseed intercrop, decreasing the yield of the intercrop and reducing total productivity and profit.

The different herbicide options available for use in these intercropping systems could also provide alternative management options for grain growers.

This research was part of a larger project that had field experiments sown at additional sites in north-west and south-west Victoria.

Acknowledgements

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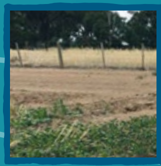

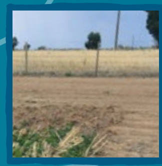

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Farming Smarter — a soils project for the next generation

Lisa Castleman[1], Kirsten Barlow[2], Rebecca Waalkens[1], Ben Fleay[2]

[1] Riverina Local Land Services

[2] Precision Agriculture Pty. Ltd.

Key points

- Dual-depth (0–10cm, 10–20cm) grid soil sampling was used to map surface and subsoil pH across 81 properties and 4372ha of farmland in the eastern Riverina area of southern NSW.
- Soil sampling showed an average variation in pH of 0.8–1.0 pH units across a paddock in both the surface and sub-surface layers, with marked differences in soil pH between the two sampling depths.
- Exchangeable aluminium (Al) levels increased rapidly in the soil sample where pH was lower than 4.6, with minimal amounts of exchangeable aluminium detected where soil pH was higher than 4.6.

Aim

This project aimed to reduce the erodibility of high-risk landscapes through an increase in the area of land planted to perennial pasture species, which are both more productive and more persistent when not constrained by acidity; low soil pH and aluminium toxicity.

The project also aimed to increase awareness, knowledge and understanding of soil acidification and management options for topsoil and subsoil acidity. Traditional blanket-rate lime practices do not address the issue of increasing subsoil acidity, nor target areas where acidity is most severe, and the project explored dual-depth grid soil mapping in combination with variable rate lime application for more effective and longer-term management of soil acidification. The project aims to increase the area of soil limed to at least pH 5.2 in the topsoil (0–10cm), before the establishment of new perennial pastures occurs.

Based on intensive soil sampling, the project also developed property soil nutrient and liming plans to identify soil constraints, including acidity and fertility, that can influence the establishment and maintenance of perennial pasture systems.

Background

Soil acidity is known to affect at least 50 per cent of Australia's agricultural land (this may be higher due to ongoing re-acidification) and is a major constraint to pasture and crop productivity in areas of southern NSW, where annual rainfall is 550–800mm.

Soil acidification is a natural process driven by rainfall and accelerated by the removal of agricultural products, which are generally alkaline. Acidity is also affected by the balance of nitrogen in the system and influenced by processes in the nitrogen cycle, such as nitrate leaching, the loss of nitrogen due to the harvesting of produce, volatilisation or by denitrification under waterlogged conditions.

Standard soil tests, taken at a depth of 0–10cm, provide a measure of soil pH in the surface root zone of crops and pastures. In these surface soils, the developing root systems of newly established pasture or crop species, as well any soil rhizobia present, are exposed to soil pH and any associated toxicities, including aluminium toxicity. Soil pH can be inherently variable, both horizontally and vertically, in the profile and there has been a recent focus on the stratification of pH in the upper 20cm of the soil profile by soil scientists.

Farming Smarter — a soils project for the next generation is a five-year project supported by Riverina Local Land Services, through funding from the Australian Government's National Landcare Program. The project utilises precision agriculture techniques to identify the severity of soil acidity in a paddock and the range of in-paddock variation in soil pH, both horizontally and vertically. This data will be used to provide guidance around the liming rates required to establish and maintain perennial pastures, as soil acidity can reduce nitrogen fixation by pasture legumes and acid-sensitive rhizobia.

The dual-depth sampling process used in this project enables variable-rate lime application to be explored for managing the amelioration of acidity in both the top and sub-soil layers and which can be used to increase the efficiency of applying lime and fertiliser inputs.

This article summarises the results of dual-depth soil sampling undertaken in the eastern Riverina area of southern NSW during autumn 2019 (year one) and late summer/early autumn 2020 (year two). Soil sampling was conducted across a range of paddocks used for mixed farming and grazing, selected for future perennial pasture establishment by the landholders.

This project recognises the value in having a better understanding of pH stratification in soils and focuses on understanding the variation in pH across the paddock, especially between the topsoil, which receives a surface application of lime, and the subsurface layer, which cannot be ameliorated until the acidity in the topsoil is saturated.

