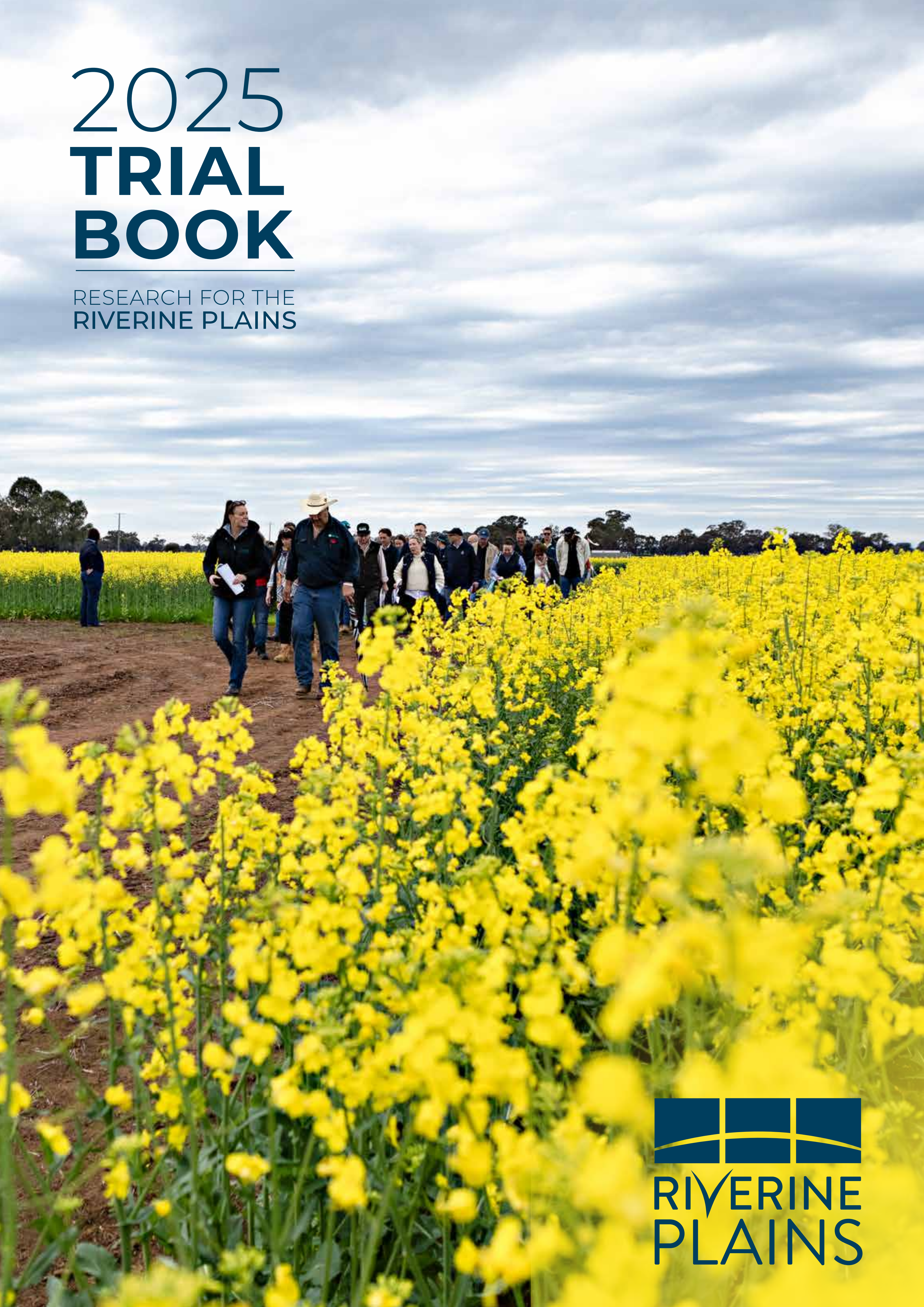
2025 TRIAL BOOK

RESEARCH FOR THE RIVERINE PLAINS



RIVERINE PLAINS

ORGANISATIONAL PARTNERS

PREMIER PARTNERS

ABA Alvan Blanch Australia

SIGNATURE PARTNERS

Bendigo Bank Agribusiness

Nutrien Ag Solutions

Grain Growers

Wiesners

O'Connors Case IH Agriculture

VALUED PARTNERS

Hunters Trade • Rural • Hardware

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Pioneer Brand • Seeds

Elders Insurance Wodonga & Murray Goulburn

PROGRAM PARTNERS

AgriFutures Australia

Elders

Australian Government Department of Agriculture, Fisheries and Forestry | Future Drought Fund

FRRR Foundation for Rural Regional Renewal

Australian Rural Leadership Foundation

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DISCLAIMER

CEREAL GROWTH STAGES

A growth stage key provides a common reference for describing crop development. The most commonly used growth stage key for cereals is the Zadok 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). Zadock growth stages are described below:

0 GERMINATION

00 Dry seed

01 Start of imbibition (water absorption)

03 Imbibition complete

05 Radicle (root) emerged from seed

07 Coleoptile (shoot) emerged from seed

09 Leaf just at coleoptile tip

1 SEEDLING GROWTH

10 First leaf through coleoptile

11 First leaf emerged

13 3 leaves emerged

15 5 leaves emerged

17 7 leaves emerged

19 9 or more leaves emerged

2 TILLERING

20 Main shoot only

21 Main shoot and 1 tiller

23 Main shoot and 3 tillers

25 Main shoot and 5 tillers

27 Main shoot and 7 tillers

29 Main shoot and 9 or more tillers

3 STEM ELONGATION

30 Pseudostem (leaf sheath) erection

31 First node detectable

32 2nd node detectable

33 3rd node detectable

34 4th node detectable

35 5th node detectable

36 6th node detectable

37 Flag leaf just visible

38 Flag leaf half visible

39 Flag leaf ligule just visible

4 BOOTING

41 Early boot - flag leaf sheath extending

43 Mid boot - boots just visibly swollen

45 Full boot - boots swollen

47 Flag leaf sheath opening

49 First awns visible

5 INFLORESCENCE (EAR/PANICLE) EMERGENCE

51 First spikelet of inflorescence just visible

53 Inflorescence 30 % emerged

55 Inflorescence 50% emerged

57 Inflorescence 70% emerged

59 Inflorescence 90% emerged

6 ANTHESIS (FLOWERING)

60 Whole spike visible

61 Early – 20% spike with yellow anthers

63 30% of spikes with yellow anthers

65 Mid- 50% of spikes with yellow anthers

67 70% of spikes with yellow anthers

69 Late – 90% of spikes with yellow anthers

7 MILK DEVELOPMENT

71 Kernal watery ripe, clear liquid

73 Early milk, liquid off-white

75 Medium milk, contents milky liquid

77 Late milk, more solids in milk

79 Very late milk, half solids in milk

8 DOUGH DEVELOPMENT

81 Very early dough, more solids and slides when crushed

83 Early dough, soft, elastic and almost dry, shiny

85 Soft dough, firm, crumbles but fingernail impression not held

87 Hard dough, fingernail impression held, spike yellow brown

89 Late hard dough, difficult to dent

9 RIPENING

91 Kernal hard (difficult to divide)

92 Caryopsis hard (not dented by thumbnail)

93 Caryopsis loosening in daytime

94 Over-ripe straw dead and collapsing

95 Seed dormant

96 Viable seed giving 50% germination

97 Seed not dormant

98 Secondary dormancy induced

99 Secondary dormancy lost

ACHIEVEMENTS AT A GLANCE 2024

EVENTS JANUARY – DECEMBER 2024

- Sykesy's Buraja Meeting
- Resilient pastures field walk, Savernake
- Irrigation Discussion Group field day, Congupna
- Harvest wrap-ups, Rand, Katamatite, Murchison
- Input workshop, Boorhaman
- Optimal heifer performance discussion, Tintaldra
- Stock containment Boosting Business workshop, Dookie
- Soil pit and pastures day, Cudgewa
- Youth in Ag: GRAZE
- Resilient pastures webinar
- On-farm sustainability workshop, Eskdale
- Stock containment Boosting Business workshop, Corryong
- Working dog training, Rennie
- Youth in Ag: Cultivate & Connect
- Hyper profitable crops Discussion Group, Corowa
- Dry sowing, stubble and crown rot field walk, Murchison
- Rural and Remote Frist Aid training, Rennie, Walbundrie, Dookie
- Farm Water Management Workshop Savernake, Henty
- Burramine Field Day
- In-season Update
- Harvester Set-up Workshop
- Evan Moll Gerogery Field Day
- Building soil carbon in the Riverine Plains Webinar

EVENTS

28 EVENTS

FLAGSHIP EVENTS

- YOUTH IN AG: GRAZE
- YOUTH IN AG: CULTIVATE & CONNECT
- IN-SEASON UPDATE

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2024	472 MEMBERS

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- SOILS
- LIVESTOCK
- CLIMATE
- DROUGHT
- BUSINESS
- GRAINS
- FODDER
- PEOPLE
- SUSTAINABILITY

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THANK YOU TO OUR 2024 HOST FARMERS

Thank you to the members who very generously donated their time, paddocks and experience to enable Riverine Plains to undertake research, extension and validation locally. Your contribution to our region is very much appreciated.

The Brown family
John and Sarah Bruce
The Coulthard family
Gus and Sue Campbell
Jane and Barry Clarke
Nico and Allison Courtney
Adam Feuerherdt and the Bird family
Chantelle and Christine Gorman
Roy, Leanne and Michael Hamilton
Ross Heywood
Adam and Ingrid Inchbold
The Kellock family
The Marshall family
Lee Menhenett
Nathan and Kara Lawless
Lawson Grains
Beau and Rebecca Longmire
The Moll family
Don Piper
Kate and Neville Reilly
Craig Reynolds
Andrew and Sue Russell
The Sandral family
Damien and Carissa Schneider
The Spence family
The Stedman Family
Bronwyn and Lawson Thomas
Craig and Julia Thomas
Ian and Melanie Trevethan
Tim and Lara Trevethan
Uncle Tobys (Nestlé)
The Webster family
Ian and Kaye Wood

PROJECT PARTNERS

Riverine Plains was proud to collaborate with the following research and extension partners:

AgriSci, AgGrow Agronomy, Agricultural Marketing & Production systems, Australian Centre for International Agricultural Research (ACIAR), Ag Excellence Alliance, Agriculture Victoria, AgriFutures Australia, Australian Government's Future Drought Fund, Australian Government's Preparing Australian Communities Program, Australian Government's Department of Climate Change, Energy, the Environment and Water, Australian Government's National Landcare Program Smart Farms Small Grants Initiative, Australian National University, Birchip Cropping Group, Black Duck Foods, Bureau of Meteorology, Burdekin Productivity Services, Central West Farming Systems, Charles Sturt University, Corowa District Landcare, CSIRO, Deakin University, Farming Systems Groups Alliance, Federation University, FAR Australia, FarmLink, Food and Fibre Gippsland, First Nations Governance Circle, Foundation for Rural and Regional Renewal (FRRR), Gap Flat Track Native Foods, Gecko ClaN, Grain Orana Alliance, Grains Research and Development Corporation (GRDC), Goulburn Broken Catchment Management Authority, Grower Group Alliance of Western Australia, Griffith University, Herbert Cane Productivity Services, Holbrook Landcare Network, Hughes Creek Catchment Collaborative, Irrigation Farmers Network, Irrigation Research and Extension Committee, La Trobe University, Local Land Services NSW, Mallee Regional Innovation Centre, Mallee Sustainable Farming, Many Mobs Indigenous Corporation, Monaro Farming Systems CMC, Nicon Rural Services, NSW Department of Climate Change, Energy, the Environment and Water, NSW Department of Primary Industries & Regional Development, Ricegrowers' Association, Rural Aid, South Australian Research and Development Institute (SARDI), Soil CRC, Southern Farming Systems, Southern Growers, Southern Cross University, Southern NSW Drought Resilience Adoption and Innovation Hub (SNSW Innovation Hub), Toni Nugent, The University of Melbourne, University of Canberra, University of Wollongong, University of Southern Queensland, University of Tasmania, Victoria Drought Resilience Adoption and Innovation Hub (Vic Drought Hub), Western Australian No Tillage Farmers Association (WANTFA), Western Murray Land Improvement Group, West Hume Landcare and West Midland Group.

NEW PROJECTS

During 2024 Riverine Plains commenced the following new projects:

NEXT GENERATION TOOLS TO SUPPORT HIGHER PERFORMING SOILS

TERM DATE: 2024–2027

This project is focused on developing a suite of novel decision support tools designed to assist farmers and advisors in soil amelioration decisions. The tools are based on models and algorithms developed in previous research conducted by the CRC for High Performance Soils (Soil CRC). Riverine Plains is involved in validation and testing, via an existing trial site at Rand, and will also be involved in workshop participation, to ensure tools are easy to use.

This project is funded through the Soil CRC.

SCOUT: RAINSTICK – IMPROVING CANOLA ESTABLISHMENT

TERM DATE: 2024–2025

Riverine Plains is supporting novel bioelectrical technology startup, Rainstick, through early-stage problem and market validation. This technology has the potential to increase crop resilience through increasingly variable climate conditions, including unfavourable sowing conditions.

Rainstick merges First Nations knowledge with modern bioelectrics to enhance sustainable agriculture. The company focuses on using electricity to improve crop yield. Their key technology, the Variable Electric Field (VEF) treatment, mimics the natural effects of lightning, which has been traditionally associated with boosting plant growth.

This project is funded by the Victoria Drought Resilience Adoption and Innovation Hub and the Riverine Plains SCOUT program.

LONG-TERM TRIALS OF DROUGHT RESILIENT FARMING PRACTICES IN VICTORIA

TERM DATE: 2024–2026

This project is investigating innovative cropping, grazing and mixed farming practices through the lens of drought resilience and associated risk management. The project supports the trialling and demonstration of practices that have the potential to contribute to drought resilience related to on-farm productivity and natural capital. As part of this project Riverine Plains has established a trial site at Murchison, Victoria.

This project is funded by the Australian Government's Future Drought Fund, through the Victoria Drought Resilience Adoption and Innovation Hub.

LONG-TERM TRIALS OF DROUGHT RESILIENT FARMING PRACTICES IN NSW

TERM DATE: 2024–2026

This project is investigating innovative farming practices that support drought resilience and associated risk management in New South Wales. The project supports the trialing and demonstration of practices that have the potential to contribute to drought resilience related to on-farm productivity and natural capital, with sites established at Corowa and Burrumbuttock in New South Wales (NSW).

This project is funded by the Australian Government's Future Drought Fund, through the Southern NSW Drought Resilience Adoption and Innovation Hub.

LONG TERM TRIALS – EVALUATING NOVEL APPROACHES FOR DROUGHT RESILIENCE

TERM DATE: 2023–2028

This project continues to investigate how novel practices for drought resilience, such as cover crops and soil amendments, can affect soil water storage, crop water use efficiency and crop yield variability. Data collected from the long-term trial (LTT) site at Burramine in north east Victoria, and other project sites in NSW, Victoria and Western Australia, is being used to develop models that will help quantify how these practices can help mitigate long-term financial risk for farmers.

This project is funded by the Soil CRC through the Australian Government's Future Drought Fund.

CARBON FARMING OUTREACH PROGRAM

TERM DATE: 2024–2026

The Carbon Farming Outreach Program is a national initiative providing independent information to farmers and land managers about carbon farming strategies. This project is supporting Riverine Plains staff to deliver workshops to increase knowledge and skills on farm and land emissions, as well as carbon storage.

This project is funded by the Grower Group Alliance of Western Australia (GGA Inc) through the Australian Government's Department of Climate Change, Energy, the Environment and Water.

BUILDING SOIL CARBON THROUGH LAND MANAGEMENT STRATEGIES

TERM DATE: 2024–2025

This project supports NSW farmers in the Riverine Plains to explore their soil carbon potential and showcases eligible land management practices that are best suited for potential soil carbon projects.

The focus of the project is on understanding soil carbon in the Riverine Plains region and supporting farmers to develop strategies to increase or maintain soil carbon through effective land management techniques.

This project is supported by the Soil CRC as part of the 'Soil Carbon Capacity Building Resources for Farmers and Advisors' project, supported by the NSW Government as part of the Primary Industries Productivity and Abatement Program.

COMPANION CROPPING LEGUMES FOR LOWER COST NITROGEN SUPPLY IN FARMING SYSTEMS

TERM DATE: 2024–2027

Grain growers are increasingly reliant on inorganic fertiliser nitrogen for crop production and are looking at innovative ways of reducing synthetic nitrogen inputs. Incorporating legumes can help farmers add nitrogen to the soil that can be taken up by subsequent non-leguminous crops.

This project is testing nitrogen fixation in companion cropping scenarios at different desiccation timings, to establish the impact on the non-leguminous crop. It is also testing the nitrogen-fixating contribution to the farming system, as well as the costs associated with sowing and desiccation.

This project is an investment of the Grains Research and Development Corporation (GRDC).

OPTIMISING SLUG MANAGEMENT

TERM DATE: 2024–2026

Slugs are becoming an increasingly difficult problem to manage across the Riverine Plains. This project involves the monthly monitoring of slug populations in dryland and irrigated paddocks located in NSW and Victoria, as well as the design and establishment of annual spring baiting trials, including non-chemical treatments, in collaboration with SARDI. Extension events and activities will support farmers in better understanding and managing their slug populations

This project is an investment of the GRDC.

NON-CHEMICAL SLUG CONTROL

TERM DATE: 2024–2025

This project is helping to understand key trends in the presence or absence of slugs on-farm, to inform future projects. The project aims to understand the potential for non-chemical strategies for slug control and help farmers avoid the significant costs associated with chemical control. In doing so, the project also aims to increase business and system resilience, as well as sustainability.

This project is funded by the Australian Government's Future Drought Fund, through the Victoria Drought Resilience Adoption and Innovation Hub.

NEW PROJECTS

HYPER PROFITABLE CROPS

TERM DATE: 2024–2027

The Hyper profitable crops (HPC) project initiative aims to boost on-farm profitability for wheat and barley growers in Australia's high rainfall zones by bridging the gap between current crop yields and their full profitability potential.

The project builds on the successes of previous GRDC Hyper yielding crops and Hyper yielding cereals work. Its focus is on closing the yield gap through informed decisions on variety selection, sowing dates, fertiliser use, and disease management.

This project is an investment of the GRDC.

FARM DATA: LOCAL WEATHER DATA FOR IMPROVED DECISION MAKING

TERM DATE: 2024–2025

This project is exploring how farm weather and soil moisture data can support improved decision making on-farm, increasing farm business resilience and farmers' ability to prepare and adapt to changing climate conditions.

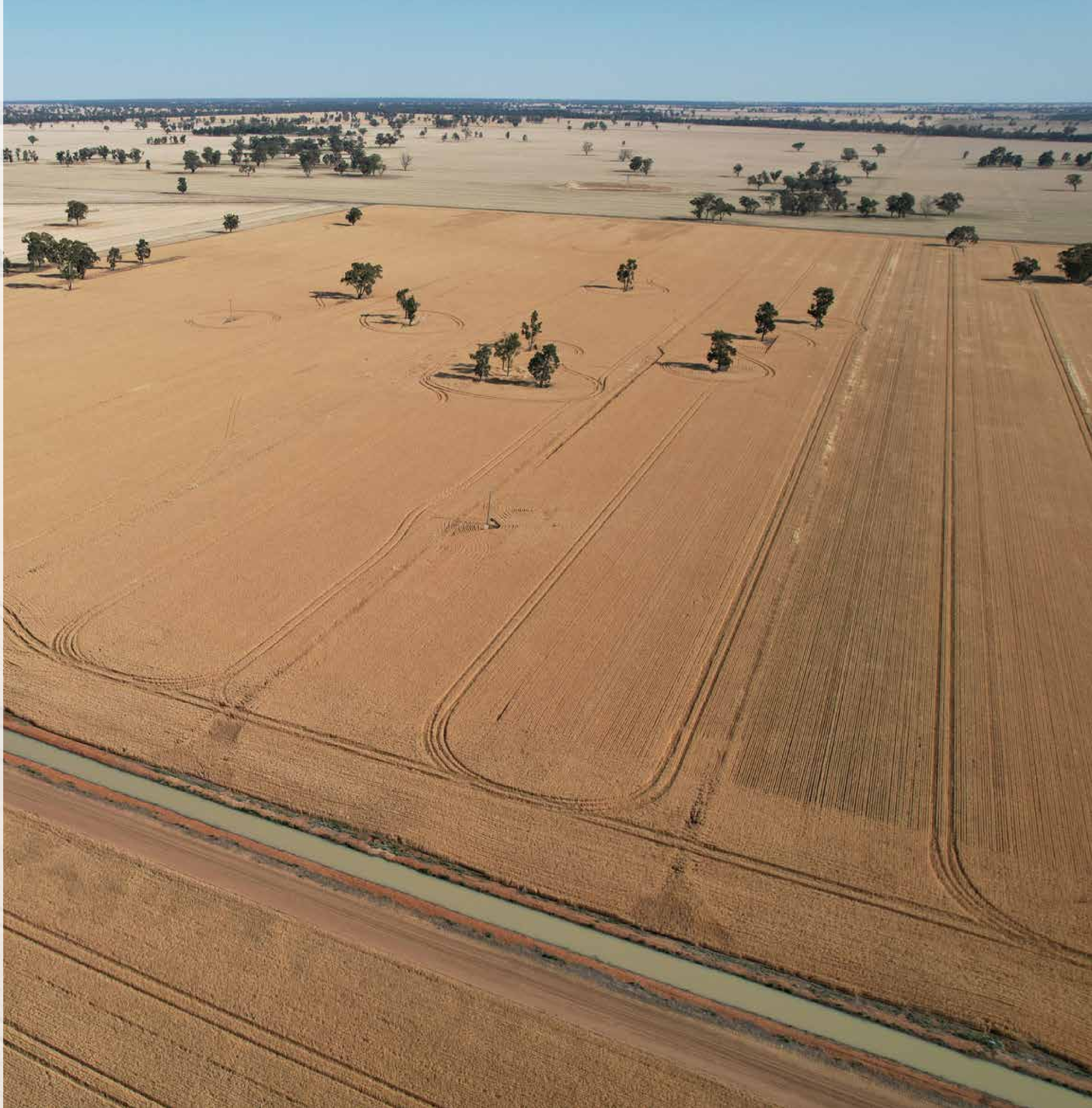
This project received funding through the Victoria Drought Resilience Adoption and Innovation Hub.

RISKWI$E: ENTERPRISE FINANCIAL DECISIONS

TERM DATE: 2024–2028

Grain growers are continually making decisions, ranging from strategic, to tactical, to the day-to-day. Decisions are made within a continually changing operating environment and this project is helping to better understand the processes, considerations, distractions and stresses that can manifest during the decision-making process

This project is an investment of the GRDC and is part of the larger GRDC RiskWi$e program, which aims to increase farmers' confidence in managing risks inherent to decision making in their businesses.