Method

Dual-depth grid soil mapping was undertaken during autumn 2019 (year one of the five-year project) and late summer/early autumn 2020 (year two). Samples were collected from 167 paddocks (across 81 farms), representing a total area of 4372 hectares of southern NSW farmland (Figure 1).

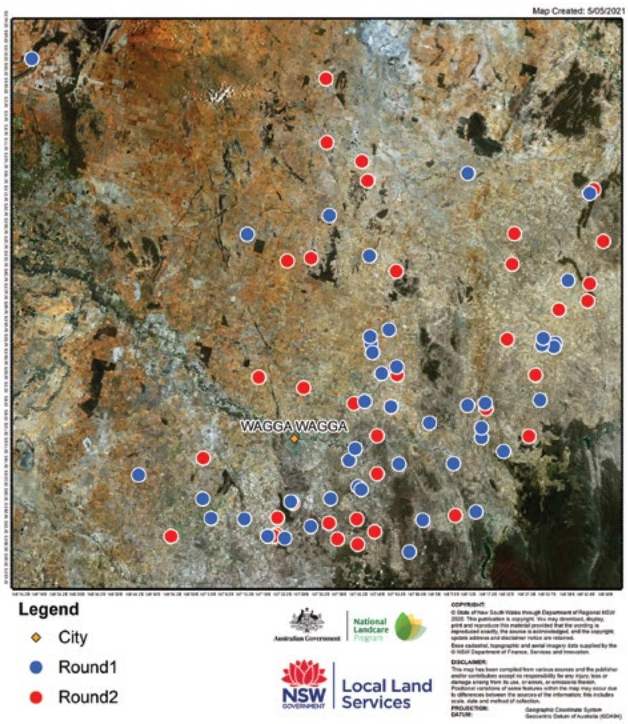


FIGURE 1 Distribution of the project sampling sites across southern NSW

The grid soil sampling involved dividing each of the 167 paddocks into two-hectare grids, which were treated as individual units for soil sampling. The sampling process consisted of (a) creating digitised paddock boundaries and sampling plans; (b) the collection of GPS referenced samples (0–10cm, 10–20cm) by manual sampling, with eight sub-samples collected on a diagonal across each sampling grid; (c) sending of samples to an accredited laboratory to analyse pH ($CaCl_2$) and exchangeable cations (calcium [Ca], magnesium [Mg], potassium[K] and sodium [Na]).

After initial results were received, further analysis was conducted for each property, with the two most acidic points selected for further analysis of exchangeable acidity (aluminium and hydrogen) in both the 0–10cm and 10–20cm layers.

Results

Soil pH was highly variable across the 167 sampled paddocks. In the surface soil (depth 0–10cm), the average pH ranged from 3.8–7.1 (Figure 2). While 80 per cent of the sampled paddocks had an average surface soil pH of less than 5.2, 51 per cent of the paddocks had an average pH of below 4.8, placing them in the 'highly acidic' or 'severely acidic' categories.

There was significant variation between paddocks and within paddocks. The range in soil pH across a single paddock varied by 0.09–2.56 pH units, with an average range of 0.83 pH units.

In the sub-surface (10–20cm depth), average soil pH across the 167 paddocks ranged from pH 3.9–7.5, with individual paddocks measuring ranges from 0.1–2.9 pH units (average range of 0.89). Based on these average figures, the range and variability of the surface and sub-surface soils are reasonably consistent. However, soil pH data for the 10–20cm depth in Figure 3 (ranked according to surface

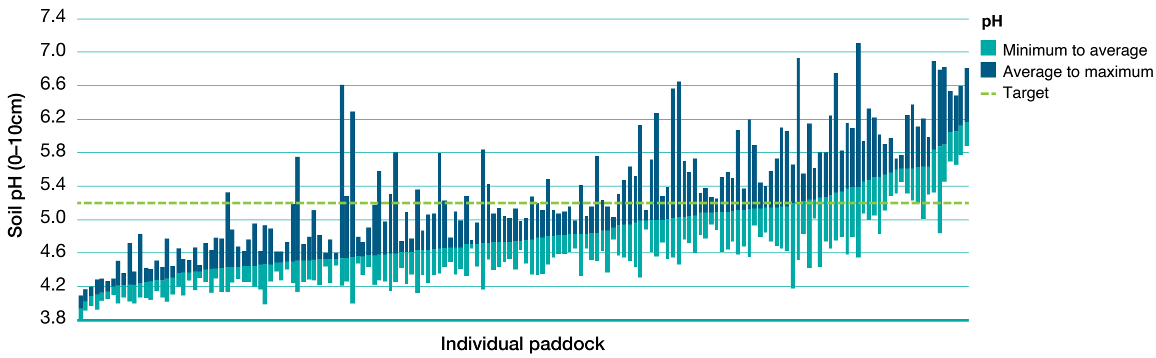


FIGURE 2 Soil pH at 0–10cm depth for 167 individual paddocks from 2019 and 2020, shown as individual bars and ranked according to their average pH

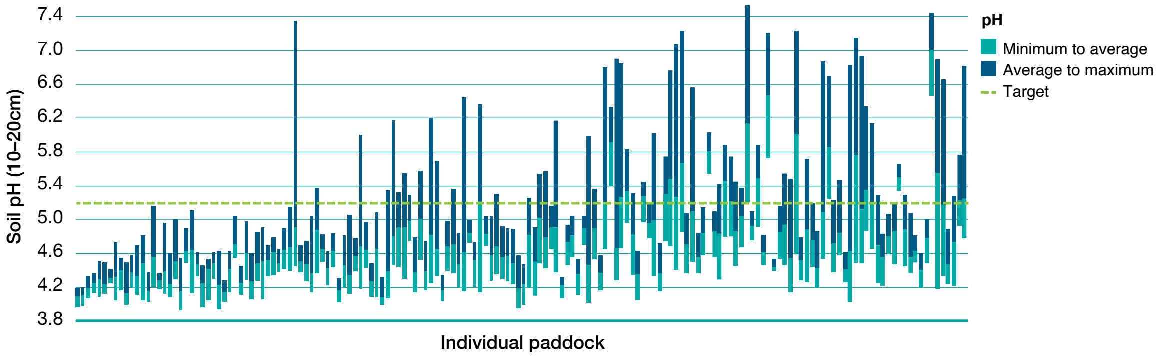


FIGURE 3 10–20cm soil pH across 167 paddocks from 2019 and 2020 shown as individual bars ranked in the same order as Figure 2

soil pH) indicates there wasn't a consistent trend in the pH distribution between the surface and sub-surface layers. The exception to this was for the 25 most acidic surface soils (0–10cm), which were also consistently acidic in the sub-surface (10–20cm).

Paddock sampling occurred across a range of soil types and included a mix of cropping, pasture and mixed farming systems, however there were no obvious differences in soil acidity between soils with different land-uses. While the majority of paddocks sampled as part of this project had a history of lime application (at a rate of 2t/ha or greater), the combined effects of farming system, soil type, long-term rainfall patterns and long-term management practices is likely to be driving results.

One of the additional management challenges for acidic soils is the potential for increasing levels of exchangeable aluminium to amounts that are toxic for plant growth. The results from the 81 properties where exchangeable aluminium was measured (for the two most acidic points in each property), show a strong relationship between soil pH and exchangeable aluminium levels (Figure 4). This relationship is strong for both the surface and sub-surface layers, which is consistent with previous studies. These results show that minimal exchangeable aluminium was detected where soil pH was above 4.6, however where soil pH decreased below 4.6, exchangeable aluminium levels increased rapidly.

Based on the grid soil mapping results, three variable rate lime application scenarios were calculated to optimise lime inputs and ameliorate the soil profile. The first scenario involved ameliorating the 0–10cm layer to a target pH of 5.2, while the second involved ameliorating both the topsoil (0–10cm) and subsurface layer (10–20cm) to a target pH of 5.2. The third scenario was designed to achieve a longer-term aspirational goal and involved ameliorating the top 0–20cm to a target pH of 5.8 and maintaining pH