CURRENT PROJECTS

Projects that continued during 2024:

SUPPORTING GREENHOUSE GAS INVENTORIES AND LIVESTOCK DATA DEVELOPMENT IN FIJI

TERM DATE: 2023–2025

Riverine Plains is supporting the delivery of an international research project in Fiji, funded by the Australian Centre for International Agricultural Research (ACIAR). This project is the first of its kind for Riverine Plains and is focused on National Inventory (greenhouse-gas accounting) and livestock data development in Fiji.

The project aims to co-develop an improved measurement, reporting and verification system for livestock in Fiji. This project is one way Australia is supporting Pacific Island Countries meet the larger commitment of 'Net-Zero by 2050' under the Paris Agreement.

LINK BETWEEN CEREAL STUBBLE, SUBSURFACE ACIDITY AND CROWN ROT

TERM DATE: 2023–2026

Sampling conducted as part of a previous project identified high levels of Fusarium crown rot at sites with high stubble loads and subsurface acidity across the Riverine Plains. The build-up of Fusarium crown rot has likely been favoured by recent consecutive good seasons, along with stubble retention and tight cereal rotations in the region.

This project is investigating the potential link between Fusarium crown rot, subsoil acidity and stubble management techniques through demonstrations, surveys and trials to help farmers mitigate yield loss.

This project is an investment of the GRDC.

ON FARM WATER MANAGEMENT

TERM DATE: 2023–2025

Managing water effectively can minimise the impacts of drought on livestock, pastures, soil health, and natural assets, ultimately improving production during and after drought.

This project aims to help farmers develop farm water management strategies to improve water quality, maintain livestock health, and preserve soil and natural assets. The project supports landholders in developing farm water management plans to ensure their dams, tanks and waterways meet stock and domestic needs, especially during drought.

This is a Southern NSW Drought Resilience Adoption and Innovation Hub project, funded by the Australian Government's Future Drought Fund.

ENHANCING THE ADOPTION OF IMPROVED SOIL MANAGEMENT PRACTICES

TERM DATE: 2023–2026

The Soil CRC has delivered learnings and outcomes that support grower groups, advisors and extension officers to extend soil management information to farmers.

As part of this project, Riverine Plains and other grower groups are designing and testing extension packages that improve project delivery, resulting in better engagement and improved adoption of outcomes from all Soil CRC projects.

This project is funded by the Soil CRC.

MACHINE LEARNING FOR MANAGING SOIL CONSTRAINTS

TERM DATE: 2023–2025

This project aims to find the best ways to manage multiple soil constraints such as sodicity, acidity, and salinity to help farmers make informed soil management decisions to maximise productivity and profitability.

The project uses data and a computer-based approach to predict which management and amelioration practices will work best for a particular soil, to enhance soil productivity and profitability for farmers.

This project is funded by the Soil CRC.

IRRIGATION DISCUSSION GROUPS

TERM DATE: 2023–2025

This project aims to link new and innovative research investments by GRDC with local farmer-driven groups to improve the adoption of practices that improve the efficiency and sustainability of irrigated crop production.

The project follows on from the Facilitated Action Learning Groups to support profitable irrigated farming project.

This project is an investment of the GRDC.

DE-RISKING EARLY SOWN CROPS

TERM DATE: 2023–2025

Dry and early sowing of cereal crops is a practice commonly used by farmers in southern Australia to combat erratic and late opening season rainfall, and to effectively manage the sowing program on increasingly large farms.

This collaborative project aims to enhance the adoption of strategic dry sowing crop management techniques to help farmers reduce their production risk and better manage increasingly large sowing programs.

This project is supported by Ag Excellence Alliance Inc, through funding from the Australian Government's Future Drought Fund.

DEMONSTRATING RYEGRASS CONTROL STRATEGIES

TERM DATE: 2023–2025

Cereals form a key part of the rotation for growers in the Riverine Plains region, with reports of increased ryegrass numbers in this phase due to limited control options. This has been exacerbated by poor trafficability in wet and waterlogged paddocks over recent years, with excessively wet conditions also impacting pre-emergent weed control for some product uses.

This GRDC National Grower Network project is evaluating diverse ryegrass management strategies, with the aim of enhancing crop yield and combating herbicide resistance.

This project is an investment of the GRDC.

ORGANIC FERTILISERS FOR CROP NUTRITION

TERM DATE: 2022–2026

In partnership with FAR Australia, this project is looking at the value of faba bean stubble with and without organic manures in restoring fertility and increasing yield in the following wheat crop. The impact of two different timings of nitrogen application on the faba crop in the subsequent wheat crop will also be assessed.

This project is an investment of the GRDC.

REWARDING SOIL STEWARDSHIP

TERM DATE: 2022–2025

This project, led by Charles Sturt University, is configuring, trialing and evaluating novel financial mechanisms to reward soil stewardship.

The project is working to improve connections among soil scientists, growers and the finance sectors and review the benefits, costs and uncertainties related to different soil stewardship practices, as well as the available returns from different markets/sources.

This project is funded by the Soil CRC.

BUILDING SOIL RESILIENCE AND CARBON THROUGH PLANT DIVERSITY

TERM DATE: 2023–2026

This project, led by Southern Cross University, follows on from the *Plant based solutions to improve soil performance* project. The project continues to investigate changes in soil function, resilience and carbon stocks under a range of agronomic practices that incorporate plant diversity in cropping systems.

The project also investigates how much carbon from rhizo-deposits from cover crop and intercrop species is stabilised in soil and its contribution to soil aggregation.

This project is funded by the Soil CRC.

HELPING REGIONAL COMMUNITIES PREPARE FOR DROUGHT – GOULBURN COORDINATION

TERM DATES: 2023–2025

This project is strengthening drought preparedness and driving local action in the Goulburn region through the coordination of Community Impact Program activities and evaluation administration.

This project is supported by FRRR through funding from through the Australian Government's Future Drought Fund.

CURRENT PROJECTS

COMMERCIALISING THE PENETROMETER

TERM DATE: 2023–2026

A previous Soil CRC Smart Soil Sensors project led to the development of the 'Smart Penetrometer'. Once completed, this farm-ready tool will be able to simultaneously measure soil moisture, penetration resistance (compaction) and salinity while being driven into the soil.

Riverine Plains is providing technical guidance to the project and will participate in the testing of this tool, once ready.

This project is funded by the Soil CRC.

RIVERINE PLAINS INNOVATION EXPO EVENTS

TERM DATES: 2023–2025

This project aimed to build depth of social connection and increase skills, knowledge and understanding of the risks posed by drought and climate change by delivering Innovation Expo and In-season Update events, awareness and education activities from 2023-2025.

This project was supported by FRRR through funding from the Australian Government's Future Drought Fund. The Riverine Plains 2023 Innovation Expo was also supported by Alvan Blanch Australia, Uncle Tobys, Bayer Crop Science, New Edge Microbials, GRDC, Australian Grain Technologies, ANZ, Thera Capital Management, Wiesners, Goldacres, AgriFutures Australia, Agriculture Victoria and Moira Shire.

LADIES' LUNCHEON

TERM DATES: 2023–2025

This project aims to build depth of social connection, a shared sense of purpose and longer-term community belonging that can be drawn upon in future drought by hosting Ladies' Lunches in 2023 and 2025. The lunches celebrated the role and achievements of rural women in the Riverine Plains region, reducing social isolation and building local networks and social supports for women in this remote region.

This project is supported by FRRR through funding from the Australian Government's Future Drought Fund. The 2023 Ladies Luncheon was also supported by Riverine Plains Project Partner, Grain Growers.

YOUTH IN AG

TERM: 2023–2025

This project aims to build depth of social connection, a shared sense of purpose and longer-term community belonging that can be drawn upon in future drought through the facilitation of two mentoring and networking events for youth in the region and two 'Youth in Ag' dinner events.

This project is supported by FRRR through funding from the Australian Government's Future Drought Fund. The 2023 and 2024 Youth in Ag Program was also supported by Riverine Plains Youth in Ag Program partners, Corteva Agriscience and Elders Rural Services, Elders Shepparton, Elders Yarrawonga, Elders Albury.

SOUTHERN NSW DROUGHT RESILIENCE ADOPTION AND INNOVATION HUB

TERM DATE: 2022–2026

The Southern NSW Drought Resilience, Adoption, and Innovation Hub is a consortium of nine regional partners including primary producers, Indigenous, industry and community groups, researchers, entrepreneurs, education institutions, resource management practitioners and government agencies.

The outcome of this partnership is user-driven innovation, research and adoption and the facilitation of transformational change through the co-design of research, development, extension, adoption, and commercialisation activities.

This project is funded through the Australian Government's Future Drought Fund.

ASSESSING SOIL WATER STORAGE

TERM DATE: 2022–2025

This project aims to improve the understanding of crop access to water and resources. Through installation of field sensors, the project is quantifying changes in soil water infiltration, storage, drainage, and crop interaction, due to the diagnosis and management of soil constraints at an existing Soil CRC project site at Burramine. This is allowing the development of tools supporting soil management for increased access to soil water and give a better understanding of the competition for water and resources between mixed species cover crops and impacts on soil water availability.

This project is funded by the Soil CRC.

SMALL FARM DAM SUITABILITY ASSESSMENT

TERM DATE: 2022–2025

This project is led by Southern Farming Systems and aims to create a spatial tool to rapidly calculate the likely runoff (frequency and volume under current future climate scenarios) into existing farm dams to help prepare, cope, and recover from drought. This type of calculator does not exist, with current approaches designed for flood rather than drought planning.

This project is funded by the Australian Government's Future Drought Fund.

BEST PRACTICE LIMING

TERM DATE: 2021–2025

This project aims to increase awareness of the speed of acidification and stratification of soils in the region and the availability of tools to assist in the management decision process.

It involves a replicated lime treatment field trial at Lilliput, Victoria, which aims to demonstrate best practice liming methods and how the incorporation of top-dressed lime can improve its distribution down the soil profile, lessening the impacts of soil acidity on subsequent crops.

This project is an investment of the GRDC.

VICTORIA DROUGHT RESILIENCE ADOPTION AND INNOVATION HUB

TERM DATE: 2021–2026

The Victoria Drought Resilience, Adoption, and Innovation Hub is led by the University of Melbourne's Dookie Campus and is conducted in association with Deakin, La Trobe, and Federation Universities and Agriculture Victoria.

Riverine Plains leads the Northeast Victoria "Node", consulting the agricultural industry through farmers, councils, businesses, health organisations, and community groups in their region about building drought resilience at the local level. This process has led to the development of pilot projects to address specific knowledge or technical skill gaps identified through the hubs, capacity building and the brokering of knowledge between nodes.

This project is funded through the Australian Government's Future Drought Fund.

CURRENT PROJECTS

Projects that concluded during 2024

VISUALISING AUSTRALASIA'S SOILS

TERM DATE: 2023–2024

This project aimed to increase the soils data and related information that can be discovered through the Visualising Australian Soils portal, to sustain a soil knowledge system that is inherently useful for research, development, extension and adoption.

This project was led by Federation University and funded by the Soil CRC.

SUPPORTING CLIMATE RESILIENCE THROUGH WEATHER STATIONS

TERM DATE: 2022–2024

The project investigated the feasibility of bringing together five networks of weather stations and moisture probes across southern Australia into a single, standardised platform to inform key stakeholders on a series of localised climatic information to assist with disaster planning.

This project received grant funding from the Australian Government through the Preparing Australian Communities Program.

SILICON FERTILISER FOR DROUGHT RESILIENCE IN BROADACRE CROPPING

TERM DATE: 2022–2024

This project was led by The University of Melbourne and hosted on large plot demonstration sites at four locations across northern Victoria.

Around fifty small-scale replicated research trials were used to evaluate a broader set of varieties and management options, including silicon fertiliser application for drought mitigation in broadacre cropping. In this project, granular silicon fertiliser was applied below the seed at sowing for wheat and faba beans, while foliar silicon fertiliser was applied throughout the season.

The potential role of legumes in the standard cropping rotation and dual-purpose wheat options was also demonstrated, as well as an evaluation of indigenous plant species.

This project was funded by the Australian Government's Future Drought Fund.

TECHNOLOGY UPTAKE PROGRAM

TERM DATE: 2023–2024

The agtech space is complex and continually evolving. This means it can be difficult for farmers to work out which technology provides the best solution when solving a problem on farm. The *Technology uptake program* supported farmers in the Riverine Plains region to understand the types of agtech available, and how it can benefit their farming operation through a series of workshops, field tours, and case studies.

This project followed on from Riverine Plains *Producer technology uptake* program, which involved online technology workshops and case studies of local farmers adopting new technology.

This project was funded by AgriFutures Australia.

OPTIMISING SOILS AND AVAILABLE WATER TO IMPROVE DROUGHT RESILIENCE

TERM DATE: 2022–2024

This project established 12 demonstration sites across southern NSW and north east Victoria, covering a range of soil types, environments, and land uses. The project demonstrated three proven strategies that improve drought resilience compared to conventional farming, including diverse legume rotations, early sowing of slower-maturing crops and measuring residual nitrogen in the soil.

This project was supported through funding from the Australian Government's Future Drought Fund Drought Resilient Soils and Landscapes Grants Program, and was co-funded by GRDC.

DROUGHT RESILIENT PASTURE SYSTEMS

TERM DATE: 2022–2024

This project, led by Holbrook Landcare Network, used the latest research on species and management to increase the use of perennial pasture species within farming landscapes and

increase resilience in dry seasons.

The project supported farmers to improve their pasture base, either by using practices to enhance favourable species already present, or to establish new pastures. This helped address feed-base management and farmer concerns around its impact on drought resilience.

This project was supported by the Southern NSW Drought Resilience Adoption and Innovation Hub, through funding from the Australian Government's Future Drought Fund.

SOIL EXTENSION ACTIVITIES

TERM DATE: 2023–2024

The project aimed to give farmers a better understanding of their soils and how soils can be managed to improve production and water retention. This project supported land managers by promoting the benefits of increased frequency of extensive soil sampling and testing to inform soil management decisions and take action to improve soil health.

This project was funded by the Australian Government through the National Landcare Program Smart Farms Small Grants initiative. This project was co-funded by the GRDC.

HYPER YIELDING CROPS

TERM DATE: 2020–2024

This project aimed to close the yield gap of wheat, barley and canola in the high rainfall zone. Riverine Plains established annual focus farm sites at various locations in support of the NSW Centre of Excellence at Wallendbeen.

Riverine Plains also established Discussion Groups to link local growers with the focus farm paddock trials at these sites.

This project was an investment of the GRDC.

DIAGNOSIS FRAMEWORKS FOR MULTIPLE AND COMPLEX SOIL CONSTRAINTS

TERM DATE: 2021–2024

The productivity of 77 percent of Australian agricultural soils is limited by one or more soil constraints, however, efficiently ameliorating constrained soils often requires an accurate diagnosis.

This project developed and validated diagnostic methodologies to diagnose soil constraints from the data that producers already have access to (e.g., crop yields, surface soil tests), in combination with information in the public domain. This aimed to reduce the cost associated with detailed soil sampling.

This project was funded by the Soil CRC.

CLOSING THE YIELD GAP IN FABA BEAN WITH IMPROVED DISEASE MANAGEMENT, NUTRITION AND CANOPY MANIPULATION

TERM: 2021–2024

This project, led by FAR Australia, was designed to deliver local development and extension to maximise farming benefits from grain legume production. This was achieved through grower-driven grain legume validation and demonstration trials across the region.

This project was an investment of the GRDC.

STOCK CONTAINMENT FEEDING TO BOOST RESILIENCE AND PERFORMANCE

TERM DATES: 2023–2024

Containment feeding of livestock can lead to improved productivity, reproductive performance, and enhanced landscape and pasture management, as well as greater drought resilience and profitability.

This project aimed to boost the adoption of containment systems on farms by training and assembling a network of containment adoption advisors connected to farming systems groups from across Victoria, South Australia and Tasmania. The delivery of small group producer workshops and follow-up 1:1 advice provided tailored support to producers at all stages of implementing containment feeding systems.

This project was funded by the Australian Government's Future Drought Fund through the Victoria Drought Resilience Adoption and Innovation Hub and was supported by the South Australian Drought Resilience Adoption and Innovation Hub

VICTORIA DROUGHT RESILIENCE ADOPTION AND INNOVATION HUB

Riverine Plains, as the Victoria Hub North East Node leader, is working closely with a wide range of organisations, farmer members, and community groups to deliver research, activities and resources that help build drought resilience across the region.

Through collaboration with groups such as the Goulburn Drought Resilience Plan Group, Landcare networks, Many Mobs and Towong Shire, Riverine Plains is helping to identify key community needs and develop targeted, locally relevant projects.

PROMOTION OF MENTAL HEALTH AND FARM SAFETY

Riverine Plains has a continuing focus on mental health and farm safety to support farmer resilience. Jenn Pegler, Murrumbidgee Local Health District, reminded farmers to “look after themselves and others” at the Riverine Plains In-season Update, which was especially relevant given the dry and frosted conditions experienced across the region during spring 2024. Riverine Plains also hosted the Rural and Remote First Aid practitioners to promote on-farm safety, training and equipment at various events and locations across the region.

Riverine Plains will continue to work with partners to strengthen connections and develop projects that build farmers’ safety skills and resilience.

TIMELY INFORMATION FOR LIVESTOCK FARMERS

A prolonged dry period commenced in 2024 and Riverine Plains identified livestock feeding and management as key themes for farmers. In response, Livestock Production Co-ordinator with Elders, Rob Inglis, attended the August In-season Update to discuss feeding strategies to keep livestock in good condition. Riverine Plains Livestock Project Manager, Sophie Hanna, also actively supported farmers in the Towong Shire by delivering a number of targeted workshops and events.

Riverine Plains is continuing to work with Hub and other partners to upskill farmers in pasture management and its role in optimising livestock production.

IDENTIFICATION AND VALIDATION OF NEW TECHNOLOGIES

Riverine Plains worked with novel bioelectrical technology startup, Rainstick, through early-stage problem and market validation as part of the SCOUT project, supported by the Victoria Drought Resilience Adoption and Innovation Hub. Their technology merges First Nations knowledge with modern bioelectrics to enhance seed germination, with a focus on using electricity to boost plant growth and improve crop yield. Riverine Plains is collaborating with Rainstick to understand if their technology can support seed germination in scaled cropping systems.

This early-stage technology validation was also supported by Hub partners, who shared information on canola varieties being currently sown in their geographies and the appetite to trial this technology in both canola and horticulture commodities.

Riverine Plains are also using field trials to validate the potential of microbial product Loam Bio to build soil carbon and system resilience.

FROST IDENTIFICATION AND MANAGEMENT

Riverine Plains provided resources to farmers about the options for managing the damaging frost event that occurred during the third week of September, 2024, which impacted many wheat, canola and barley crops. Riverine Plains also partnered with local farmers to host the Evan Moll Gerogery Field Day, providing an additional forum for farmers to further discuss the impact of these frost events. At the Gerogery Field Day, Elders Agronomist Sheree Hamson shared technical expertise on identifying frost and how to estimate the losses, as well as management options. At the field day, the mental health impact of the frost was also acknowledged and discussed.

PEST MANAGEMENT AND CHEMICAL USE

Riverine Plains sought broad consultation to understand slug management in farming systems, while also exploring opportunities to reduce chemical use on-farm, to support increased system resilience and sustain production through drought.

As part of this work, Riverine Plains conducted a farmer survey, which generated 54 responses, with results analysed by Dr Michael Nash. The survey results are being used to develop a co-design project with partners including Birchip Cropping Group, Irrigation Farmers Network, Southern Farming Systems and VicNoTill, along with Dr Michael Nash.

BETTER WEATHER DATA FOR INFORMED DECISIONS

In 2024, the North East Node commenced a new project that leverages the significant investment in the Local Weather & Soil Moisture Network, while also collaborating with multiple farming system groups and the North West Node. The Farm Data: Local weather data for improved decision-making platform allows farmers to easily access local, real-time weather and soil moisture data for decisions such as spraying, harvesting, planting and insurance. During the project period, Riverine Plains collaborated with scientists (University of Sydney) and farmers to see how historical weather data and soil moisture data can be used to increase accuracy in weather models and forecasts, and improve decision making and planning in changing climate conditions.

SUMMARY

Riverine Plains, as the Victoria Hub's North East Node leader, is continuing to work on the following strategic goals to increase community resilience for future droughts:

- Increase farmer knowledge of pasture management and livestock production.
- Increased adoption of practices that build system resilience (eg, soil amelioration, stubble retention, rotational cropping, ground cover retention).
- Increased use of local climate information to make more informed decisions.
- Support events that bring members of the community together to strengthen and increase social community connections.
- Promote events that improve mental health and provide farmers with work, health and safety skills.
- Support farmers to build their business skills, to better understand the factors leading to a healthy business that can survive climatic variability.

For further information, please contact Riverine Plains Senior Project Manager, Kate Coffey by emailing kate@riverineplains.org.au.

COLLABORATING FOR DROUGHT RESILIENCE: RIVERINE PLAINS AND THE SOUTHERN NSW DROUGHT RESILIENCE ADOPTION & INNOVATION HUB

Riverine Plains continues to collaborate with the Southern NSW Drought Resilience Adoption & Innovation Hub to deliver practical, farmer-focused solutions aimed at improving drought resilience. Working with other Hub partners, Riverine Plains ensures local farming priorities shape Hub projects, fostering region-specific research, trials, and extension activities.

Over the past four years, our joint initiatives have established multiple demonstration sites to evaluate soil management strategies, resilient pasture systems, and effective on-farm water management.

OPTIMISING SOILS AND WATER MANAGEMENT

In collaboration with the Hub, GRDC and CSIRO, Riverine Plains led the *Improved Drought Resilience through optimal management of soils and available water* project. This project built on the work of Dr John Kirkegaard's Southern Farming Systems Project and established 12 demonstration sites across southern NSW, including locations in Wagga Wagga, Rand, Howlong, and Mulwala in collaboration with Central West Farming Systems, FarmLink, Southern Growers, and Charles Sturt University. The project evaluated strategies such as diverse legume rotations, early sowing of slower-maturing crops, and nitrogen banking. Findings indicated that legume rotations could significantly increase residual nitrogen levels, while early sowing practices helped widen planting windows and reduce frost risk.

ENHANCING PASTURE RESILIENCE

The *Changing landscapes with drought-resilient pastures* project focused on improving pasture systems' resilience to drought. Demonstration sites at Barooga and Savernake tested various lucerne-based systems under different grazing management practices. Results highlighted the benefits of rotational grazing and optimal lucerne seeding rates in enhancing pasture persistence and quality, contributing to more reliable feed sources during dry periods.

ON-FARM WATER MANAGEMENT PLANNING

Recognising the critical role of water in farming, Riverine Plains supported the *On-farm water management planning* project. This initiative assisted farmers in developing comprehensive water management plans through workshops and one-on-one sessions. The plans aimed to help farmers assess their current and future water needs, improve water quality, and implement efficient storage and delivery systems to bolster drought resilience.

Throughout the past year, Riverine Plains has facilitated numerous workshops and field days, disseminating findings from these projects to the farming community. By fostering collaboration between farmers, researchers, and industry professionals, Riverine Plains ensures that practical, evidence-based strategies are accessible and adoptable, strengthening the region's capacity to withstand future droughts.

THE YEAR IN REVIEW

KEY MESSAGES

- **Decile 8-10 rainfall across the Riverine Plains in January increased stored soil moisture reserves.**
- **Frost in September saw farmers weigh up the benefits of cutting for hay vs taking through to grain.**
- **Timely October rainfall combined with stored soil moisture from the previous season played an important role in maximising yield and water use efficiency.**
- **Yields were better than expected given the dry conditions and frost, with barley a standout and reports of very good gross margins from pulses, especially faba beans and lupins.**
- **Dry conditions increased supplementary feeding requirements for livestock, adding cost and labour pressures for farmers.**

SUMMER RAINFALL

January rainfall across most of the Riverine Plains was in the decile 8–10 range, placing it among the top 20 percent of years (Table 1). The early summer rain was largely a carryover of the combined effects of a positive Southern Annual Mode and a weakening El Niño. While excellent for water storage and perennial pasture growth, the rain increased pressure on farmers to keep up with summer weed control programs. February rainfall was average to below average for many locations across the Riverine Plains.

It's estimated that most areas retained about 50 mm of summer rainfall through to sowing, though this will have varied depending on location, soil type, and the effectiveness of summer weed control.

AUTUMN SOWING CONDITIONS

March brought average to below-average rainfall, while rainfall in April was average. Early sown crops (April) tended to emerge on soil moisture, while later sown crops (May) had to wait for additional rainfall. Variable paddock moisture conditions also contributed to a staggered germination in canola and a subsequent lag in development, although most crops managed to compensate by harvest. Early sown pastures established well, providing a good base for winter feed production.

Severe slug damage wasn't widely reported in 2024, likely due to a band of dry soil that prevented slugs from moving from moist soil at depth to the surface.

WINTER–SPRING CONDITIONS

Rainfall dropped to below average (decile 1-3) in June before returning to average levels in July. The absence of waterlogging aided establishment and improved trafficability, allowing better delivery of nitrogen compared to previous years.

August and September were particularly dry, with rainfall ranging from deciles 1–4.

A significant frost event in mid-late September had grain growers weighing up the advantages and disadvantages of cutting crops for hay versus keeping for grain. Hindsight tells us that the frost damage was less severe than initially thought, with damage more prevalent in canola and wheat and variable in pulses. A key learning was to be patient and assess damage over 1-2 weeks before making a decision, as individual contexts varied. Where more moisture was available, frost recovery was better for indeterminate crops such as canola and pulses.

The region was fortunate to receive widespread and timely rainfall in mid October, which was "just in time" for many crops following an extended dry winter–spring period. This combined with stored soil moisture to provide most crops with enough moisture for grain fill, with crops grown on heavier soil types tending to perform better. The drier winter–spring also made disease management easier.

BETTER THAN EXPECTED HARVEST

November saw another spike in rainfall, reaching decile 8–10 levels, while December was also wetter than average in many parts of the Riverine Plains. This interrupted harvest and hindered hay production, although it increased stored soil moisture at depth in some areas. In many cases trafficability was a major issue, with farmers having to wait until paddocks dried out before resuming harvest, to avoid bogging paddocks and machinery. Grain dust was also an issue after the rain, increasing the fire risk and contributing to a higher number of machinery fires. The rain also impacted grain quality (test weights, falling numbers) in cereals, potentially also impacting germination and vigour in seed retained for 2025.

Crops generally yielded better than expected given frost and the dry conditions, with barley a standout and reports of very good gross margins from pulses, especially faba beans and lupins. This was in part due to returns from nitrogen fixation in pulses, and lower associated urea inputs, as well as good prices. Crop water use efficiency was impressive in many cases, although later sown crops generally suffered a yield penalty.

Overall, gross margin returns across the Riverine Plains were highly variable due to the dry conditions and frosts, as well as the high cost of nitrogen and other inputs.

LIVESTOCK

Sheep producers had a better year, with rain at the right time for pasture production and prices recovering at the start of 2024. The drier year helped keep diseases at bay, however dust caused widespread pink-eye issues, particularly in cattle. Dry conditions also meant that supplementary feeding was required through much of the year (and into 2025), which increased labour and cost pressures on farmers. Cattle prices remain an ongoing challenge for producers.

The November and December rains also helped dryland lucerne growth, enabling good quantities of high quality lucerne hay to be produced.

Table 1 Monthly rainfall and deciles (dec) for various locations across the Riverine Plains, 2024

	EUROA	DEC	RUTHERGLEN	DEC	DOOKIE	DEC	YARRAWONGA	DEC	COBRAM	DEC
January	135	10	71	9	94	9	99	10	47	7
February	10	3	47	8	19	5	20	6	20	6
March	12	2	17	4	6	2	12	3	9	3
April	34	5	24	5	23	4	23	5	29	6
May	59	6	47	6	67	7	40	5	79	9
June	37	3	33	4	23	2	22	3	32	6
July	46	3	53	5	38	4	34	3	27	5
August	21	1	30	3	24	2	26	3	11	1
September	28	2	39	4	18	2	33	5	15	2
October	51	5	41	5	41	6	41	6	45	7
November	87	9	129	10	96	10	81	10	140	10
December	43	6	41	5	40	7	56	8	25	5
Year (Jan-Dec)	563	3	572	5	489	4	487	5	479	6

	ALBURY	DEC	HENTY	DEC	COROWA	DEC	LOCKHART	DEC	URANA	DEC
January	44	6	70	8	52	7	49	8	53	8
February	19	4	13	4	47	8	4	2	4	2
March	22	4	25	5	24	5	18	5	19	5
April	31	5	49	7	25	5	37	7	27	6
May	32	3	23	3	36	5	32	5	55	8
June	39	4	18	2	20	3	20	2	23	4
July	60	5	46	4	49	5	36	4	29	4
August	51	3	36	3	41	4	31	4	18	3
September	41	3	26	3	10	1	26	4	18	2
October	42	4	31	4	27	3	23	3	29	5
November	90	9	105	10	74	9	74	9	39	6
December	38	5	35	6	50	7	30	5	34	7
Year (Jan-Dec)	509	2	477	3	455	3	380	3	348	3

DEC = decile

Rainfall totals sourced from Bureau of Meteorology, ClimateARM, Riverine Plains

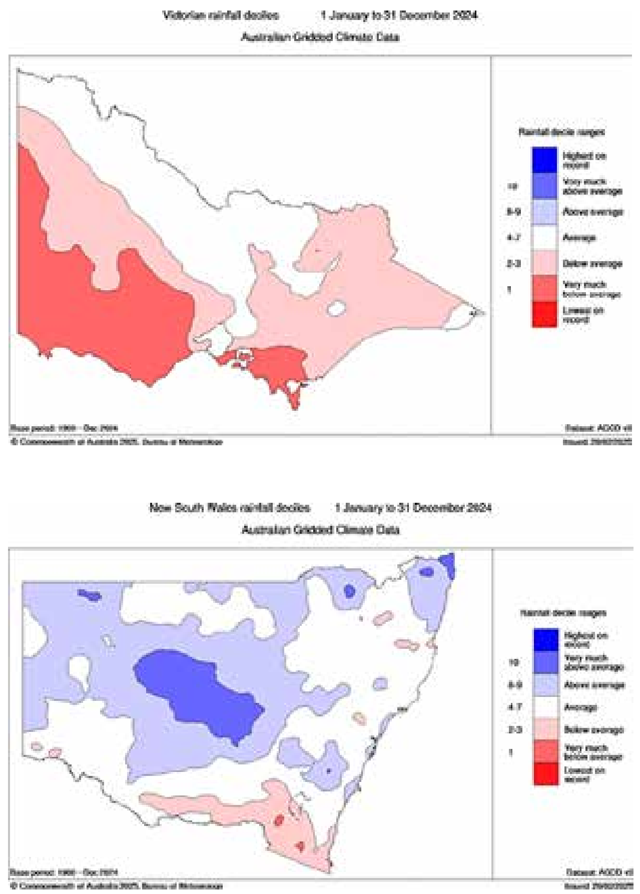


Figure 1a and 1b Full year rainfall deciles across Victoria and NSW during 2024 (source BoM, 2025)

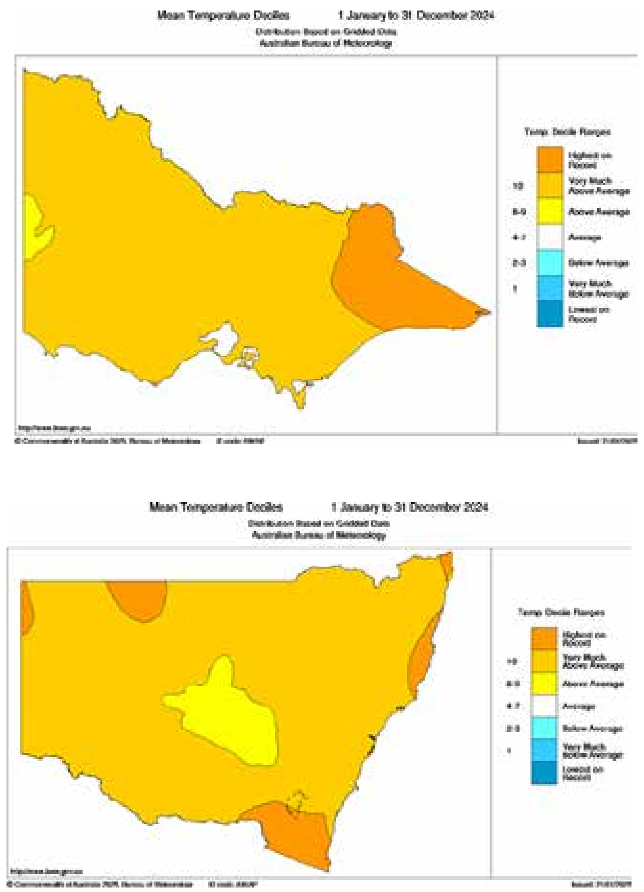


Figure 2a and 2b Mean temperature deciles across Victoria and NSW during 2024 (source BoM, 2025)

YEARLY RAIN AND TEMPERATURE

Overall, 2024 rainfall was average to below average across south east New South Wales and north east Victoria (Figure 1a, 1b)

Last year was also Australia's second-warmest year since national records began in 1910, with the national annual average temperature 1.46 °C warmer than the long-term (1961–1990) average.

In the Riverine Plains, mean temperature deciles were very much above average to highest on record across south east NSW and north east Victoria (Figure 2a, 2b).

SUMMARY

A wet end to 2023 and a wet start to 2024 increased stored soil moisture reserves across the Riverine Plains heading into the 2024 season. This provided an important moisture reserve given relatively low growing season rainfall received across many areas, and when coupled with a timely October rainfall event, made a significant contribution to grain yield.

The dry spring, frost damage and rain at harvest caused significant logistical challenges, however crops generally yielded better than expected, with some impressive water use efficiency results. There were significant variations in rainfall and the level of frost damage experienced in 2024 and this contributed to highly variable gross margins across the region.

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TRIAL RESULTS

RESULTS FROM THE DEMONSTRATING RYEGRASS CONTROL STRATEGIES TRIAL NORTH EAST VICTORIA

KEY MESSAGES

- **A trial at Wahgunyah showed a no till treatment had extremely low ryegrass numbers throughout 2024, compared to treatments that received a speed till (autumn tickle).**
- **A ryegrass "blowout" in a previous crop can cause a legacy effect; this can take time and multiple strategies to manage effectively.**
- **A "high-level chemistry" approach can be high cost and high risk if conditions aren't suitable at the time of application.**
- **In this trial, there was a trend to decreasing ryegrass numbers when the sowing rate was increased by 50 percent for canola sown in 2024.**
- **In 2024, ryegrass seed testing indicated resistance to Hoegrass (Group 1, fops) and in 2025, resistance to Roundup (Group 9) and Glean (Group 2, sulfonylurea), was also detected, highlighting how resistant populations can develop over time.**
- **Herbicide resistance testing can inform farmers about the likelihood of a herbicide failure or reduced effectiveness ahead of sowing; if resistance to a herbicide group is detected, farmers can switch to a different group or alter their crop rotation or variety choice.**
- **Non-chemical (cultural) methods of ryegrass control such as choosing a cultivar with a growth habit adapted to the region, increasing seeding rates, cutting hay to prevent ryegrass seed set, grazing, burning and harvest weed seed control can help manage ryegrass populations.**

BACKGROUND

Ryegrass blowout—when ryegrass numbers start to increase at uncontrollable rates—and its subsequent management, was identified as a priority issue for north east Victoria.

The issue had been exacerbated in recent years by excessively wet conditions and poor trafficability, making application of pre-emergent weed control difficult for some products. Consequently, grain growers observed an increase in ryegrass numbers, due to limited control options available over subsequent wet seasons. As a result, there was interest in exploring management strategies in other phases of the rotation, to drive down ryegrass numbers.

This led to the establishment of a two-year demonstration trial at Wahgunyah, in north east Victoria, as part of a Grains Research and Development Corporation (GRDC) National Grower Network (NGN) project investment. The trial demonstrated locally validated weed management strategies to assist growers improve control of ryegrass populations emerging in different environments, and where herbicide application alone fails.

AIM

Controlling annual ryegrass is an ongoing issue for farmers in the Riverine Plains and this trial aimed to explore a range of options to manage, control and ultimately reduce the impact of annual ryegrass in broadacre cropping systems, across a range of seasonal conditions.

METHOD

A two-year demonstration trial (2023–2024) was established to explore and compare current methods of annual ryegrass control. The trial was jointly managed by Riverine Plains and Uncle Tobys and was hosted at the Uncle Tobys trial paddock in Wahgunyah, Victoria.

In consultation with local agronomists, a range of treatments were established in 2023 using the GRDC Weedsmart 'Big 6' framework, as a key reference in the trial design. The 'Big 6' reference principles include: 1) rotate crops and pastures, 2) increase crop competition, 3) optimise spray efficacy, 4) mix and rotate herbicides, 5) stop weed seed set, 6) implement harvest weed seed control.

The treatments used in the trial reflect common practices used by grain growers across the Riverine Plains and the agronomists advising them.

Year 1 (2023)

Table 1 describes the timing of various operations for each treatment applied to a grazing wheat crop (cv Beaufort) sown in 2023. All treatments received pre-emergent chemistry of 1.5 L/ha Trifluralin and 118 g/ha Sakura, incorporated by sowing (IBS), with the exception of the high-level chemistry treatment (Treatment 2) which received Trifluralin IBS. The high-level chemistry treatment received 1 L/ha Mateno herbicide applied early post-emergent (EPE), with glyphosate applied as a desiccant in early December as per label directions. In addition to the described treatments, the entire site also received an in-crop broadleaf herbicide application, as well as a fungicide application. Rainfall at the site during 2023 was 515 mm. No summer sprays were applied between the 2023 harvest and the start of the 2024 winter cropping season.

Ryegrass plant emergence counts were taken across each treatment and at intervals throughout the season, to understand the effect of each treatment. Ryegrass plant samples (collected in-season) and seed samples (collected at maturity) were also sent to Charles Sturt University (CSU) for herbicide resistance testing.

Year 2 (2024)

OptimumGLY® (cv PY525GY) canola was sown during mid April using a tyne seeder with press wheels, as per the farmer's rotation. The trial plots were sown east to west, at right angles to the 2023 trial, to observe legacy effects of the Year 1 treatments, with plots measuring 8m x 8m (Table 2). The site was sown at 25.4 cm row spacings, with 75 kg/ha MAP at sowing and 300 kg/ha urea spread in two separate 150 kg/ha applications on 19 May and 19 July. All treatments, except Treatment 2 (no till), received a speed till in March to a depth of 2.5 cm, using a disc machine.

Table 1 2023 (Year 1) treatments applied to wheat in the *Demonstrating ryegrass control strategies* trial at Wahgunyah

TREATMENT DESCRIPTION	DETAILS
1-Control	-
2-High level chemistry	1 L/ha Mateno herbicide applied early post-emergent (EPE) Glyphosate applied as a desiccant in early December as per label directions
3-Sowing rate increased by 50%	Sowing rate: 120 kg/ha
4-Cut for Hay	Hay cut: 17 October
5-Grazed and burnt	This treatment was grazed and later burnt

Table 2 2024 (Year 2) treatments for the Demonstrating ryegrass management strategies trial at Wahgunyah

TREATMENT DESCRIPTION	CULTIVATION	TREATMENT APPLIED	HARVEST OPERATION
1-Control	Speed till	Standard chemistry	Windrow
2-No till	No till	Standard chemistry	Windrow
3-Direct head	Speed till	Standard chemistry	Direct head
4-High-level chemistry	Speed till	Double-knock with Paraquat Overwatch IBS	Windrow
5-High level chemistry + direct head	Speed till	Double-knock with Paraquat Overwatch IBS	Crop desiccation (Reglone) + direct head
6-50% increased sow rate	Speed till	50% increased sowing rate (sowing rate: 3.3 kg/ha)	Windrow
7-Hay cut	Speed till	Hay cut	Hay removed

Standard chemistry was applied in-season to all plots and the farmer's surrounding canola crop. This included trifluralin, two applications of glyphosate and Dropzone® (2,4-D as dimethylamine and monomethylamine 500 g/L) herbicides and represents common farmer practice in the region. AMS Aviator® Xpro® (bixafen 75 g/L, prothioconazole 150 g/L) was also applied across all plots in late August 2024.

The high-level chemistry treatments in 2024 included standard chemistry, plus a double knock of paraquat (Gramoxone at 835 mL/ha) followed by Overwatch® (bixlozone 400 g/L) incorporated by sowing (IBS). High-level chemistry was only applied to the "high-level chemistry" and "high-level chemistry + direct head" treatments.

The hay cut treatment was applied on 8 October, with the hay removed on 17 October. Crop desiccation in the "high level chemistry + direct head" treatment was achieved by an application of 200 g/L diquat (Reglone) on 1 November. The remaining treatments were windrowed on 4 November and the site was harvested on 23 November.

RESULTS AND DISCUSSION

YEAR 1, 2023

Ryegrass populations across the 2023 Year 1 treatments are shown in Table 3, with relatively low numbers of ryegrass indicated across all treatments throughout the season. Excepting a dry September, the 2023 season was ideal for both crop growth and ryegrass seed set, and the plant counts at sampling on 6 December are lower than expected given the conditions.

Due to logistics at harvest, the original HWSC treatment planned for 2023 (harvest and use a mechanical seed mill) did not proceed, with the treatment instead grazed, then burnt.

Table 3 Average ryegrass plant populations in Year 1 of the *Demonstrating ryegrass control strategies* trial treatments in wheat, Wahgunyah 2023

SAMPLE DATES & WHEAT GROWTH STAGE	19 JULY (GS20)	2 OCTOBER (GS40-50)	6 DECEMBER (PHYSIOLOGICAL MATURITY)
Treatment	**Ryegrass population (plants/m²)**		
Control	6	6	6
High level chemistry	12	6	4
Sowing rate increased by 50%	-	2	1
Cut for Hay	1	2	-
Grazed & burnt	2	1	1

YEAR 2, 2024

Annual ryegrass populations were measured three times over the course of the 2024 season, with the average per treatment presented in Table 4.

Table 4 Average ryegrass populations and grain yield for treatments applied to canola at the *Demonstrating ryegrass control strategies* trial, Wahgunyah, 2024, plus February 2025 ryegrass counts

SAMPLE DATE	23 APRIL	10 JULY	29 NOVEMBER	GRAIN YIELD	18 FEBRUARY 2025
Canola growth stage	**Early vegetative**	**Stem extension / mid vegetative**	**Post-harvest**		**Summer fallow**
Treatment	Average ryegrass population (plants/m²)			(t/ha)	Ryegrass (plants/m²)
Control	180	100	20	0.63	1
No till	4	12	8	1.75	0
Direct head	104	88	12	0.84	2
High level chemistry	48	144	12	0.69	4
High level chemistry + direct head	96	140	12	1.30	4
50% increased sow rate	68	96	24	1.46	0
Hay cut	40	116	8	N/A	0

All treatments except the no till treatment had a speed tillage treatment applied in March

As shown in Table 4, 2024 average ryegrass populations fluctuated from early season to mid-July across all treatments, except for the no-till treatment, which remained extremely low throughout the season. High variation was also seen in treatments which had received the same applications to mid July, for example the control and direct head treatments, as well as the high-level chemistry and high-level chemistry + direct head treatments.

Speed tillage was applied to all treatments except the no till treatment and the high early ryegrass populations seen in late April across the speed tilled treatments suggests that ryegrass emergence was stimulated by the soil disturbance. In contrast, the lack of soil disturbance in the no till treatment likely suppressed germination of the ryegrass seed bank, holding back numbers throughout the year. The low ryegrass populations in this treatment potentially increased the amount of moisture available to the canola crop, which was reflected in a more uniform germination and higher yield.

Ryegrass populations in the two high-level chemistry treatments were only marginally different to the standard chemistry treatments (control and direct head treatments) across the three population count timings. The incorporation of Overwatch® IBS in both high-level chemistry treatments was unfortunately met with a subsequent lack of moisture for activation, due to forecast rain not eventuating, leading to minimal response in the target ryegrass plants. The Overwatch herbicide application also failed to generate the commonly observed bleaching, which was only evident in some canola plants by mid-season. As per the Overwatch label, the crop was sown with tynes and press wheels.

Direct heading didn't appear to have any effect on ryegrass numbers compared to windrowing in this demonstration. Choosing which method is best to harvest canola comes down to timeliness, weather conditions and cost, bearing in mind that direct heading allows for a potentially higher maximum yield under ideal conditions, and can help avoid weather-related windrow losses (for example from wind in light windrows or in lodged crops), however there is a higher risk of shattering. In weedy situations, direct heading has a higher risk of weed seed-set, especially if no dessicant is used.

The post-harvest ryegrass counts (December 2024) were much lower than expected across all treatments. This was likely due to a combination of competition by the canola and the effectiveness of the pre-emergent chemistry applied across all treatments. Given the similarity in ryegrass numbers across treatments, it's also possible that the final assessment occurred too late to be fully representative, or that the ryegrass population had already senesced.

The high ryegrass numbers seen early in the 2024 trial are not fully explained by the ryegrass populations present in 2023. High ryegrass populations were visually observed in the 2023 grazed and burnt treatment, and this may have led to increased ryegrass numbers in 2024 along the eastern side of the trial where the grazing treatment was located. While ryegrass is considered to be short-lived (most of the seed population will germinate the following autumn), it's possible that a sizeable ryegrass seedbank carried over from the 2022 season and the 2024 speed tillage operation (autumn tickle) stimulated its emergence.