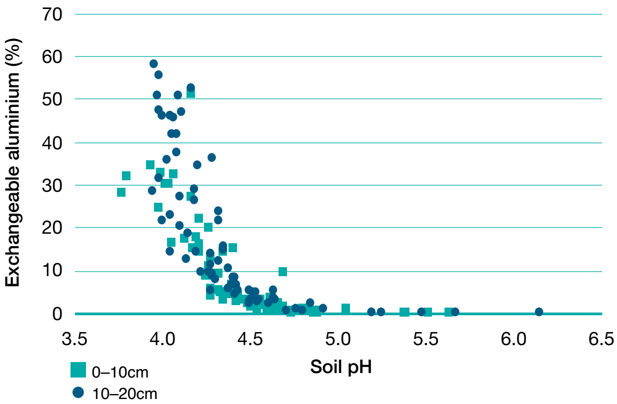
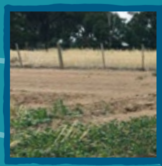
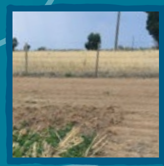


FIGURE 4 The relationship between pH and exchangeable aluminium as measured at the two most acidic points on each property during 2020 at 0–10cm depth and 10–20cm depth

above a benchmark figure of 5.5. In year 2 of the project a fourth scenario was considered, whereby a targeted VR lime map was requested to suit the farm plan and paddock goals. Typically, this scenario sat midway in terms of lime requirements between the project's second and third scenarios; more lime than scenario two and less lime than scenario three.

In order to ameliorate the top 0–10cm of the profile to the target pH of 5.2 using variable rate applications (scenario 1), an average lime rate of 1.3 t/ha was required, with 10 per cent of paddocks receiving no lime and 10 per cent of paddocks requiring an average lime application rate in excess of the industry standard (2.5 t/ha). Where the aim was to ameliorate to a depth of 20cm (scenario 2), higher rates of lime were required with an average paddock rate of 2.4 t/ha and 40 per cent of paddocks requiring an application rate greater than 2.5 t/ha. No analysis was conducted for scenario 3 as this is a longer-term goal and is unlikely to be achieved using a single application, especially where lime rates exceed 5.0 t/ha.





Observations and comments

Soil pH was observed to be highly variable, both horizontally and vertically, within all paddocks tested as part of this project. The range in surface pH across paddocks averaged 0.8 pH units, while the range in sub-surface pH across paddocks and all two-hectare grids averaged one pH unit.

There was not a consistent correlation between the surface and sub-surface pH, due in part to the management and liming history of individual paddocks, as well as the history of product removed from each paddock. This highlights the value of dual-depth sampling when planning management actions such as amelioration (liming) or when considering acid-tolerant species for planting in an acidic topsoil (acid-tolerant species are still vulnerable to toxicities and deficiencies present in the more acidic 10–20cm layer).

When pH drops below 4.6, the levels of exchangeable aluminium were observed to increase. Low soil pH, accompanied by aluminium toxicity, creates a less favourable environment for pasture growth and rhizobial survival, which will reduce the amount of nitrogen fixed by legume pasture species. Pastures grown on acidic soils often also have a diminished root volume, will be more prone to weed invasion, more likely to encounter nutritional deficiencies and have a shorter life-span than pastures grown on higher pH soils.

There are economic and soil health benefits from placing lime more strategically in areas of highest need within the paddock. Tailoring the lime-rate to achieve target pH values will reduce the severity of aluminium toxicity and arrest the re-acidification of the 0–10cm topsoil. Using target pH values for both soil layers addresses ongoing acidification in the sub-surface (10–20cm) layer, which occurs when the 0–10cm layer is acidic and acidification processes are ongoing.

Dual-depth grid soil mapping allows for more strategic use of lime in the short-term and long-term by targeting those areas that need it the most, allowing for the lime resource to be allocated more efficiently.

Variable rate lime application strategies were developed for each paddock as a part of individual property management plans and delivered to landholders at workshops during June 2019 (Round 1) and by phone consultation during June 2020 (Round 2).

It is anticipated the property management plans, combined with variable rate lime strategies, will enable the successful establishment of perennial pastures to improve the quality and quantity of feed-on-offer and will persist beyond the period it takes to recoup the establishment costs.

Acknowledgements

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Twenty-three years of the North-East Paddock Survey

Dale Grey
Agriculture Victoria Bendigo

Background

During the past 23 years, Agriculture Victoria has been conducting a land-use survey based on the same set of 682 paddocks located across north-east Victoria. The survey is conducted annually during November and provides an indication of changing land-use over time.