The increased canola seeding rate treatment of 3.3 kg/ha was designed to increase competition with weeds. Mid season averages suggest that the increased rate helped suppress ryegrass growth compared to most of the other treatments.

YIELD

Dry spring conditions, frost damage late in the season, and harvest rains meant that canola yield was generally lower than expected. As this was a demonstration trial, statistical analysis of yield wasn't possible, however the no-till treatment yielded the most at 1.75 t/ha, which was almost three times as much as the lowest yielding control treatment (0.63 t/ha). The increased sowing rate treatment yielded 1.46 t/ha, while the high-level chemistry + direct head treatment yielded 1.30 t/ha. Due to the high variation in ryegrass numbers across treatments it's difficult to attribute yield response to ryegrass populations alone. However, it's likely that reduced ryegrass numbers in the speed tilled treatment increased moisture availability, promoting more even early emergence and better yields.

FOLLOW-UP COUNTS, 2025

Following a wet late spring and early summer, conditions turned hot and dry during early 2025. Rainfall data from the Bureau of Meteorology Corowa Airport site shows approximately 64 mm rainfall from December 2024 to January 2025; while there may have been enough early summer rain to stimulate ryegrass emergence, there was not enough follow-up to sustain plant growth. This was reflected in the very low ryegrass populations seen across all treatments when counts were conducted in February 2025 (Table 4), which was just before the farmer applied herbicide for seasonal weed control. No chemical or mechanical interventions were applied to the site between harvest and mid February, 2025, other than a buffer spray around the trial site with glyphosate during mid-late December.

LEGACY EFFECTS OF 2023 TREATMENTS

The 2024 OptimumGly® canola treatments were overlaid at right angles to the 2023 wheat treatments, and plant counts taken from the treatment areas provide an opportunity to examine the legacy effects (Table 5).

Table 5 Ryegrass populations measured at the Demonstrating ryegrass control strategies site at Wahgunyah, 2024, showing Year 1 (2023) and Year 2 (2024) treatments

2023 TREATMENT	2024 TREATMENT																				
	Control			No till			Direct head			High level chem			High level chem, direct head			Increased sowing			Hay cut		
	Ryegrass plant population (plants/m^2)																				
	E	M	L	E	M	L	E	M	L	E	M	L	E	M	L	E	M	L	E	M	L
Control	116	120	0	4	4	12	76	72	0	52	72	4	136	108	0	48	84	16	12	100	0
High level chemistry	260	148	4	8	8	0	256	96	24	112	128	12	48	40	0	72	64	20	88	40	12
Increased sowing	88	28	12	0	12	8	40	48	24	36	44	8	92	80	0	84	28	8	32	28	4
Hay cut	192	60	32	0	32	0	96	68	8	8	104	8	132	192	20	24	128	4	8	152	12
Graze	252	144	44	8	12	20	60	156	4	24	376	32	68	288	36	112	192	64	65	268	12

E = Early ryegrass count (late April), M = Mid July counts, L = December (post-harvest) counts

The 'no-till' treatment consistently displayed lower ryegrass populations than the other treatments, even when the 2023 legacy treatments were taken into consideration. The lack of soil disturbance to stimulate ryegrass germination was the most likely cause of this effect.

Where increased sowing rates were applied in 2023, there was a trend to comparatively lower ryegrass populations in 2024.

Where grazing occurred in 2023, there was a trend towards high ryegrass population numbers in 2024, for all treatments except the no till treatment. Despite the low overall ryegrass populations observed across all treatments in 2023, the site was known to have a high background ryegrass population and it's likely that high rates of ryegrass seed shedding occurred before the grazing took place in this treatment, contributing to the numbers observed in 2024. Previous work by Riverine Plains has shown that ryegrass seeds are mostly shed in the month prior to harvest, providing a potential seedbank for the next season.

The application of high-level chemistry in 2023 did not clearly reduce ryegrass populations in 2024, however there was a trend to lower populations where high-level chemistry plus cultural controls, such as increased sowing rates and hay, were applied in 2024.

RESISTANCE TESTING

Understanding the ryegrass herbicide resistance status of paddocks can support farmers in making early, strategic management decisions in preparation for subsequent crops. As part of this project, plants were collected from the Wahgunyah trial site and sent to Charles Sturt University for "quick testing" across a wide range of herbicides. While "quick testing" conducted in 2023 showed no evidence of resistance to either glyphosate or clethodim at the trial site, ryegrass seed testing conducted in 2024 allowed for more accurate testing and showed resistance to Hoegrass, a Group 1 (Fop) herbicide. The seed testing did not detect resistance to either Select (Group 1, dim), Glean (Group 2, sulfonylurea), Simazine (Group 5), Trifluralin (Group 3) or Roundup (Group 9).

Ryegrass seed was also collected and tested in 2025. The results confirmed resistance to Hoegrass (Group 1, fop), and also indicated resistance to Glean and Roundup. The change in status to Glean and Roundup from 2024 (not resistant) to 2025 (resistant), highlights how the resistance status of populations can change over time. It is worth noting that these results only apply to the samples provided, which were collected from within the trial area across the two years of the trial.

CONCLUSION

Using a combination of techniques as part of an integrated management strategy is likely to have the best effect on reducing ryegrass populations, while also helping prevent the development of herbicide resistance, which occurs when the same chemistry is used repetitively.

When selecting varieties, consider their adaptation to the local environment and their ability to suppress weed growth in high pressure paddocks, or that allow alternative in-crop herbicides to be used (for example OptimumGly® canola). Crop growth habit and maturity can also be used as a tool to manage problem populations. Crop topping (dessication), grazing or cutting weedy paddocks for hay, can also help manage heavy ryegrass populations, but their effectiveness will depend on timing and the season at hand.

Making good use of resources such as resistance testing allows a more informed approach to ryegrass management and more efficient use of herbicides.

ACKNOWLEDGEMENTS

The *Demonstrating ryegrass control strategies* project is an investment of the GRDC. Riverine Plains would like to thank our farmer hosts Ian, Kaye and Jack Wood, and Uncle Tobys (Nestle) for the use of their land and support throughout this trial.

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NON-CHEMICAL CONTROL OPTIONS FOR SLUGS – RESULTS FROM THE RIVERINE PLAINS INDUSTRY SURVEY

Report prepared by Dr MA Nash for Riverine Plains, October, 2024

KEY MESSAGES

- **A 2024 Riverine Plains' slug survey found that slug damage had increased over the past five years, likely in response to wetter seasonal conditions.**
- **Slug management cost 33 percent of respondents between $1– 50/ha, while 56 percent spent $50–100 /ha, and 4 percent spent over $100/ha.**
- **The survey revealed a high reliance on three insecticide groups — 4A, 1B & 3A — which are all disruptive to carabid beetles (predators of slugs).**
- **The survey suggests some confusion between the direct impacts of modern farming practices, such as conservation agriculture on slug populations, and the indirect effects of burning and cultivation.**

BACKGROUND

Despite the increase in molluscicide sales (Figure 1), damage to establishing crops caused by slugs has increased across southern Australia.

The extent of slug threats has expanded in recent years, both into new regions, including northern Victoria and the central slopes of NSW, and to crops such as lentils. Several contributing factors have been suggested for the increase, yet none have been directly tested. Some hypotheses include favourable weather conditions (i.e. wet springs), the application of calcium, the overuse of seed treatments limiting natural enemies such as carabid beetles, increased nitrogen usage, adoption of conservation agriculture (for example stubble retention, no or minimum till), exotic slug species adapting to new niches and tightening crop rotations.

In the Riverine Plains region, which includes south east NSW and north east Victoria, slugs have become a significant threat to productivity, with the economic cost to farmers of annual chemical control programs also significant. However, it has been identified by Riverine Plains that the use of non-chemical control options for slugs poses key knowledge gaps for farmers.

To better understand grower needs, a survey was developed through funding from the Victoria Drought Resilience Adoption and Innovation Hub, supported by the Australian Government's Future Drought Fund, to capture current practices used by Riverine Plains members and others to manage slugs. Riverine Plains is the North-East Node lead of the Hub and the aim was to develop a broader understanding of the slug problem across the region's cropping ecosystems to inform larger research projects, such as the GRDC slug modelling project.

AIM

This survey was developed to better understand current practices used by farmers. The survey also aimed to investigate patterns that may have caused increases in slug populations in north east Victoria and southern NSW over the last five years.

METHOD

The survey was designed in consultation with several experts. It was open from June to September 2024, and run in collaboration with the Irrigation Farmers Network, Vic No Till, and Birchip Cropping Group (the North-West Node lead for the Victoria Drought Resilience Adoption and Innovation Hub). The survey was promoted at several events including the GRDC Grains Research Update at Numurkah during July 2024.

A total of 17 questions were asked of respondents using SurveyMonkey® (Appendix 1), with key results described below.

RESULTS

DEMOGRAPHICS – WHO RESPONDED AND WHAT WE FOUND

Of the 54 respondents, 72 percent were farmers (Figure 2). The highest proportion of respondents (57 percent) identified as members of Riverine Plains, while the Irrigation Farmers Network (22 percent), Vic No Till (13 percent) and Birchip Cropping Group (8 percent) were also represented (Figure 3). A high number of respondents (17) skipped this question, possibly because they didn't belong to a farming system group, or were members of Farmlink or Southern Growers (not listed as options).

A large proportion of respondents (87 percent) reported slug issues over the last 5 years, however the survey also captured responses from those that did not, or who were unsure (13 percent) (Figure 4).

Livestock play a role in most of the enterprises surveyed, with only 31 percent of respondents having no livestock grazing crops or residues in their farming system (Figure 13). Nearly 69 percent of respondents indicated that they grazed crop residues, which is a practice that can help reduce the risk by removing slug refuges.

Over the last five years, 94 percent of respondents indicated that they had sown canola, 96 percent had sown wheat, 63 percent had sown barley, with faba beans (71 percent) the dominant pulse grown (Figure 16). There was a higher proportion of oats grown than expected, with 51 percent of respondents having sown them in the past five years. Overall the diversity of crops grown in the region is quite low, but comparably greater than some other areas.

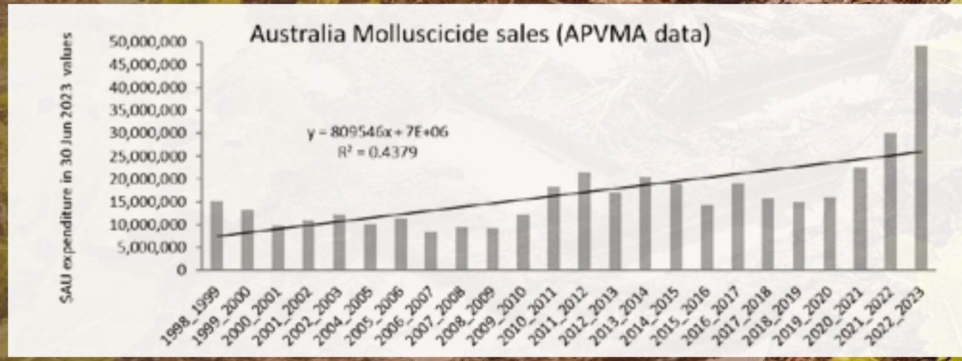

Figure 1 Australian molluscicide sales data, corrected for inflation.

The results also showed that over 75 percent of surveyed growers get their advice about slug management from agronomists, with GRDC, other farmers and experts also rating highly (Figure 10). Paddock history informed slug management strategies for 35 percent of respondents.

IMPACT OF SLUGS

On a scale of 0-100 (where 0 represented no problem and 100 represented their worst year in the past five years), respondents (45) rated the severity of their slug problem at an average of 70 (Figure 5). The slug problem has increased slowly over the past five years, with 25 percent of surveyed farmers reporting issues dating back five or more years, 42 percent indicating the problem arose three–four years ago and a further 33 percent reporting slugs becoming a problem one–two years ago (Figure 6). The region experienced several wet growing seasons in a row from 2020–2023 (and the first half of 2024), which correlates to the increase in slug numbers seen during this time.

This increase in slug problems is supported by the area over which molluscicides baits were applied in 2023. Only four percent of respondents indicated they did not apply bait (Figure 7) in 2023, while over 26 percent of respondents baited more than 800 ha. In terms of bait expenditure in 2023, 33 percent of respondents spent between $1– 50/ha, 56 percent spent $50–100 /ha, and four percent spent over $100/ha (Figure 8). Concern at the cost was evident, with one respondent commenting that "constantly baiting isn't sustainable".

Where baits were applied, 60 percent of respondents had used the metaldehyde product Metarex Inov in the past five years, with eight percent using an iron product such as IRONMAX Pro (Figure 15).

In 2023, respondents also reported having to resow large areas due to slug damage, with 36 percent having to resow 1–50 ha, 16 percent having to resow 50–100 ha and one farmer having to resow more than 100 ha (Figure 9).

FARMING PRACTICES

When looking at farming practices that may contribute to slug threats, a large proportion of respondents had practiced some form of conservation agriculture in the past five years, with nearly 39 percent indicating they used no-tillage and 67 percent used minimum tillage (Figure 11). Kelly chaining (37 percent of respondents) and speed tillage (35 percent) were the two most popular tillage methods used, with a variety of deep and shallow cultivation techniques also practiced.

The survey confirmed that stubble retention is widely practiced by respondents, with over 77 percent retaining stubble in the past five years (Figure 12). Managing heavy stubble loads at sowing can be a problem and 69 percent indicated they had burnt stubble in the last five years, while 44 percent had baled straw and 33 percent had mulched. Only 10 percent rolled their stubble, despite this being an effective tool to prevent slug damage, while six percent used a biological stubble digestor.

It's likely the widespread adoption of minimum till and stubble retention (conservation agriculture) has provided slugs with a more favourable habitat. However several comments made within the survey demonstrated a gap in knowledge regarding the effectiveness of stubble removal techniques, such as stubble burning for slug control, compared to burning for crop establishment (burning aids crop establishment in cold environments but is not always failsafe).

Soil acidity, sodicity and structural issues occur frequently across the Riverine Plains and this is reflected in the high percentage of respondents having applied ameliorants such as gypsum (83 percent) and lime (81 percent) in the survey (Figure 14). The survey did not provide information on whether soil ameliorants were incorporated post-application by participants and whether this reduced slug damage.

Over 75 percent of respondents reported using high amounts of nitrogen as urea, while 27 percent used lower rates of nitrogen and 25 percent pre-spread urea.

In trying to understand the likely disruption to natural enemies of slugs, the survey revealed a high reliance on three insecticide groups — 4A, 1B & 3A — which are all disruptive to carabid beetles (predators of slugs) (Figure 15). However, 15 percent of responses indicated the use of a softer insecticide option (Group 28) for control of lepidopteran larvae.

A comment from the survey highlighted the need for further extension of knowledge in the area of biological controls, referencing the use of neonicotinoids ("NeoNics") as seed dressings and sprays in broadacre crops and their negative impact on beneficial predators and parasitoids, such as carabid beetles.

DISCUSSION

Although this survey was focused on the Riverine Plains region, the number and extent of responses suggest that this survey covered a much wider area than anticipated.

The increase in slug problems reported in the last one–two years suggests that this pest is not only expanding in range, but that numbers have also increased in areas where they have existed for some time. Furthermore, the damage caused by slugs in 2023 saw large areas resown as a result of farmers being unaware of the extent of slug populations in their paddocks. The yield penalty for late (resown) canola crops was estimated at 1 t/ha in north east Victoria and this should be considered an opportunity cost on top of the direst costs of molluscicides.

It's sometimes a difficult and risky decision as to whether to bait emerging crops for slugs. We've estimated that not baiting canola — and losing the crop — would incur additional cost in resowing and the subsequent yield loss due to later sowing (estimated at $840/ha). This has to be weighed up against the cost of baiting, noting that 56 percent of respondents spent $50–100/ha in slug control during 2023.

Variation in seasonal conditions means that extensive baiting programs, such as was needed in 2023, are not required every year. However, budgeting $60-80/ha for slug control when growing canola in high-risk situations and seasons is likely to be prudent. In 2024 the cost of baiting was less due to drier seasonal condition, with no reports of resowing due to slug damage.

RISK

In this survey, growers identified key factors perceived to increase risk.

CROP ROTATION

A survey response referred to canola following faba beans, with the observation that "slug numbers are a lot higher after a wet spring and faba beans". While faba beans are a poor food source for slugs, it's likely that slug populations build up under faba beans due to favourable micro-habitats.

One of the biggest issues facing Australian broadacre farming systems is lack of diversity due to tight crop rotations, including cereal on cereal or wheat – canola – wheat rotations. Tight rotations can have a bearing on the buildup of damaging pest populations, such as slugs, however the responses suggest farming systems in the areas covered by this survey are not as tight as other regions.

Linseed is known to limit slug populations by drying out the soil, but the crop was only grown by a single respondent in this survey and its adaptation to the Riverine Plains region is unclear. Incorporating chickpeas into farming systems where slugs and snails threaten production is also known to limit population increases, however chickpeas have not been widely adopted in the Riverine Plains region, likely due to their susceptibility to waterlogging and the prevalence of acid soils. Only three respondents grew chickpeas in the past five years.

FUTURE RESEARCH

A potential future area of research would be the influence of crop rotation in limiting slug numbers, and therefore production loss.

DIRECT AND INDIRECT IMPACTS OF MODERN FARMING PRACTICES ON SLUGS

Written responses in this survey suggest there is some confusion between the direct impacts of modern farming practices, such as conservation agriculture on slug populations, and the indirect effects of burning and cultivation which can improve crop establishment, thus limiting slug damage. Cultural tools which can improve establishment, whilst also limiting slug activity, are discussed in greater detail in the GRDC publication Strategies to limit slugs threats other than baits.

Some specific field demonstrations that could be assessed for their effectiveness in managing slug threats in the Riverine Plains region include:

1. Rolling after sowing to establish its impact on canola establishment, bait efficacy and slug activity, especially on dispersive soil types
2. Effects of gypsum and lime with shallow incorporation on slug activity and canola establishment
3. Impacts of predrilling urea prior to sowing on slug activity post sowing and speed of establishment; and
4. Monitoring slug predator and parasite communities and function in response to seed treatments and tillage

Building on previous research from other regions, it's likely that undertaking localised research in the Riverine Plains to investigate the interaction between cultural and baiting strategies, including the potential use of strategic tillage to incorporate lime or gypsum while simultaneously reducing slug habitats (by drying out the soil), would provide growers with an integrated approach to slug management.

NUTRITION

Another survey response drew a link between balanced plant nutrition and reduced slug and snail damage. This comment highlights how the role of soil health in providing a more resilient farming system, and the role plant nutrition plays in establishing crops, needs to be further explored.

INTEGRATED PEST MANAGEMENT

The concept of "bottom-up" integrated slug management involves leveraging current canola establishment investments by GRDC which are focused on physical and chemical constraints. This could incorporate a greater understanding of the biological factors that not only influence plant establishment but also enhance crop tolerance to herbivory.

The use of biological stubble digestors, used by six percent of respondents to this survey, is one such tool that could be further investigated.

Increasing crop diversity, enhancing natural enemies, decreasing urea usage by improving plant nutrition and strategic tillage are all part of an ecological approach to managing slug threats in wet years, and to also limiting losses caused by other intangible establishment pests.

ACKNOWLEDGEMENTS

This survey was delivered through funding from the Victoria Drought Resilience Adoption and Innovation Hub, funded by the Australian Government's Future Drought Fund. Thank you to collaborators including the Irrigation Farmers Network, Vic No Till and Birchip Cropping Group, as well as all the survey respondents.

For further information, please contact Sabita Duwal, Riverine Plains Project Support Officer by emailing sabita@riverineplains.org.au

APPENDIX 1 SURVEY RESULTS

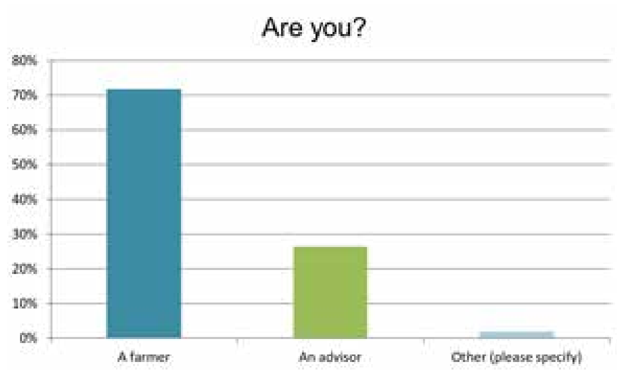

Figure 2 Riverine Plains' 2024 slug survey Question 2; demographics

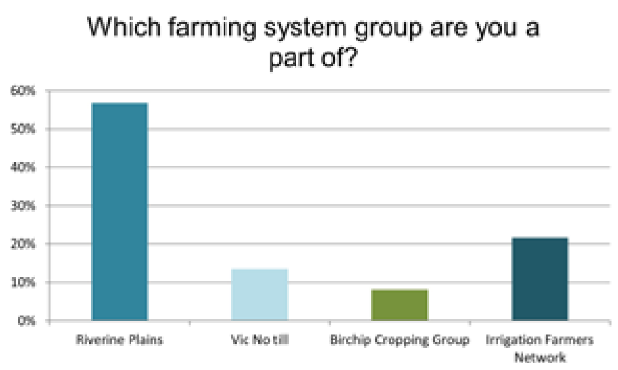

Figure 3 Riverine Plains' 2024 slug survey Question 2; Farming group membership

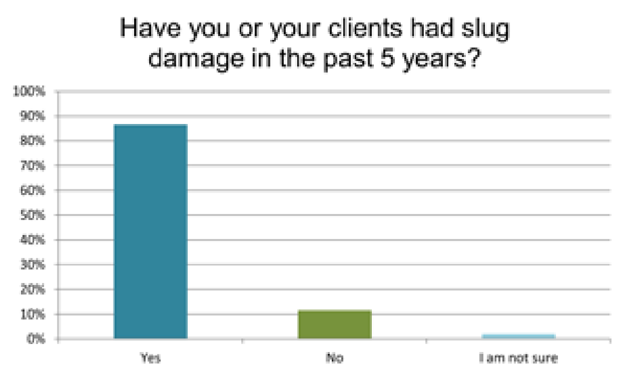

Figure 4 Riverine Plains' 2024 slug survey Question 3; slug damage occurrence

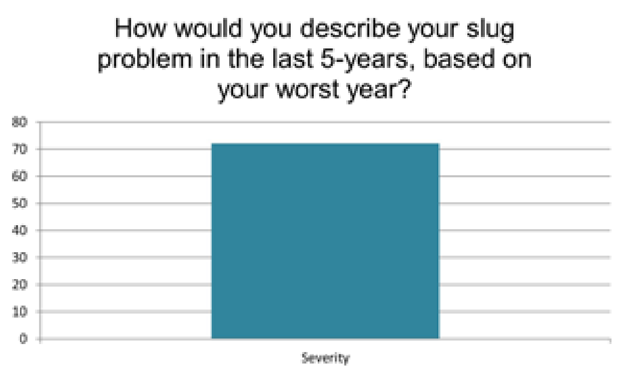

Figure 5 Riverine Plains' 2024 slug survey Question 4; severity of damage

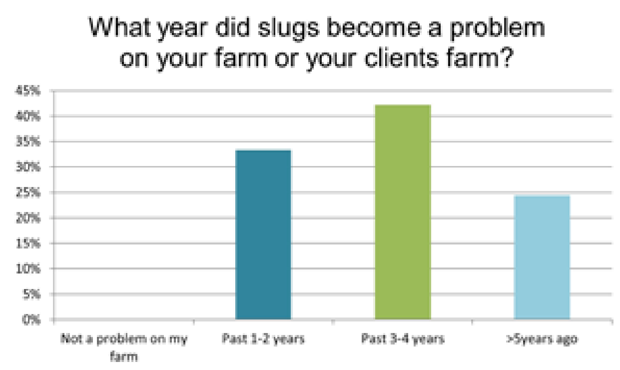

Figure 6 Riverine Plains' 2024 slug survey Question 5; year slug damage first detected

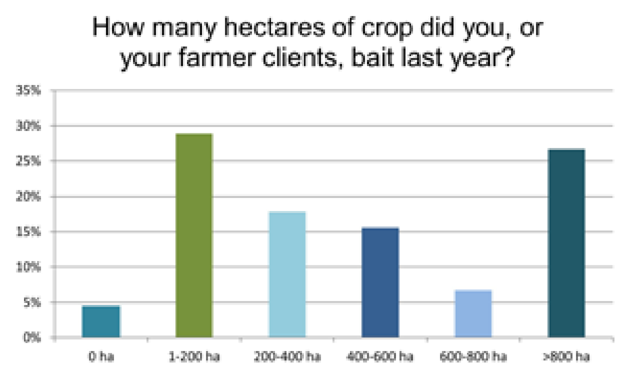

Figure 7 Riverine Plains' 2024 slug survey Question 6; area baited

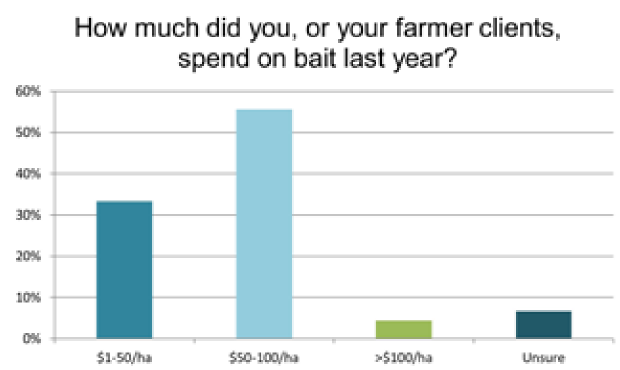

Figure 8 Riverine Plains' 2024 slug survey Question 7; cost of bait applied/ha

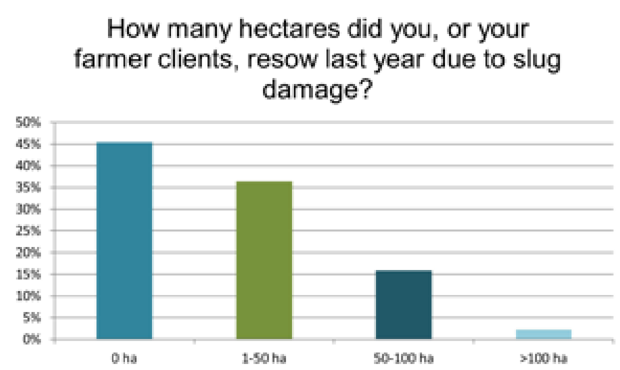

Figure 9 Riverine Plains' 2024 slug survey Question 8; area resown due to damage

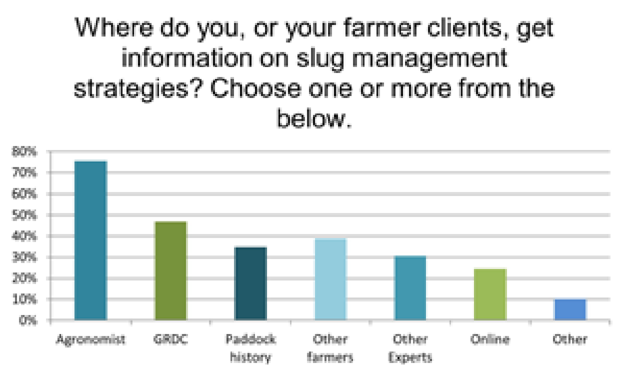

Figure 10 Riverine Plains' 2024 slug survey Question 9; source of management information

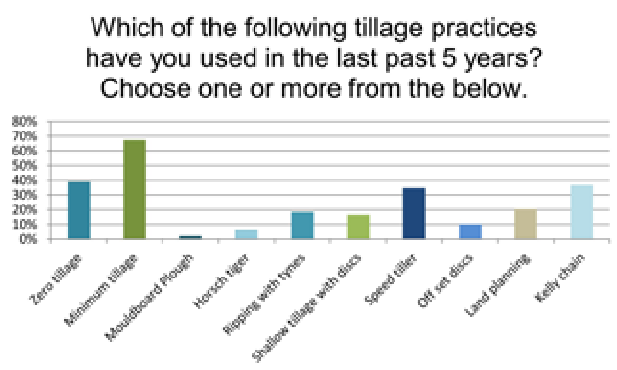

Figure 11 Riverine Plains' 2024 slug survey Question 10; tillage methods

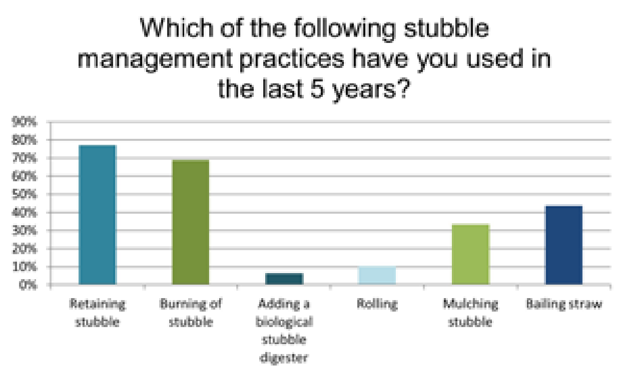

Figure 12 Riverine Plains' 2024 slug survey Question 11; stubble management

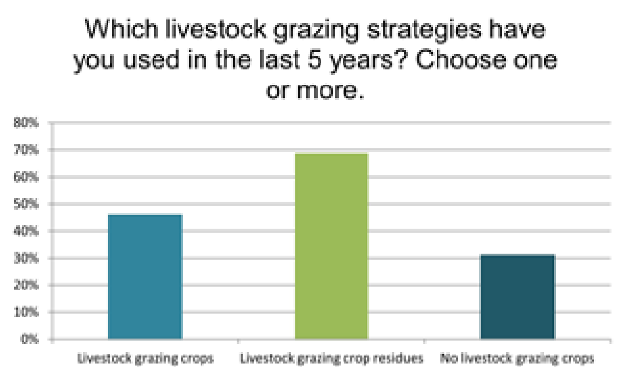

Figure 13 Riverine Plains' 2024 slug survey Question 12; livestock

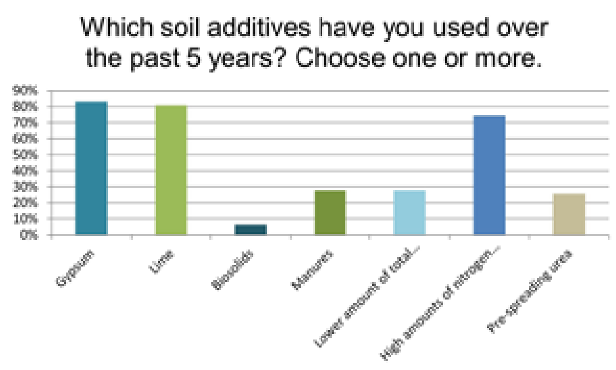

Figure 14 Riverine Plains' 2024 slug survey Question 13; soil additives

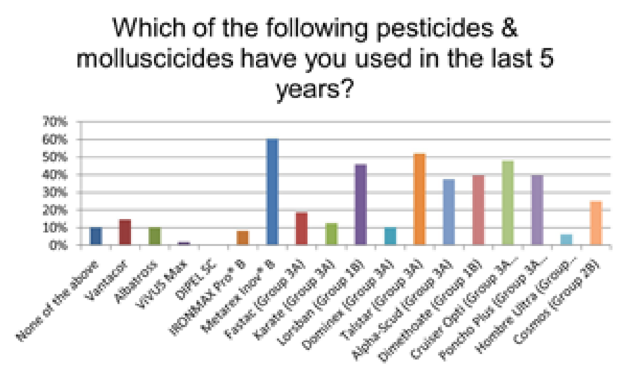

Figure 15 Riverine Plains' 2024 slug survey Question 14; pesticide use

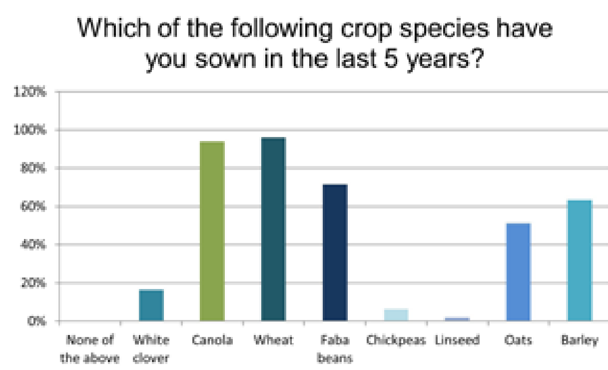

Figure 16 Riverine Plains' 2024 slug survey Question 15; crop rotation

UNDERSTANDING THE LINK BETWEEN CEREAL STUBBLE, SUBSURFACE ACIDITY AND CROWN ROT – DEMONSTRATION TRIAL RESULTS

KEY MESSAGES

- **Two years of break crops (faba bean followed by canola) reduced Fusarium crown rot levels from "high" to "below detection", demonstrating the benefit of crop rotation in controlling the disease.**
- **Predicta B testing in 2025 showed that 8 out of 14 paddocks tested as part of this project had a medium to high risk for Fusarium crown rot, indicating that the disease is still present at high levels across the Riverine Plains region.**
- **Soil acidity is thought to exacerbate Fusarium crown rot severity and soil tests showed 60 percent of paddocks tested as part of this project during 2025 had pH below 5 at a depth of 5–20 cm.**
- **Even though there were very few whiteheads in paddocks in 2024, Predicta B soil testing and stubble plating analysis showed Fusarium crown rot levels were still "high risk" in 2025. This highlights the importance of testing paddocks before sowing cereal crops as stem browning and whiteheads are not always reliable signs of Fusarium crown rot, with other pathogens causing similar symptoms.**
- **Unreplicated demonstration trials showed a trend to reduced levels of Fusarium crown rot following barley compared to after wheat, and when a higher seeding rate was used in 2024.**
- **Using a nitrification inhibitor (eNpower), which can maintain nitrogen in ammonia form for longer, also showed a trend to reduced levels of Fusarium crown rot, compared to urea in one year of unreplicated trials.**

BACKGROUND

Fusarium crown rot is an increasing concern for cereal growers in the Riverine Plains, yet its impact remains largely unrecognised. This is partly due to the masking of disease symptoms in recent seasons, with wet conditions minimising the expression of whiteheads and reduced yields typically associated with Fusarium crown rot, which mostly occur when crops are filling under moisture stress. However, these same wet conditions are likely to have contributed to a build-up and persistence of the disease in the soil.

In 2021, Riverine Plains conducted the *Improving Soils to Optimise Water Use on Farm* project, which studied the effects of cereal stubble management and subsurface acidity on yield at Murchison. Subsequent Predicta B testing of stubble treatments in January 2023 revealed a potential link between stubble management, subsurface acidity, Fusarium crown rot infection, and yield loss.

To further explore these findings, the Grains Research and Development Corporation (GRDC) and Riverine Plains launched the *Understanding the link between cereal stubble, subsurface acidity, and crown rot* project. This National Grower Network (NGN) initiative commenced in October 2023 and will continue through December 2026, aiming to provide growers with practical management strategies to mitigate the impact of Fusarium crown rot in cereal crops.

AIM

This project aims to determine how stubble management strategies and break crops can impact Fusarium crown rot pathogen levels over time. The project is also investigating the potential link between stubble management, subsurface acidity, and Fusarium crown rot in cereals over multiple seasons.

METHOD

Riverine Plains invited local farmers to test high-risk paddocks for Fusarium crown rot in January 2024—a high risk paddock was considered to be one that was intended for wheat or barley in 2024 and which also had a history of tight cereal rotations. From the 14 paddocks in the trial, Predicta B DNA testing identified nine of these paddocks as at high risk of damage from Fusarium crown rot.

In June 2024, two NSW farmers (Rand North West, Rand North) and one Victorian farmer (Murchison) with high-risk paddocks established demonstration strips trials to evaluate management strategies that could reduce the risk of damage. These strategies included limiting total available nitrate nitrogen (N) to the crop, using different crop rotations and using different seeding rates.

During late January 2025, Predicta B sampling was conducted across all trial sites, while cereal stubble was also collected for stubble plating analysis. Predicta B soil samples were sent to PIRSA:SARDI and cereal stubbles were sent to Dr Steven Simpfendorfer, NSW DPI, for analysis of Fusarium crown rot risk levels in soil and cereal stubble respectively.

SITE 1: RAND NORTH WEST – NITROGEN

TRIAL RATIONALE

Both local and overseas research has shown that having excessive nitrogen available in the soil in nitrate form (plant available) can worsen Fusarium crown rot compared to nitrogen in ammonium form (not plant available) (Eddine et al, 2020 and Buster et al, 2023). Nitrification inhibitors like 3,4-dimethylpyrazole phosphate (DMP) slow the conversion of ammonium to nitrate; this can help reduce nitrogen loss to the environment from volatilisation and leaching, while also slowing the release of fertiliser nitrogen to the plant. The Rand North West demonstration tested the effect of applying nitrification inhibitor treated urea (eNpower®), compared to regular urea and a high nitrogen treatment.

METHOD

The site was inter-row sown to Sceptre wheat on 11 May 2024 (Table 1). The paddock was previously sown to canola, with the stubble Kelly-chained before sowing. The three treatments established at the site included a standard urea (control) treatment representing standard farmer practice, a nitrification inhibitor treatment (eNpower) and a high nitrogen treatment which included standard urea plus nitrification inhibitor (eNpower) treated urea. Each treatment was one seeder width wide by the length of the paddock, which was approximately 1.3 km.

All treatments received 60 kg/ha MAP and 50 kg/ha urea as starter fertiliser at sowing, as well as an early season application of 60 kg/ha urea on 25 June. On 26 August, the standard urea (control) treatment received an additional 80 kg/ha urea and the nitrification inhibitor treatment received 80 kg/ha eNpower urea, while the high nitrogen treatment received 80 kg/ha urea + 80 kg/ha eNpower (Table 2).

Table 1 Site details for the Riverine Plains Fusarium crown rot demonstration site at Rand North West, 2024.

TREATMENT	DETAILS	
Sowing date:	11 May, 2024	
Variety:	Scepter wheat	
Sowing rate:	60 kg/ha	
Starter fertiliser (May):	MAP at 60 kg/ha (incl Flutriafol), urea at 50 kg/ha	
Growing season rainfall:	190 mm	
Treatments (nitrogen delivery):	1. Standard area (control): urea at 190 kg/ha 2. Nitrification inhibitor: 110 kg/ha urea + 80 kg/ha eNpower urea 3. High nitrogen: 190 kg/ha urea + 80 kg/ha eNpower urea	
Harvest date:	25 November, 2024	
Soil test results:		
Predicta B:	**High** Fusarium risk level (January 2024)	
Soil pH:	Sample depth	pH
	0-5 cm	5.5
	5-10 cm	4.6
	10-15 cm	4.7
	15-20 cm	5.1

Table 2 Trial treatment details for the Riverine Plains Rand North West Fusarium crown rot demonstration site, 2024

TREATMENT	STARTER FERTILISER		EARLY NITROGEN	MID-SEASON NITROGEN		TOTAL N APPLIED*
Timing	11 May		25 June	26 August		
Fertiliser input	MAP (kg/ha)	Urea (kg/ha)	Urea (kg/ha)	Product	Rate (kg/ha)	(kg N/ha)
Standard urea (control)	60	50	60	Urea	80	94
Nitrification inhibitor treated urea (eNpower)	60	50	60	eNpower urea	80	94
High nitrogen	60	50	60	Urea + eNpower urea	80+80	130

*The nitrogen content of both urea and eNpower urea is 46 percent

RESULTS & DISCUSSION

The highest plant counts at establishment (59 plants/m²) and head counts at milky dough (265 heads/m²) were observed in the high nitrogen treatment, while the lowest counts were observed in the nitrification inhibitor treated urea treatment (44 plants/m² and 199 heads/m², respectively (Table 3). However, all three treatments in this trial tillered similarly, ranging from 4.5 to 4.8 tillers/plant. This suggests that the differences observed in plant and head counts may be due to paddock variation, rather than treatment differences.

When measurements were taken at medium milk maturity (GS74) on 23 October, there were no whiteheads visible in any treatment.

Basal stem browning—a common indicator of Fusarium crown rot—was assessed visually, with slightly higher stem browning in the nitrification inhibitor treatment (48 percent) compared to the standard urea (control) (32 percent) and high nitrogen treatments (35 percent). Soil analysis indicated the presence of other potential pathogens, including Pythium, Sclerotina, Macrophomina phaseolina and nematodes, all of which are known to cause similar stem browning symptoms to Fusarium crown rot in wheat. Therefore, the high incidence of basal browning observed in the nitrification inhibitor treatment may be due to the combined effects of these pathogens, rather than just crown rot alone. The application of nitrification inhibited urea (eNpower) also occurred later than anticipated (during late August, due to logistical issues), which may have impacted the basal browning results. Random environmental variability may also be at play, noting that this is difficult to establish given the unreplicated nature of the trial.

Cereal stubble plating and Predicta B soil analysis were both conducted after the 2024 harvest. Stubble plating analysis showed a trend to lower rates of crown infection in the nitrogen inhibitor treatment (13 percent) compared to the standard urea (36 percent) and high nitrogen (20 percent) treatments. The nitrification inhibitor treatment also returned the lowest overall infection level (low–medium), while the high nitrogen treatment had medium infection, and the standard urea had medium–high infection. However, Predicta B testing returned a high Fusarium crown rot risk reading for all treatments. The difference between the Predicta B and stubble plating results may be due to the nature of the tests; stubble plating relies on culturing live Fusarium from plant tissue, but its results can underestimate Fusarium crown rot if beneficial microbes like Trichoderma suppress pathogen growth, especially after a wet fallow. In contrast, Predicta B, a DNA-based test, is more sensitive and can detect Fusarium crown rot from both viable and non-viable sources, which can overestimate risk if the detected DNA comes from decomposed or inactive residues. While the risk ratings may vary, both Predicta B and stubble plating are considered reliable indicators of the disease risk.

No other differences were observed between treatments, including for yield, protein or grain quality parameters. Further research is needed on the effects of using nitrification inhibitors for Fusarium crown rot management to draw any conclusions.

Table 3 Plant development, Fusarium crown rot and yield results, Rand North West, 2024

MEASUREMENTS	CONTROL (STANDARD UREA)	NITRIFICATION INHIBITOR (ENPOWER UREA)	HIGH NITROGEN
Plants/m²	53	44	59
Heads/m²	259	199	265
Whiteheads (%)	0	0	0
Brown stems (%) /metre row	32	48	35
Growth stage, 23 October	Medium milk	Medium milk	Medium milk
Yield (t/ha)	3.9	3.5	3.8
Protein (%)	10.9	10.1	10.6
Screenings (%)	<1	<1	<1
Moisture (%)	9	9	9
Predicta B risk rating (post-harvest 2025)	**High**	**High**	**High**
Stubble plating results			
Crown Infection* (%)	36	13	20
Stem Infection* (%)	16	5	10
Infection level*	**Medium–high**	**Low–medium**	**Medium**

*Stubble plating results courtesy of Steven Simpfendorfer, NSW DPI

SITE TWO: RAND NORTH – CEREAL ROTATIONS

TRIAL RATIONALE

Although barley is susceptible to Fusarium crown rot, it generally, has a shorter growing season than wheat, which often allows it to avoid the moisture stress associated with Fusarium crown rot infection during grain-fill. This means that barley is less likely to produce the typical whiteheads associated with Fusarium crown rot, while also being less likely to suffer yield loss, compared to wheat.

To test this theory, the Rand North demonstration site compared two barley varieties, Neo and Planet, to a farmer control sown to Coota wheat (Table 4).

METHOD

Each treatment was one seeder width wide, and the length of the paddock, which was approximately 1.2 km. The wheat was sown on April 24, 2024, and both barley varieties were sown the next day. The treatments were sown into burnt wheat stubble from the previous crop, into the same row.

Table 4 Site and treatment details for the Riverine Plains Rand North Fusarium crown rot demonstration, 2024.

TREATMENT	DETAILS	
Sowing date:	Barley: April 25	
	Wheat: April 24	
Treatments (cereal rotation):	1. Control (Coota wheat), sown at 75 kg/ha 2. Neo barley, sown at 60 kg/ha 3. Planet barley, sown at 70 kg/ha	
Fertiliser:	April: 75 kg/ha MAP June: 100 kg/ha urea August: 100/ha kg urea	
Growing season rainfall:	210 mm	
Harvest date:	Barley: 8 December	
	Wheat: 14 December	
Soil test results (January 2024)		
Predicta B:	**High** Fusarium risk level (January 2024)	
Soil pH:	Depth	pH
	0-5 cm	5.1
	5-10 cm	5
	10-15 cm	4.9
	15-20 cm	5.2

RESULTS AND DISCUSSION

In this trial, wheat had the lowest (2.9) tillers/plant followed by Neo barley (7.8) tillers/plant and Planet barley (9.12) tillers/plant (Table 5).

No whiteheads were observed in any of the treatments during assessments on 23 October at the medium milk stage (GS75), likely because plants did not experience sufficient stress to trigger their expression. However, the absence of whiteheads does not necessarily indicate the absence of disease, as yield losses can still occur even without visible symptoms.

Predicta B analysis identified the paddock as high risk for disease in 2024, and at the medium milk stage (GS75), Planet barley showed the highest incidence of brown stems (8 percent), followed by Neo barley (7 percent) compared to just 1 percent in wheat. The presence of high levels of pathogens like Pyrenophora, Pythium, nematodes and pratylenchus likely contributed to the browning observed in the stems and crowns and the paddock also experienced significant frost damage, which can also cause stem browning. As a result, the typical visual stem and crown browning symptoms could not be used as a reliable indicator of crown rot infection in this trial last year. It is also worth noting that barley is still susceptible to Fusarium crown rot and can act to increase inoculum levels in the paddock for a following cereal crop.