The survey concentrates on the predominantly dryland regions from Barmah in the west, and follows a transect from the Murray River to the Broken River, before finishing at Barnawartha in the east.

Method

Originally, the survey process simply involved driving the designated route, with a note taker looking left and right every two kilometres and then noting the land use of the paddock (i.e. dryland or irrigated annual crop type, perennial pasture or other use). This involved a 'rally track' like pace-note system. As with all else, the system has now been modernised, with GPS locations loaded onto an iPad, which has improved accuracy and repeatability.

Results

In 1998 the cropped area represented 27.5 per cent of the landscape and this has risen steadily to a high of 55.4 per cent in 2019, reducing just slightly to 54.5 per cent in 2020 (Table 1, page 67). The area sown to pasture has been retreating over this time, reducing from a high of 65.4 per cent of area in 1998, down to 41.8 per cent in 2019. The last time crop and pasture area were of roughly equal proportions was probably in 2008.

During 2020, the major crop sown across north-east Victoria was wheat, representing 27.7 per cent of land-use, which was slightly down on the record area of 30.4 per cent sown in 2011. The next most-frequently sown crop during 2020 was canola, at 15.8 per cent, slightly lower than the record area of 18.3 per cent sown during 2017.

Oats grown for hay, grazing and/or grain are a common feature of north east Victorian farming systems, exhibiting a constant area of between 4–7 per cent. Roughly half of the oat paddocks are regularly cut for hay, with 2020 being no different.

The area sown to barley during the past 23 years has slowly increased to account for a similar area to oats, rising from 0.7 per cent in 1998 to 4.5 per cent in 2020, slightly down on the high of 6.8 per cent in 2019.

Triticale, traditionally a common crop, which represented 11.1 per cent of area in 2002, has now receded to an almost non-existent level. During the past few years, the survey has shown 1–4 paddocks annually, however in 2020 no triticale was recorded in the survey paddocks, with only three other paddocks observed across the whole transect.

Legume crop production remains low, varying between 1.5–2.5 per cent of land-use area. Faba bean area (1.5 per cent in 2020) has been slowly increasing to overtake lupin area (0.6 per cent in 2020) and during the past four years vetch has appeared (0.4 per cent in 2020) where it was not previously grown before.

Fodder production is seasonally variable, dependant on prices, frost and spring rainfall. This year saw an opportunity for dryland pasture and lucerne hay production, with 3.8 per cent of paddocks being cut for hay or silage (the highest since the spring of 2016). The area used for cereal hay was at the more common low levels of 3.1 per cent of paddocks, down from the drought-induced highs of 2006–08 and 2018–19.

The use of mechanical long fallow has been low for decades across the region, ever since the advent of direct drilling. In 1998, mechanical long fallow represented 3.5 per cent of area and this retreated to a low of 0.1 per cent in 2017, before lifting marginally in 2020 to 0.7 per cent.

Conclusion

Since the survey was initiated during 1998, cropping has steadily increased as a land use across north-east Victoria, at the expense of pasture production, with wheat and canola showing the biggest increases over this time.

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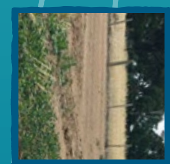
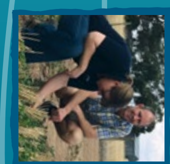
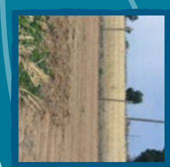
TABLE 1 Land-use as a percentage of paddocks surveyed as part of the North East paddock survey, 1998–2020