Neo barley had the highest yield (4 t/ha), compared to Planet barley (3.5 t/ha) and wheat (3.5 t/ha). Barley, and Neo in particular, was observed to perform especially well across the Riverine Plains in 2024, and these results are consistent with farmer experiences in the context of frost damage and dry spring conditions experienced this season.

Table 5 Plant development, Fusarium crown rot and yield results, Rand North, 2024

MEASUREMENTS	CONTROL COOTA WHEAT	NEO BARLEY	PLANET BARLEY
Plants/m²	144	82	87
Heads/m²	424	646	794
White heads (%)	0	0	0
Brown stems/metre row (%)	1	7	8
Growth stage, 23 October	Medium milk	Medium milk	Medium milk
Yield (t/ha)	3.5	4	3.5
Protein (%)	10.9	11.5	11.8
Screenings (%)	<1	<2	<2
Moisture (%)	11.4	11.3	10.5
Predicta B risk rating (post-Harvest 2025)	**High**	**Medium**	**Low**
Stubble plating results			
Crown infection* (%)	0	4	14
Stem infection* (%)	2	12	10
Infection level*	**Low**	**Low–medium**	**Low–medium**

*Stubble plating results courtesy of Steven Simpfendorfer, NSW DPI

SITE 3: MURCHISON – SOWING RATES

TRIAL RATIONALE

Research conducted in Central West NSW during 2023 indicated that a high seeding rate may have reduced the impact of Fusarium crown rot. It's theorised that a high seeding rate may deplete soil moisture faster, hastening crop maturity so that the crop avoids severe heat stress and the effects of Fusarium crown rot. However, as this work represents only one year of research, it was decided to test the theory by establishing a demonstration trial at Murchison during 2024, to compare the standard farmer seeding rate (control) to both a higher and lower seeding rate.

METHOD

The Murchison site was sown to wheat Scepter wheat on 2 May (Table 6) into a retained wheat stubble (inter-row sown).

The demonstration included a farmer control of 68 kg seed/ha, representing local farmer practice, as well as a high seeding rate of 100 kg/ha and a low seeding rate of 50 kg/ha. Each strip was three seeder-widths wide by the length of the paddock, about 1.2 km.

Table 6 Site and treatment details for the Riverine Plains Murchison Fusarium crown rot demonstration site, 2024

TREATMENT	DETAILS	
Sowing date:	2 May	
Treatments (seeding rates):	1. Control (farmer practice): 68 kg/ha 2. Low seeding rate: 50 kg/ha 3. High seeding rate: 100 kg/ha	
Starter fertiliser:	March: MAP 100kg/ha (incl 400ml/ha Flutriafol)	
Soil mineral nitrogen (June):	128 kg N/ha	
In-season fertiliser application:	June: 58 kg N/ha urea Early August: 46 kg N/ha urea Late August: 46 kg N/ha urea (minimal rain post-application)	
Growing season rainfall:	208 mm (plus 130 mm summer rain)	
Harvest date:	10 December	
Soil test results:		
Predicta B:	**High** fusarium risk level (January 2024)	
Soil pH:	**Depth**	**pH**
	0-5 cm	6.2
	5-10 cm	5.6
	10-15 cm	5.5
	15-20 cm	5.3

RESULTS AND DISCUSSION

Plant density was 106 plants/m^2 for the farmer control treatment and 158 plants/m^2 for the higher seeding rate treatment. The higher seeding rate treatment also achieved a higher head count of 414 heads/m^2, which was in line with expectations given the greater plant establishment in this treatment (Table 7).

In this demonstration, the higher seeding rate treatment (100 kg/ha) did not have visible whiteheads when assessed on 23 October at the medium milk growth stage (GS75). However, the lower seeding rate and control treatment both showed white heads in low numbers (less than one percent).

The percentage of plants showing stem browning was highest in the control treatment (standard seeding rate), however stem browning was low overall (less than 10 percent) at this site. There appeared to be a slight difference in maturity between growth stages of the different seeding rates, likely due to the influence of seeding rate on crop development.

Results of stubble plating analysis showed the high seeding rate treatment had lower rates of stem infection and crown infection (12 and two percent respectively) compared to the standard seeding rate and low seeding rate treatments. This translated to a low–medium infection level for this treatment, compared to a medium infection level for the low seeding rate and a medium–high infection level for the standard seeding rate.

The higher seeding rate treatment also had the highest yield compared to other treatments.

Table 7 Plant development, Fusarium crown rot and yield results, Murchison, 2024

MEASUREMENTS	CONTROL	LOW SEEDING RATE	HIGH SEEDING RATE
Plant/m²	106	72	158
Heads/m²	312	331	414
Whiteheads (%)	<1	<1	0%
Brown stems/meter row (%)	10%	2%	3%
Growth stage, 23 October	Early milk	Medium milk	Medium milk
Yield (t/ha)	5.9	6.2	6.2
Protein (%)	11.71	11.14	11.48
Screenings (%)	<1	<1	<1
Moisture (%)	12.0	12.6	12.7
Predicta B (post-Harvest 2024)	**High**	**High**	**High**
Stubble plating results			
Crown Infection* (%)	16	16	2
Stem Infection* (%)	32	18	12
Infection level*	**Medium–high**	**Medium**	**Low–medium**

*Stubble plating results courtesy of Steven Simpfendorfer, NSW DPI

Overall, Fusarium crown rot symptoms are lower than expected across all treatments at this site given that Predicta B testing indicated this paddock as high risk at the start of 2024. A possible explanation is that the paddock was inter-row sown, creating distance between the new crop and the old crop, reducing the chance of cross-infection. Alternatively, the retained stubble in this paddock may have experienced more consistent residue decomposition, promoting colonisation by beneficial microbes like Trichoderma spp. which can suppress Fusarium activity. Environmental conditions during early crop development and grain fill, including low soil moisture or cooler temperatures, may have also limited disease development, despite the presence of pathogen DNA in the soil.

These results are inconclusive as to whether a higher seeding rate used up soil moisture more quickly than the other treatments and if this brought maturity forward, reducing the impact of this disease.

MURCHISON LONG-TERM DEMONSTRATION SITE

The Murchison demonstration site is providing long-term data on how rotation, stubble management strategies and soil acidity influence Fusarium crown rot.

METHOD

This site was sown to Hyola canola in 2024. The stubble treatments (Table 8) were originally implemented after a wheat crop in 2021, prior to sowing a consecutive wheat crop in 2022. All treatments received an application of 6.7 t/ha of lime in March 2022, with the two deep incorporation treatments (harvest cut high deep incorporation of stubble and harvest cut low deep incorporation of stubble) incorporated to a depth of approximately 15 cm.

RESULTS AND DISCUSSION

At the start of 2023, stubble plating tests through NSW DPI showed all treatments to be high risk for Fusarium crown rot. As such, the wheat stubble in all treatments was burnt to reduce inoculum and faba beans were sown in 2023, followed by canola in 2024. Predicta B testing in 2025 for Fusarium crown rot showed that six out of the eight treatments were below detection, while two treatments were low risk.

The demonstration shows how the use of two consecutive break crops can drastically reduce the risk of Fusarium crown rot.

Soil pH testing was not conducted in 2025 because the site was cultivated with an offset disc to a depth of approximately 10 cm as part of a drainage plan for the paddock, which would have interfered with results. However, soil testing in 2024 showed that a high rate of lime applied in March 2022 increased pH across the 0–5cm and 5–10 cm levels. At the 10–15 cm depth, where there was elevated aluminum, only the deep incorporation treatments alleviated the effect of toxic aluminium levels.

Although it was expected that deep incorporation treatments would be the highest yielding in 2025 (due to lime incorporation), this was not the case. Also, there did not appear to be a correlation between plant counts and canola yield, as the treatments with the highest and lowest plant counts (harvest cut high, shallow incorporation of stubble, and harvest cut low, shallow incorporation of stubble) had similar yields. It was concluded that other factors such as paddock variation in soil pH, nutrient availability, moisture and rainfall were influencing the yield results between treatments.

The average grain analysis results for canola in 2024 were: protein 21.5 percent, moisture content 4.5 percent, oil 45.3 percent, and test weight 65.9 kg/hL.

Table 8 Emergence counts, yield, grain quality and PredictaB results at the Riverine Plains Murchison long-term demonstration site, 2024

STUBBLE TREATMENTS APPLIED POST-HARVEST 2021 *	CANOLA ESTABLISHMENT (PLANTS/M²)	AVERAGE YIELD ± SD (T/HA)	PREDICTA B (POST-HARVEST 2024)
1-Harvest cut high and bale	15	3.30 ± 0.15	Below detection
2-Harvest cut low	12	3.40 ± 0.14	Below detection
3-Harvest cut high, deep in-corporation of stubble	16	3.30 ± 0.19	Low
4-Harvest cut low, deep in-corporation of stubble	12	3.10 ± 0.22	Below detection
5-Harvest cut high, flail mulch stubble	10	3.10 ± 0.23	Low
6-Harvest cut high, shallow incorporation of stubble	5	3.25 ± 0.18	Below detection
7-Harvest cut low, shallow incorporation of stubble	20	3.22 ± 0.19	Below detection
8-Burn	13	3.11 ± 0.14	Below detection

*Note: Standard deviation (SD) is a measure of how much yield varied between data points of the same treatment. A low SD means the yield results were very similar across the data points, which gives more confidence that the treatment had a consistent effect. A higher SD suggests more variation between each data points, so while the average yield may look good, the results were less consistent.

OBSERVATIONS AND COMMENTS

During a tight spring with heat stress, Fusarium crown rot fungi restrict the flow of water and nutrients to developing heads, which can result in pinched grain or heads with no grain. This can lead to “whiteheads” in the crop, but these don’t always occur reliably and can be confused with frost, mice or insect damage and moisture stress.

Despite dry conditions during spring, there were not many whiteheads visible at any of the trial sites during 2024. There were generally good reserves of stored soil moisture across the region, and timely rain at grain filling during October potentially meant plants may have avoided moisture stress and the triggering of whiteheads. Many of the plants were observed to have frost damage, with shrivelled grain at all three demonstration trial sites, due to a frosting event in mid-September. The Rand North site experienced more severe frosting in lower elevation areas than the other sites.

SUMMARY

The demonstration site has clearly shown that the use of break crops, such as faba beans and canola are very effective at reducing Fusarium crown rot inoculum levels.

The unreplicated demonstration trials showed a trend to reduced levels of Fusarium crown rot following barley compared to wheat and when a higher seeding rate was used. There was also a trend towards lower levels of disease when a nitrogen inhibitor (eNpower) was used to maintain soil nitrogen in ammonia form compared to nitrate form of nitrogen (urea).

Predicta B testing in 2025 also showed that Fusarium Crown Rot is prevalent at varying levels across the Riverine Plains.

Riverine Plains will continue to assess different management strategies as part of this project in 2025, including the effects of rotation and seed treatment.

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FINAL RESULTS FROM THE BEST PRACTICE LIMING TO ADDRESS SUB-SOIL ACIDITY IN NORTH EAST VICTORIA TRIALS

KEY MESSAGES

- **A replicated liming rate and incorporation trial at Lilliput clearly demonstrated how applying lime, followed by incorporation, increased subsurface pH values and reduced aluminium availability in the soil.**
- **There was no difference in yields due to liming rate or incorporation method in the replicated plot trial during 2024 or 2023, likely due to good seasonal and growing conditions.**
- **A demonstration trial looking at fine verses coarse lime quality highlighted how the rate of lime applied (3 t/ha) was more influential than the type of lime for increasing pH in this soil.**
- **Incremented soil testing helps identify the severity of acidification and allows the right amount of lime to be calculated for your soil type. It will also help identify any other subsoil constraints that could affect the incorporation method.**
- **While deep incorporation of lime has shown positive results in this trial, it's important to only incorporate lime to the depth that is suitable for that soil, considering the presence of other soil constraints (i.e. sodicity, slaking).**
- **Tools for economic analysis of liming and incorporation exist and are useful for scenario modelling, however they do not reflect the complexity of the issue.**

OVERVIEW

Acid soils have long been a major constraint to crop and pasture production in north east Victoria, with the reacidification of previously limed soils, along with pH stratification, becoming increasingly important for grain farmers in the Riverine Plains.

The *Best practice liming to address sub-soil acidity* project was developed to increase awareness of the speed of acidification and stratification of soils in the region, as well as the tools available to assist management decisions.

The project involved the establishment of a replicated field trial to demonstrate best practice liming strategies, as well as a field demonstration of the impacts of lime quality, each year for three years from 2022–2025.

The trials were designed to demonstrate different incorporation methods, evaluate the impact of different lime types and sources and extend findings, including comparisons of the economic and agronomic returns using the *Acid Soils SA* calculator tools.

The data generated through this project is supporting farmers to evaluate the most practical and economical methods to manage soil pH and paddock variability.

AIM

The project aims to support growers and advisers in north east Victoria to have an improved understanding of the state of topsoil and subsoil acidity, the limitations to crop profitability it causes, and an improved knowledge of the agronomic and economic benefits of different lime sources, lime quality and incorporation methods.

METHOD

Treatments for the project were developed in consultation with a steering committee made up of growers and researchers, as shown in Table 1.

The treatments were applied to a trial site established at Lilliput, in the Rutherglen district of Victoria, and monitored for three years from 2022–2024.

Table 1 Best practice liming trial treatments

TREATMENT #	DETAILS
1	Control – nil applied lime with nil incorporation
2	Nil lime, with incorporation by shallow discs
3	Lime to target pH 5.2, incorporated by sowing
4	High rate of lime (targeting pH 5.8 in 0–10 cm value), incorporated by sowing
5	High rate of lime (targeting pH 5.8 in 0–10 cm value), incorporated by shallow discs
6	High rate of lime (targeting pH 5.8 in 0–10 cm value), deep incorporation to 10–15cm, follow up with speed-tiller
7	High rate of lime (targeting pH 5.8 in layers to depth), deep incorporation to 10–15cm, follow up with speed-tiller (rate calculated for pH 5.8 at depth)—Deluxe option

An intense soil sampling regime was completed in February 2022 across each replicate. This provided baseline information to characterise the whole site, as well as an understanding of current pH levels and other constraints, such as sodicity, to ensure that the proposed incorporation methods were appropriate. Using this information, it was calculated that the rates of lime applied in that year would be:

- Lime required to achieve a target pH of 5.2 = 1.2 t/ha
- Lime required to achieve a target pH of 5.8 (high rate) = 5.0 t/ha
- Lime required to achieve a target pH of 5.8 to depth (high rate to depth, deluxe option) = 8.5 t/ha

The application of lime was done using a range of surface and incorporation techniques, including a shallow incorporation by sowing, incorporation by discs to a depth of 10 cm and a deeper incorporation by a Horsch Tiger to a depth of 15 cm (Treatments 6 and 7). A nil control—where no lime is applied—was used to highlight the cost of complacency when addressing pH issues in both the short and long term.

The field site was established and managed by AgriSci Pty Ltd. Table 2 shows the layout of the field-scale replicated trial.

At one end of the replicated trial, demonstration trials were established to assess the impacts of two types of lime quality, granular (Mt Gambier lime) and fine (Galong lime), applied at 3 t/ha and incorporated with sowing. The lime from Galong was very fine, with bulk density of 1.4, while the Mt Gambier lime was much coarser, with a bulk density of 1.1.

Table 2 Best practice liming replicated and demonstration trial layout, Lilliput, 2022–2024

TRIAL PLAN	
Demonstration 1: Mount Gambier lime 3 t/ha, incorporate by sowing	
Demonstration 2: Nil lime, incorporate by sowing	
Demonstration 3: Galong lime 3 t/ha, incorporate by sowing	
1 5 t/ha applied lime with deep incorporation	28 5 t/ha applied lime with incorporation by sowing
2 5 t/ha applied lime with incorporation by shallow discs	27 Nil applied lime with shallow disc incorporation
3 Control, nil applied lime with nil incorporation	26 1.2 t/ha applied lime with incorporation by sowing
4 1.2 t/ha applied lime with incorporation by sowing	25 5 t/ha applied lime with incorporation by shallow discs
5 Nil applied lime with shallow disc incorporation	24 8.5 t/ha applied lime with deep incorporation
6 8.5 t/ha applied lime with deep incorporation	23 5 t/ha applied lime with deep incorporation
7 5 t/ha applied lime with incorporation by sowing	22 Control, nil applied lime with nil incorporation
8 Control, nil applied lime with nil incorporation	21 8.5 t/ha applied lime with deep incorporation
9 5 t/ha applied lime with incorporation by sowing	20 5 t/ha applied lime with incorporation by shallow discs
10 5 t/ha applied lime with incorporation by shallow discs	19 5 t/ha applied lime with incorporation by sowing
11 Nil applied lime with shallow disc incorporation	18 1.2 t/ha applied lime with incorporation by sowing
12 5 t/ha applied lime with deep incorporation	17 Nil applied lime with shallow disc incorporation
13 8.5 t/ha applied lime with deep incorporation	16 Control, nil applied lime with nil incorporation
14 1.2 t/ha applied lime with incorporation by sowing	15 5 t/ha applied lime with deep incorporation

Plot size 40m x 13 m, buffer 30 m

Lime was applied on 16 February 2022, with incorporation completed the next day. A Horsch Tiger (tynes 125–150 mm, discs 100 mm), was used for the deep incorporation, with calibration to ensure that the depth of the lime was kept above 20 cm, as the site has a sodic layer below this depth. A speed tiller was run over both incorporated treatments to a depth of 50–75 mm, to ensure a smooth surface for ease of sowing. Once the treatments were completed, the host sowed and managed the trial site in line with the management practices used for the remainder of the paddock.

Soil sampling was conducted in January 2022, before the treatments were established, and resampled in January 2023, 2024 and 2025 to enable a direct comparison of liming treatments and their effect on soil properties over time. Soil samples were collected in increments of 0–5, 5–10, 10–15, 15–20 cm using a hand corer, while the 20–30, 30–40, 40–50cm depth increments were collected using a hydraulic trailer-mounted corer.

The site was sown to canola in 2022, however the trial was abandoned due to waterlogging and slug damage prior to harvest, meaning that no yield results were collected. During May 2023, the site was sown to Scepter wheat, with results published in Research for the Riverine Plains 2024. On 11 April, 2024 the site was sown to Scepter wheat, for the second year in a row, along with 80 kg MAP/ha. In-crop urea was applied at 250 kg/ha during the season.

GreenSeeker® measurements of Normalised Difference Vegetation Index (NDVI) were taken on 19 August, 4 September and 19 September to try to assess a difference in growth of the plots (data not presented). Photos were also taken during the season as a record of plot growth.

Harvest was carried out for both the replicated and demonstration trials by Kalyx, using a plot header on 20 December 2024. The host farmer harvested the crop remaining on the site with the rest of the paddock.

RESULTS, OBSERVATIONS AND COMMENTS

RAINFALL

While total 2024 calendar year rainfall at the site was 700 mm, only 269 mm fell during the growing season (April to October), with the site receiving very poor early spring rainfall. This meant that crops needed to rely on stored moisture for grain fill, impacting yields. The area also received 209 mm over nine days during November, which skewed the yearly total.

During 2024, the site received similar rainfall to the 2023 season, although the timing was different, however this was much less rainfall than received during the 2022 season (1159 mm) (Figure 1).

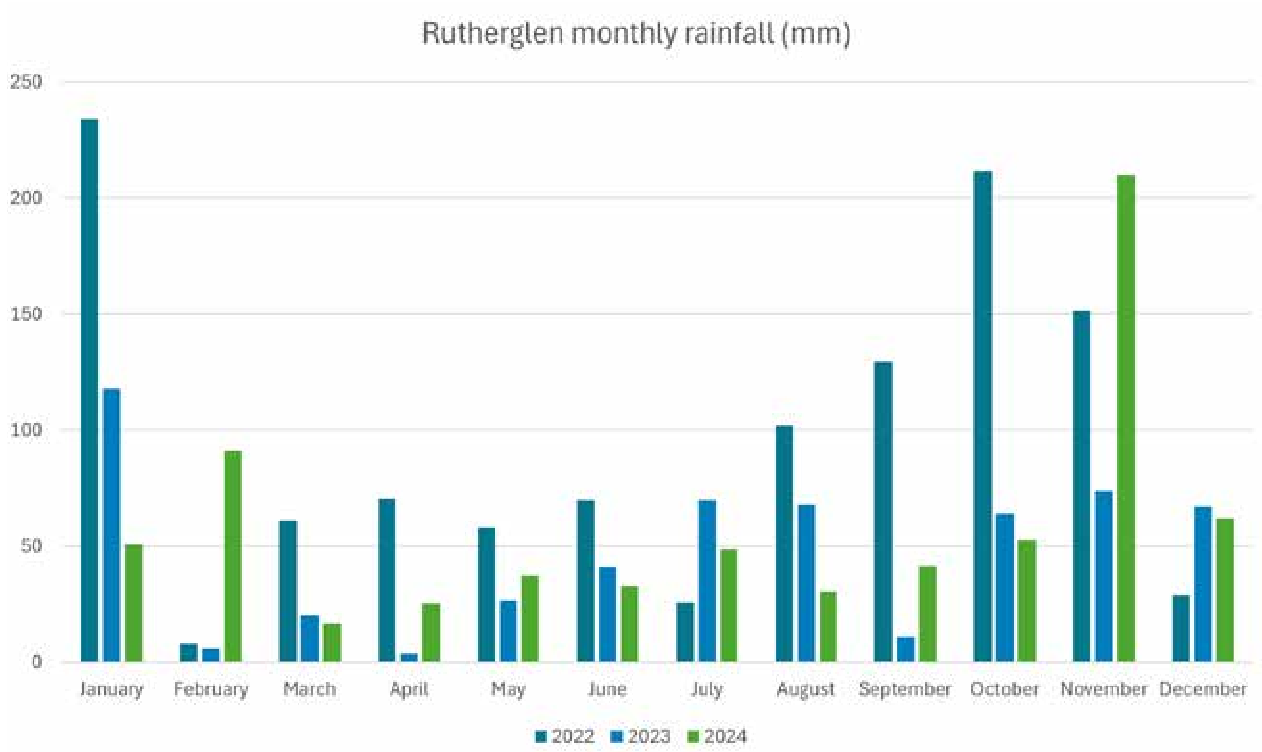

Figure 1 Monthly Rainfall taken from the Riverine Plains on-farm Rutherglen weather station , 2022–2024.

SOIL ANALYSIS

Note, while standard errors of the mean (SE) have been calculated for the following results, analysis of variance has not yet been completed due to delays in accessing statistical support. This means that any reference to treatment effects is estimated based on the SE values, not p-values.

Treatment effect on soil pH and aluminium percentage

The following graphs show soil pH and aluminium percentage in depth increments of 0–5, 5–10, 10–15, 15–20, 20–30, 30–40 and 40–50 cm along the y-axis, with the measured characteristic along the x-axis. The bars are standard error of the mean and each graph shows annual results from 2022 (prior to treatments being applied), 2023, 2024 and 2025 (after the trial was completed), sampled at the same time each year.

Treatment 1: Control – Nil applied lime with no incorporation

This is treatment was the control, with no lime applied in 2022 and sown as per the surrounding paddock.

This treatment aimed to show the result of a “do nothing” approach to soil pH, however the results show some year-on-year variance in the results which is expected in large scale plot experiments (these would all be within error, noting that the bars as measures of SE only).

From Figure 2a, pH gradually decreases in this soil as we move from the surface (0–5cm) to the subsoil, with pH then increasing down the profile, indicating the presence of an acid throttle. Mirroring the pH results, aluminium saturation is highest (>15–20 percent) at the 10–20 cm depths, which is likely causing some toxicity to plants (Figure 2b). Aluminium above five percent may affect root growth.

Treatment 2: No applied lime with shallow disc incorporation

No lime was applied to these plots, however this plot had a set of shallow discs run through it prior to sowing at the same time as incorporation was applied to the other treatments. The discs incorporated the soil to a depth of between 5–10 cm.

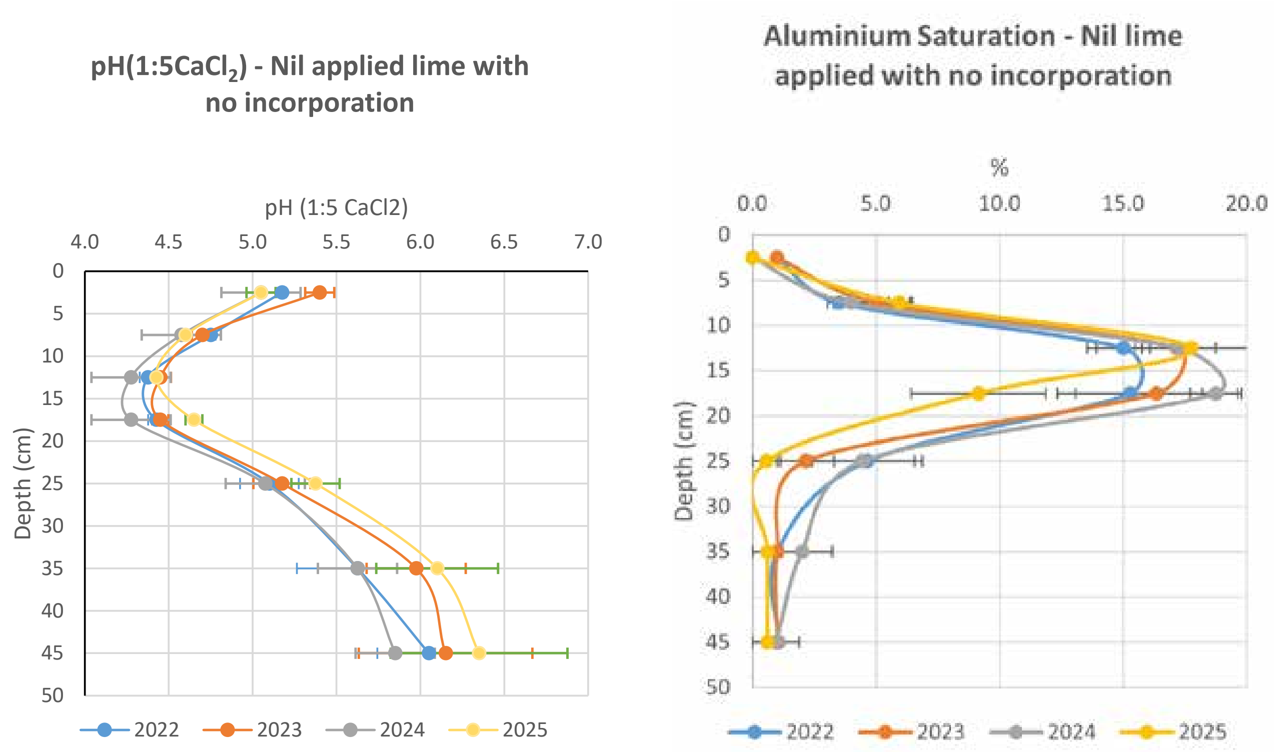

Figure 2a and 2b Soil pH and aluminium saturation (% of the CEC) in the nil lime applied with no incorporation treatment at Lilliput, 2022–2025. Bars are measures of standard error (SE).

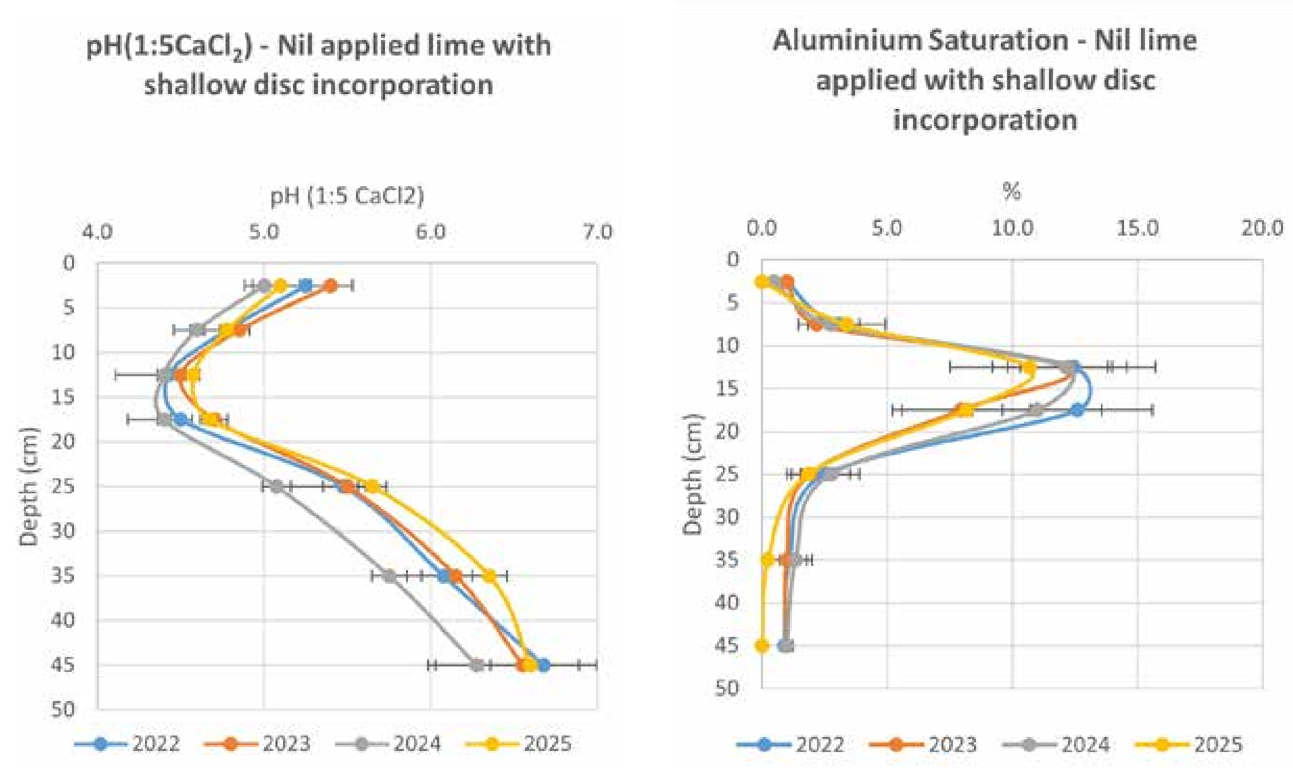

Figure 3a and b Soil pH and aluminium saturation (% of the CEC) in the nil lime applied with shallow disc incorporation treatment at Lilliput, 2022–2025. Bars are measures of standard error (SE).

Similar to the control treatment, there was no change in pH or aluminium saturation across the years (Figure 3a, b).

Treatment 3: Lime applied to target pH 5.2 and incorporated by sowing.

Traditionally, farmers in the Riverine Plains have targeted a pH of 5.2 for grain production, which generally allows a range of crops, including legumes, to be grown without the risk of yield loss. To achieve a target pH of 5.2 across the 0–10cm depth, 1.2 t/ha of lime was applied and then incorporated by sowing.

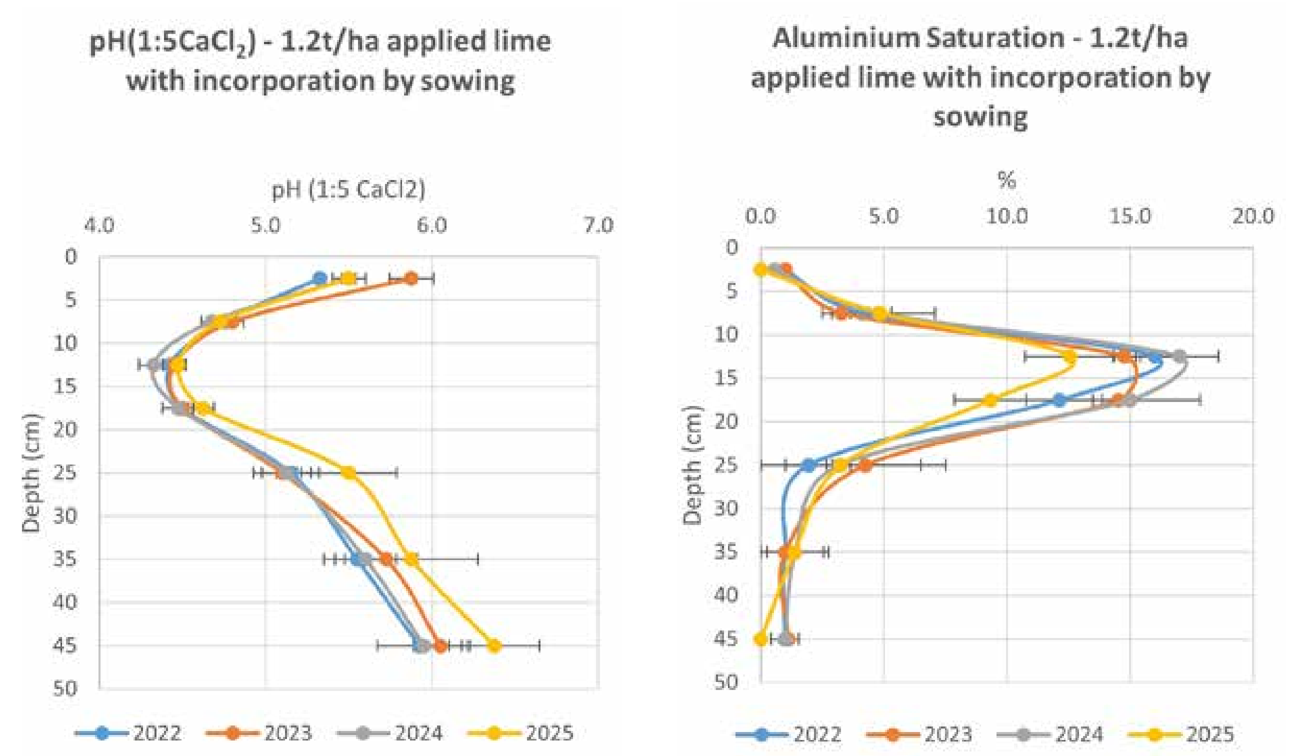

Figure 4a and 4b Soil pH and aluminium saturation (% of the CEC) in the 1.2 t/ha lime applied with incorporation by sowing treatment at Lilliput, 2022–2025. Bars are measures of standard error (SE).

The addition of lime in 2022 caused a transient pH increase at the 0 – 5cm depth in the 2023 sampling, which may be statistically significant (pending analysis of results). However, only a small shift in pH was evident at the time of the 2025 sampling time (Figure 4a, b).

Treatment 4: Lime applied to target pH 5.8 (at 0–10 cm depth), incorporated by sowing

It is now recommended that farmers target a pH of 5.8 to optimise growth across all crop varieties and provide sufficient alkali to move down into the subsurface. Initial soil testing in 2022 at this site indicated the application of 5 t/ha of lime was likely achieve this target.

The results indicate that the surface application of lime in this treatment has not yet impacted the high aluminium levels at depth in this soil, with saturation levels still at 15 percent (Figure 5a, b). The high surface pH values indicate that there is excess alkali in the surface which may be available to move down over time, however the relative impact and time requirement of this is unknown.

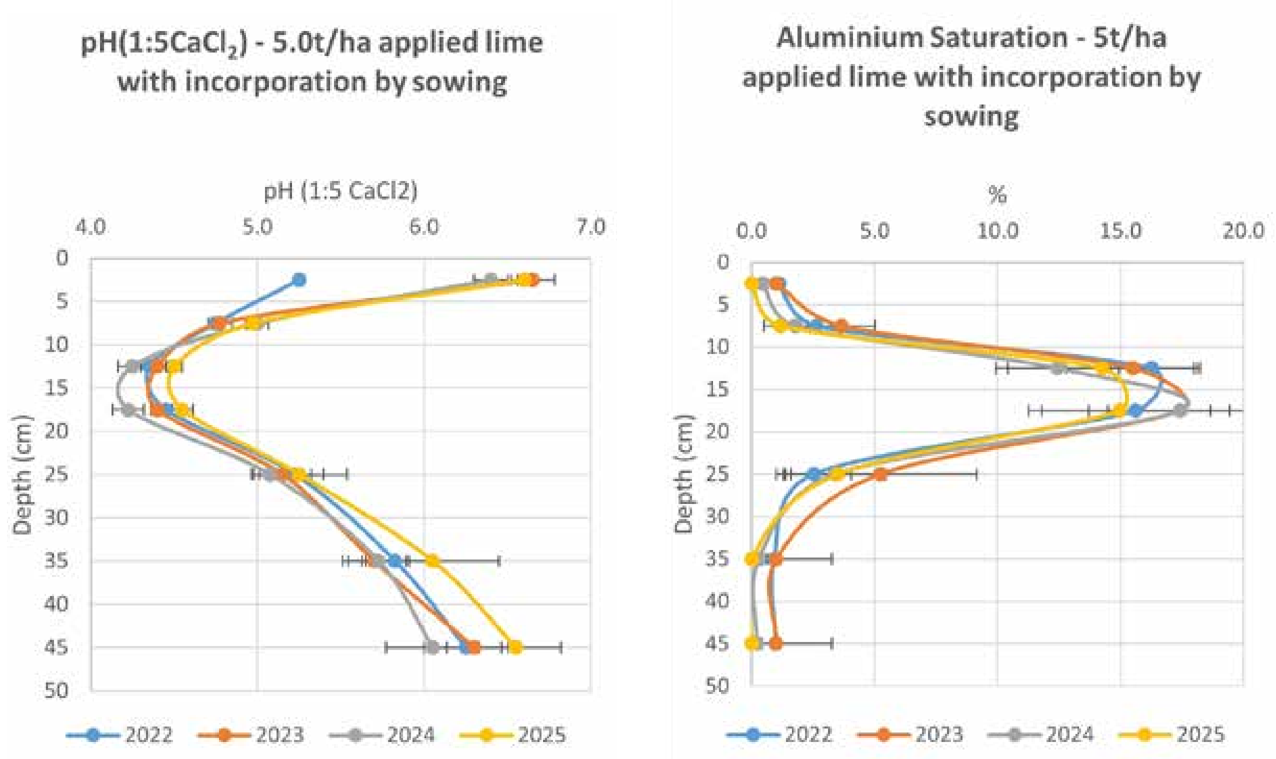

Figure 5a and 5b Soil pH and aluminium saturation (% of the CEC) in the 5 t/ha applied lime applied with incorporation by sowing treatment at Lilliput, 2022–2025. Bars are measures of standard error (SE).

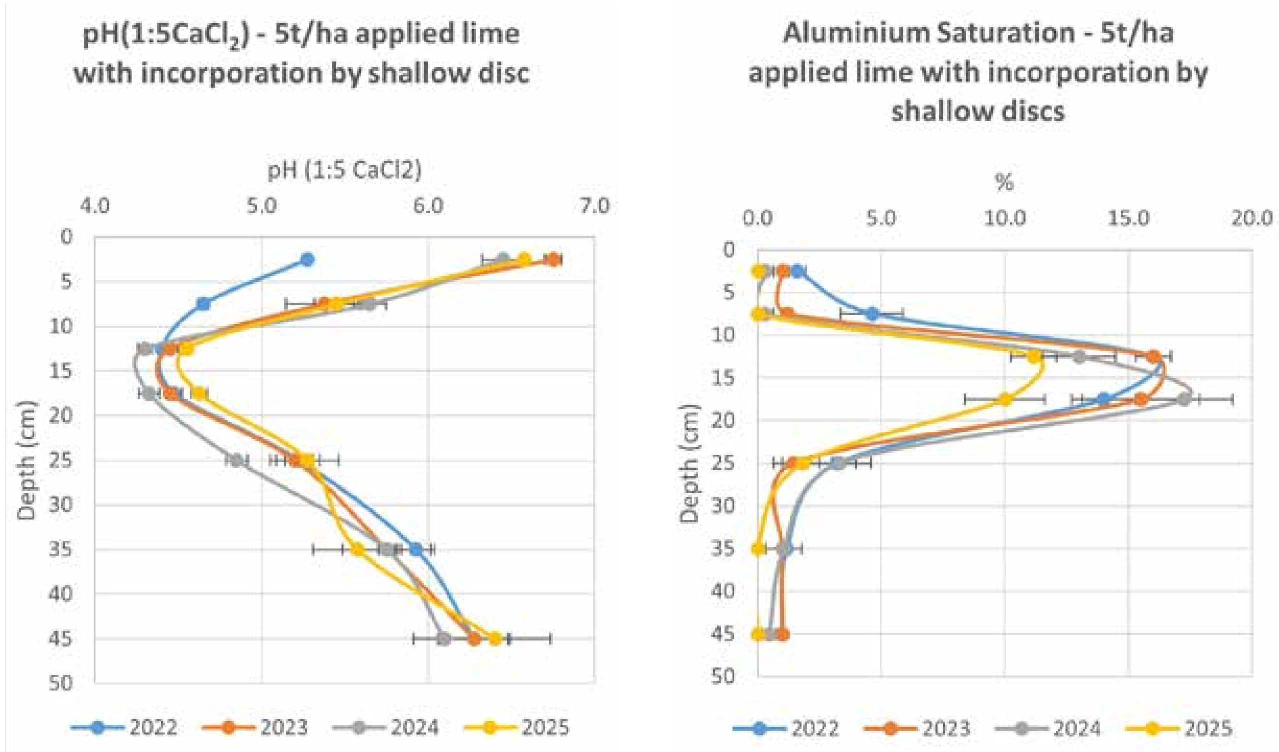

Figure 6a and 6b Soil pH and aluminium saturation (% of the CEC) in the 5 t/ha applied lime with incorporation by shallow discs treatment at Lilliput, 2022–2025. Bars are measures of standard error (SE).

Treatment 5: Lime applied to target pH 5.8 (at 0–10 cm depth), incorporated by shallow discs

Similarly to the 5 t/ha applied lime with incorporation by sowing treatment, the 5 t/ha applied lime with incorporation by shallow disc treatment aimed to achieve a target pH of 5.8 across the entire 0–10 cm depth, with the rate applied based on initial soil test results. The 5 t/ha lime incorporated using shallow discs treatment resulted in an increase in pH down to the depth of incorporation (Figure 6a, b).

By January 2025, soil pH had increased significantly down to the target depth of 10 cm after lime was applied and incorporated by shallow discs in 2022. There was also a resulting decrease in aluminium in the same target area (0–10 cm), measured across the same period; this indicates that the lime was successfully moved down the profile during the incorporation process and that it was able to react to increase soil pH within this zone.

Treatment 6: Lime applied to target pH 5.8 (at 0–10cm depth), deep incorporation (15cm)

This treatment aimed to mix the 5 t/ha of lime required to raise pH to 5.8 in the 0–10 cm depth to a depth of 15–20 cm. To do this, a Horsch Tiger was used, however a limited depth of incorporation (10–15 cm) was applied due to the presence of a sodic layer beneath this depth (mixing sodic subsoil with the surface soil would likely cause dispersion and crusting on the soil surface, potentially affecting crop emergence and limiting water infiltration).

The results show that the Horsch Tiger was successfully able to move lime down to the depth of incorporation (15 cm), with pH increasing in the 0–5, 5–10 and 10–15 cm depths between 2022 and 2025. Aluminium saturation was also reduced down to a depth of 15 cm (Figure 7a, b).

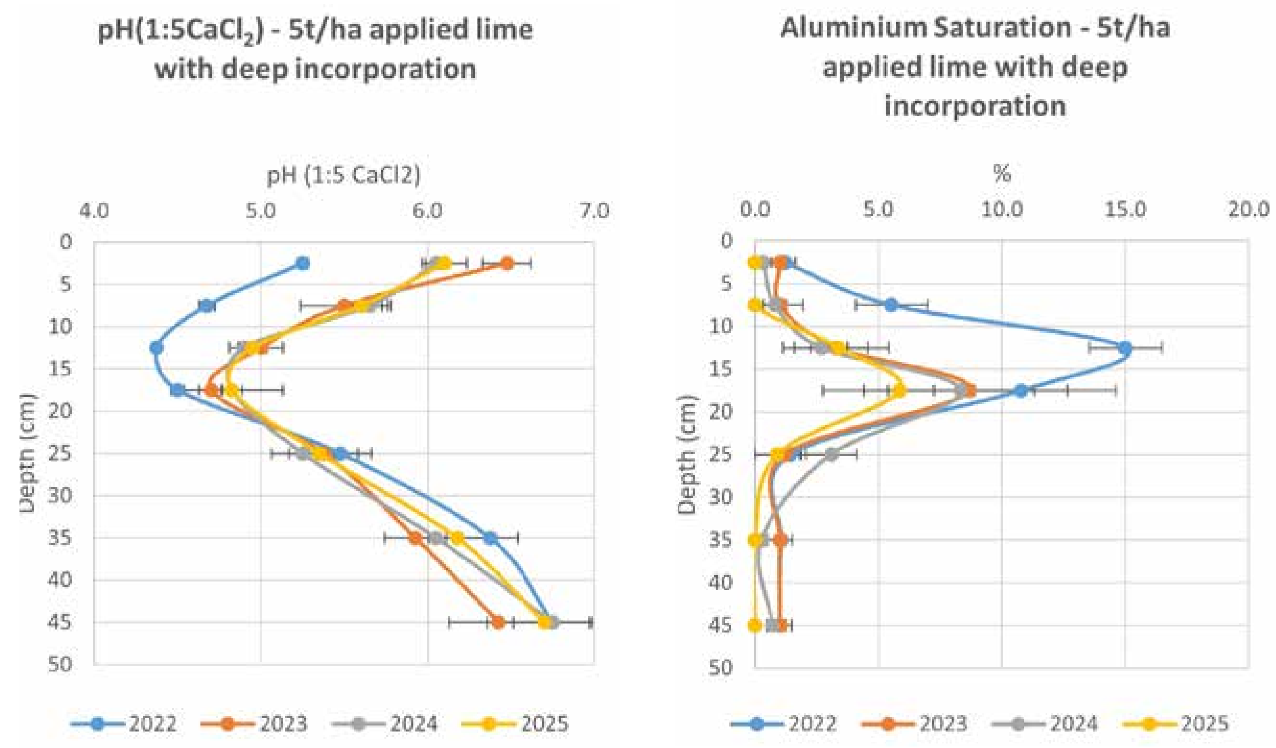

Figure 7a and 7b Soil pH and aluminium saturation (% of the CEC) in the 5 t/ha applied lime with deep incorporation treatment at Lilliput, 2022–2025. Bars are measures of standard error (SE).