NE Victoria	1998 (%)	1999 (%)	2000 (%)	2001 (%)	2002 (%)	2003 (%)	2004 (%)	2005 (%)	2006 (%)	2007 (%)	2008 (%)	2009 (%)	2010 (%)	2011 (%)	2012 (%)	2013 (%)	2014 (%)	2015 (%)	2016 (%)	2017 (%)	2018 (%)	2019 (%)	2020 (%)
Pasture	65.4	63.6	63.5	59.5	55.4	54.4	52.8	56	56.3	51.5	47.1	45	Too wet to do	46.2	46.9	47.1	47.2	44.3	45	45.2	43.4	41.8	42.2
Dryland lucerne	1.7	1.9	2.8	2.8	3.7	4.8	4.5	5.6	4.7	4.3	4.4	4.0		3.4	4.1	3.4	3.1	3.2	2.2	2.0	3.1	1.3	1.5
Phalaris	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA		NA	NA	1.0	1.2	1.6	1.5	1.8	0.6	0.3	2.1
Pasture fodder	5.4	4.7	4.4	4.1	0.9	5.1	4.4	4.5	1.2	1.3	0.6	1.2		1.3	2.6	3.8	3.4	1.8	4.7	2.2	0.9	2.3	3.8
Crop	27.5	29.6	31.2	35.3	40.2	41.3	43.0	40.0	40.0	45.3	49.6	51.0		50.1	49	49.4	49.6	52.1	52.1	51.5	53.4	55.4	54.5
Cereals	24.6	23.8	24.6	29.5	32.0	33.6	33.1	34.5	29.6	37.0	40.0	40.6		37.7	31.4	32.3	35.4	34.3	35.3	30.5	34.3	38.6	36.2
Cereal fodder	3.2	3.1	2.1	2.1	3.5	2.5	2.2	2.9	9.8	12.0	8.2	6.5		1.5	2.8	2.6	2.4	6.3	2.9	3.3	13.3	10.1	3.1
Canola fodder	nil	nil	nil	nil	nil	nil	nil	nil	4.7	5.6	1.3	0.3		nil	nil	nil	nil	nil	nil	0.1	7.8	0.6	nil
Pulses	0.9	0.7	0.4	0.9	1.3	1.2	1.6	0.6	1.8	1.5	1.0	1.3		1.9	1.5	1.5	1.3	2.2	2.6	2.7	1.5	2.6	2.5
Pulse fodder	nil	nil	nil	nil	nil	nil	nil	nil	nil	0.6	nil	nil		nil	nil	0.3	0.1	0.1	nil	2.0	0.3	0.3	0.3
Irrigation	4.1	2.6	2.8	6.6	5.1	3.2	3.7	3.2	3.4	1.2	0.6	1.3		1.6	2.9	2.9	2.5	2.9	1.3	2.4	3.7	2.3	2.1
Mech. fallow	3.5	2.3	1.8	1.8	0.7	0.6	1.0	0.9	0.9	0.4	0.3	1.3		0.9	1.2	0.7	0.9	0.7	0.1	0.1	0.7	0.4	0.7
Spray fallow	nil	nil	nil	0.7	nil	0.3	0.1	1.0	nil	0.1	nil	nil		0.6	0.1	0.3	0.4	0.3	1.0	0.4	0.6	0.7	0.6
Wheat	12.3	10.4	11.9	13.6	13.2	16.7	18.9	17.2	13.6	21.3	24.5	26.8		30.4	24.5	27.1	29.7	27	26.7	22.9	29	25.8	27.7
Triticale	6.2	6.2	6.5	10.0	11.1	8.9	8.8	8.8	8.8	7.3	6.7	3.5		1.5	0.4	0.4	0.3	nil	1.0	0.6	0.1	0.7	nil
Oats	5.4	6.3	4.5	4.5	6.0	6.3	3.8	4.8	5.9	6.6	6.3	7.9		3.7	4.7	3.5	2.8	3.8	3.8	4.9	5.1	5.9	4.0
Barley	0.7	0.9	1.8	1.3	1.6	1.6	1.6	3.7	1.3	1.8	2.5	2.3		2.2	1.8	1.2	2.6	3.5	3.1	2.1	4.1	6.2	4.5
Canola	2.0	5.1	6.2	5.0	6.6	6.6	8.1	5.0	8.7	6.9	8.5	8.9		10.6	16	15.5	12.6	15.5	14.1	18.3	13.5	14.2	15.8
Lupins	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA		NA	NA	0.6	0.4	1.0	0.3	1.2	0.3	1.2	0.6
Faba beans	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA		NA	NA	0.4	0.7	0.9	2.1	1.2	0.6	0.8	1.5
Field peas	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA		NA	NA	0.4	0.1	0.2	0.2	nil	nil	0.1	nil
Vetch	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA		NA	NA	nil	nil	nil	nil	0.3	0.4	0.2	0.4
Lentil	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA		NA	NA	nil	nil	nil	nil	nil	0.1	0.1	nil
Chickpea	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA		NA	NA	nil	nil	nil	nil	0.1	nil	nil	nil

NA = Not available.
Highest value in green.
Lowest value in orange.







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