Treatment 7: Lime applied to target pH 5.8 (0–20 cm depth), deep incorporation (15cm)

This treatment reflects a “deluxe” treatment approach not limited by the cost and practicalities of farming. The treatment targeted a pH of 5.8 from the surface, right down the profile to a depth of 20 cm. To do this, 8.5 t/ha of lime was applied and incorporated to 15 cm depth using a Horsch Tiger.

The results show that the combination of a high lime application rate and deep incorporation was able to completely ameliorate soil acidity in this situation, which resulted in a decrease in aluminium concentrations to below the toxicity threshold (Figure 8a, b). This means the soil should now support optimal root growth.

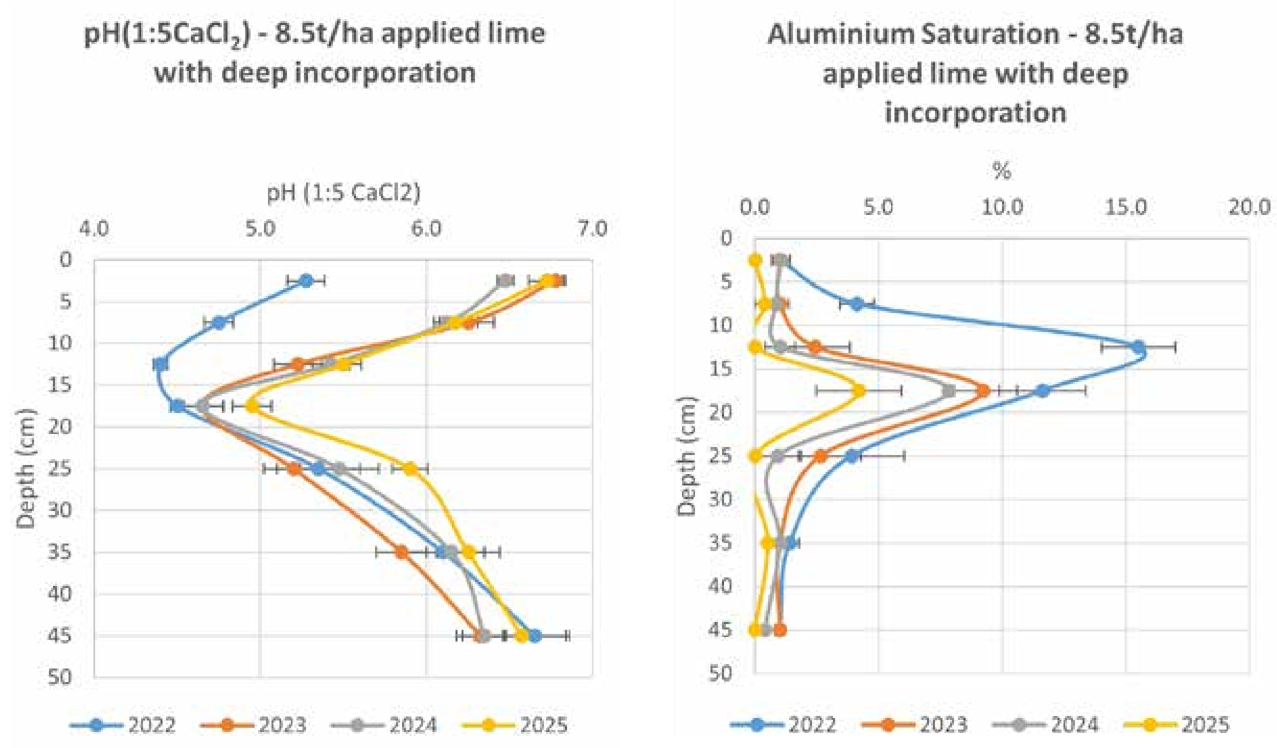

Figure 8a and 8b Soil pH and aluminium saturation (% of the CEC) in the 8.5 t/ha applied lime with deep incorporation treatment at Lilliput, 2022–2025. Bars are measures of standard error (SE).

OVERALL RESULTS

These results have clearly supported the premise of this project, that the incorporation of adequate lime is required for the amelioration of subsurface acidity.

The results from the January 2025 sampling, compared with the previous three years sampling, show that when lime is applied without incorporation, it only changes the pH value on the surface. Incorporating lime by sowing increases pH in the top 5 cm, with the rate of increase depending on the amount applied. However, incorporating lime with shallow discs, or moving lime even deeper using a cultivator like the Horsch Tiger, enables the lime to move to the depth of incorporation. In this trial, shallow discs moved lime to 10–15 cm while the Horsch Tiger was able to move lime to 15– 20 cm.

At this site, the application of 5 t/ha of lime resulted in a significant change in pH and aluminium saturation at the surface when incorporated by sowing, compared to the original test results. The 5 t/ha incorporated by shallow discs and 5 t/ha deep incorporation treatments also resulted in a significant change in pH to the depth of incorporation.

As expected, when no lime was applied, there was no change to subsurface acidity and aluminium saturation levels.

The CEC values for this soil (data not presented) show low cation levels in the 5–15 cm depth, which is typical of duplex soils with a bleached A2 horizon in the Riverine Plains region. The band of low CEC values (and low clay content) aligns with the general zone of high root activity, which is the depth of greatest subsurface acidification. Changes in CEC over time are not shown, as results only vary within the background context of clay content, with no significant impact due to treatment.

Exchangeable aluminium levels also clearly reflect the changes in pH due to amelioration in the highly acidic 5–20 cm depth, with high rates of lime and incorporation reducing aluminium to levels which may not affect plant growth.

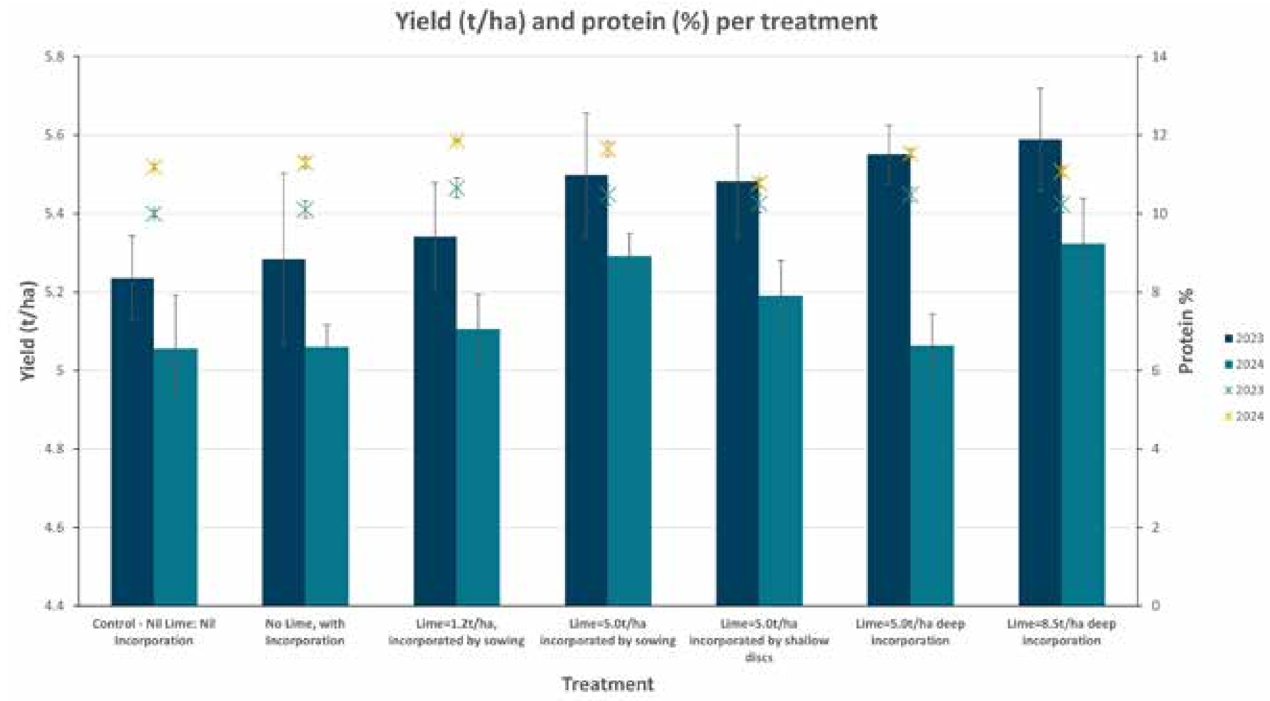

Figure 9 Yield and protein response from various treatments at the Riverine Plains and GRDC 2023 and 2024 Best practice liming trials at Lilliput. Bars are measures of standard error (SE).

GRAIN YIELD AND QUALITY

Although the lime moved to the targeted depth through incorporation in some treatments, there was no effect of lime application on yield. Due to waterlogging and slug damage at the trial site in 2022, yield was unable to be measured, thus Figure 9 shows 2023 and 2024 yields only. Overall yields were higher in 2023 compared to 2024, and there was a trend for higher yield in the 5 t/ha incorporated by sowing and 8.5 t/ha deep incorporation treatments across both years of the trial.

The 2024 replicated trial produced yields ranging from 5.05 t/ha (nil lime, nil incorporation) to 5.32 t/ha (8.5 t/ha lime, deep incorporation), which was slightly lower than observed in 2023, when the nil lime, nil incorporation treatment yielded 5.23 t/ha and the 8.5 t/ha lime, deep incorporation treatment yielded 5.59 t/ha. Both the 2023 and 2024 growing seasons had high yield potential, with minimal disruptions and timely rainfall. This helps explain the relatively small (approximately 0.3 t/ha) yield difference between the control and the deluxe treatment; had the season been drier, with plants under considerably more moisture stress, it is likely that the nil lime control treatment would have yielded comparatively less due to impaired root growth under high aluminium levels.

While there was little difference in protein results in 2023, during 2024 the higher lime rate (5 and 8 t/ha) plots with deep incorporation, also showed higher protein levels. While the reason for this is unclear (no nitrogen data was collected to provide insight), it is likely that improved nitrogen use efficiency in the treatments where acidity had been ameliorated led to higher grain protein. This was more evident in 2024 than 2023, due to the drier spring which caused moisture to be more limiting. It is also likely that water use efficiency may have shown a similar trend had moisture measurements been taken.

While 250 kg/ha urea was applied to the crop in 2024, the crop was potentially nitrogen limited at different growth stages given the high yields extracted in 2023.

Frost damage is also often exacerbated under low soil pH conditions and although severe frost events occurred across the Riverine Plains during 2024, they did not impact this specific trial site.

FUSARIUM CROWN ROT & SLUGS

Riverine Plains has been managing another GRDC investment looking at the link between cereal stubble, subsurface acidity and crown rot. A Predicta B disease assessment was done on the control, 5 t/ha incorporated by shallow disc and 5 t/ha applied lime with deep incorporation plots from this trial. The control showed a high risk level while the other treatments had a low risk level. Unfortunately, all samples from the control plots were grouped together, so it was unable to be determined if there was a correlation between subsurface acidity and crown rot levels, which may have impacted yield.

In 2022, when the trial site was decimated by slugs and then waterlogging, it was observed that the treatments that received lime with deep incorporation were less impacted by slugs. This was confirmed with NDVI imagery, however no further analysis of slug populations or damage between treatments was completed and this may be a future area for investigation.

ECONOMIC ANALYSIS

An important aspect of any major change in a farming system is determining its economic viability. The application of lime and its incorporation is a major cost for farmers, and the production benefits need to be considered over the longer term, especially when high application rates are being considered.

As part of this investment, we assessed the usability and relevance of some common tools that can calculate the effect of lime on soils, as well as the economic impact of the change. When researching tools it was found that there is currently no suitable tool for assessing lime application rates and incorporation in the Riverine Plains—while a scenario analysis was completed using the Acid Soils SA calculator tools (https://acidsoilssa.com.au/index.php/home/resources/), the pH values were in 0.5 increments, which was too broad to represent the issues being investigated in this trial. We also looked at LimeAssist tool (https://limeassist.sfs.org.au/), however this tool only addressed the cost of incorporation, without considering the long-term effect (benefit) of the incorporation.

Costing assumptions used in the analysis are listed in Table 3 below.

Table 3 Costs used for calculating amelioration options at the Riverine Plains and GRDC Best practice liming trials, Lilliput

	FREQUENCY OF APPLICATION	LIME COST# ($/HA)	SPREADING^ ($/HA)	INCORPORATION* ($/HA)	TOTAL COST ($/HA)
Nil lime, nil incorporation		0	0	0	0
Nil lime, incorporated by shallow discs		0	0		
1.2 t/ha applied lime, incorporated by sowing	3 years	90	24	0	$114
5 t/ha applied lime, with incorporation by sowing	6 years	300	80	0	$380
5 t/ha applied lime, incorporated by shallow discs	6 years	300	80	50	$430
5 t/ha applied lime, with deep incorporation	9 years	300	80	150	$530
8.5 t/ha applied lime, with deep incorporation	9 years	510	136	150	$796

#Based on a lime cost of $60/tonne
^Based on a spreading cost of $16/tonne

In the Riverine Plains, moderate rates of lime are typically applied to a paddock every 3–5 years, with the cost of liming considered over its years of effectiveness. A key message is that liming is an investment and the costs of application incurred in year 1 will increase paddock productivity for many years after. Figure 10 shows the cost of liming for the selected treatments, the potential increase in productivity for canola and wheat, and how long it would take to break even.

While this is a very simplistic approach which doesn't factor in the potential for a cumulative effect that decreases the years to break even, it's clear that the time to break even is accelerated when lime application results in a yield increase. Moreover, this economic analysis does not consider the opportunity cost of not liming, with ever-decreasing crop growth and yield if soil acidity is not ameliorated.

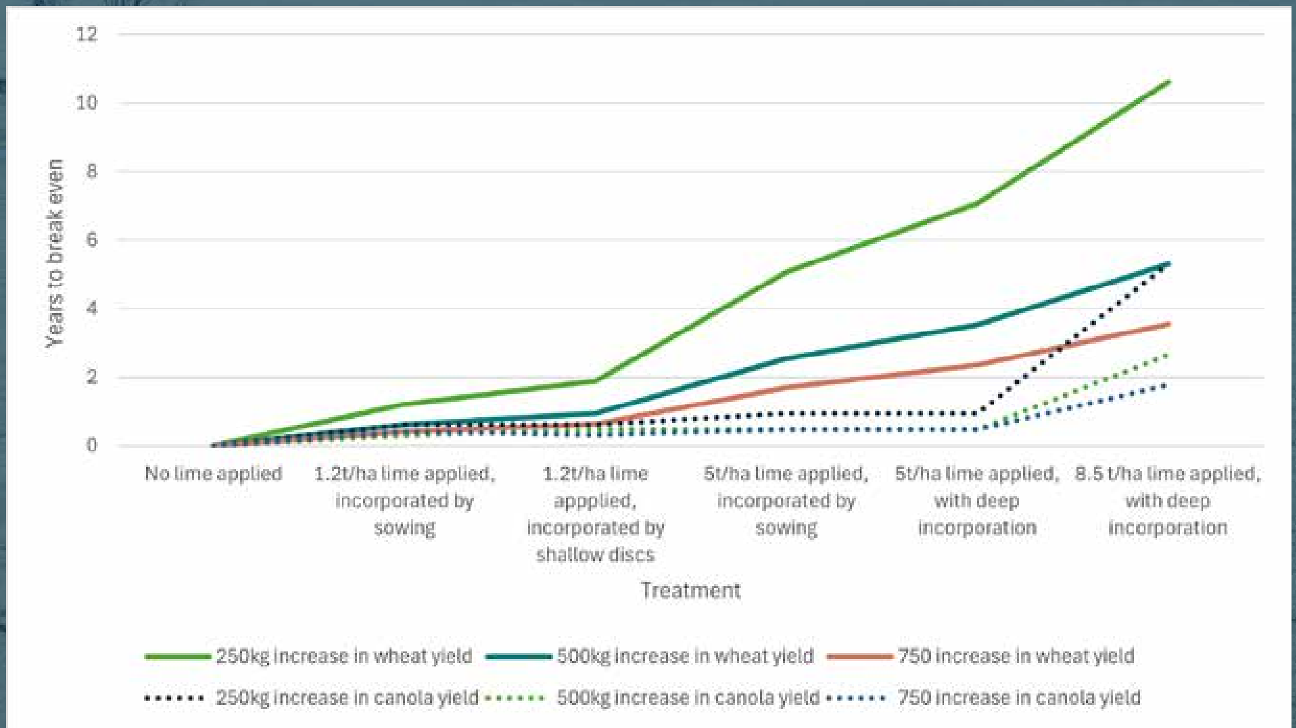

Figure 10 Potential increase in canola and wheat yield and years to break even for selected treatments at the Best practice liming trial, Lilliput

DEMONSTRATION TRIAL

The demonstration trial tested the impact of lime from different lime sources. Treatments included a coarse, soft lime from Mt Gambier, a fine lime from Galong—both applied 3 t/ha and incorporated by sowing—and a nil lime. The demonstration strips were harvested in 2024 only with a plot header, with one strip harvested in each plot (strip length 40 m).

pH results

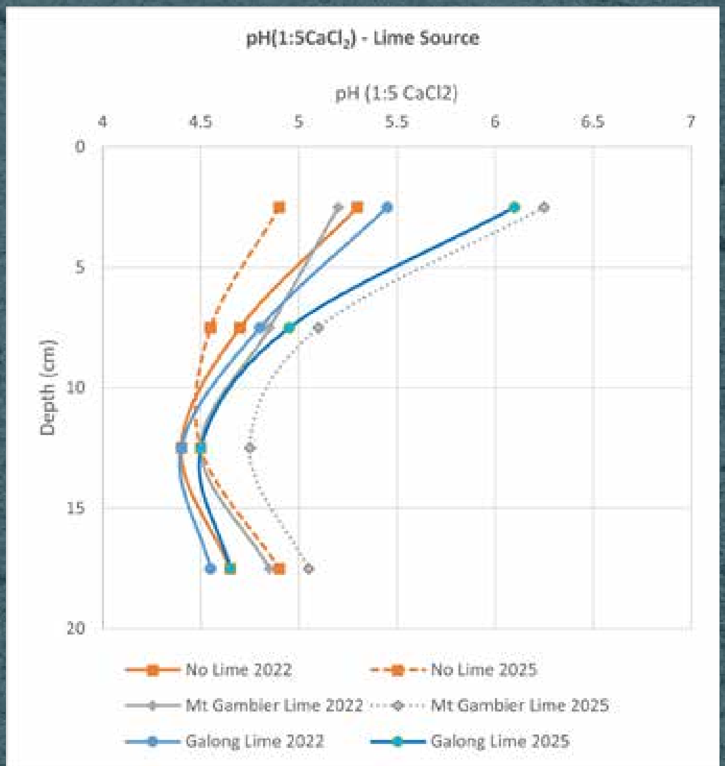

Figure 11 pH results from the lime quality demonstration (unreplicated) trial at Lilliput, sampled prior to application of lime in 2022 and re-tested in 2025

The 2025 pH testing results clearly show an increase in pH (reduction in acidity) at the surface (0–5cm) in treatments where lime was applied in 2022 compared to the nil treatment (Figure 11). A relatively high rate of lime (3 t/ha) was applied in 2022, which explains the sizeable increase in pH seen from 2022 to 2025. However, it is difficult to draw any conclusions as to whether one source of lime is better than the other, given the trial was not replicated.

CONCLUSION

The final soil analysis completed in January 2025 clearly demonstrated that applying lime, followed by incorporation, increased subsurface pH values and reduced aluminium availability in the soil.

While the results show that the correct rate of lime, incorporated to the target depth, ameliorated soil pH in this soil, we are not yet seeing this reflected in yield responses. This is perhaps due to favourable growing conditions in 2023 and 2024 which reduced plant stress, however, in a year with lower rainfall and moisture-limited conditions, a more pronounced yield response would likely have been observed.

Wheat demonstrates relatively high tolerance to acidic soils, while pulses are generally more sensitive. Had a pulse crop been grown at this site, a substantially greater negative impact on yield and plant performance would have been expected. This would also have affected the economic outcomes and extended the time to break even.

During the 2024 growing season and early in 2025, Riverine Plains hosted a number of events where results from the *Best practice liming* trial were discussed with farmers. Follow-up discussions indicated the key messages are being heard, with the top three take-away messages for farmers attending our February 2025 breakfast meetings that:

1. lime needs to be incorporated
2. the application rate of lime needs to meet the target pH, which is 5.8; and
3. soil testing for pH is important, and furthermore, that soil tests should be incremented to identify subsurface acidity

While deep incorporation of lime has shown positive results in this trial, it is important to only incorporate lime to the depth that is suitable for that soil, considering the presence of other soil constraints (for example sodicity, slaking), seedbed preparation, emergence and trafficability. If you can only cultivate to a depth of 10 cm, it's recommended to load up that zone with adequate lime for full amelioration, so that it can move to depth over time.

ACKNOWLEDGEMENTS

This project is an investment by the Grains Research and Development Corporation, delivered through a collaboration between Riverine Plains and AgriSci. We would like to thank the Spence family for hosting the site.

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SOIL WATER STORAGE: INCREASED ACCESS AND TOOLS FOR ASSESSMENT

KEY MESSAGES

- **Soil water content (how much water is in the soil) and matric potential (how tightly water is held by soil) was measured four-hourly at Burramine between March 2023 and December 2024 under summer fallow and summer cover crop treatments, followed by winter crops.**
- **Plant available water capacity (PAWC) in the sub-soil was found to be 30 mm greater under the cover crop treatment than under the control.**
- **Higher PAWC in the cover crop treatment was attributed to a greater number of soil pores at the top of the B horizon. While the cause is unknown, it may be due to more roots at depth and/or greater sub-soil drying over summer, creating cracks.**
- **There was no difference in PAWC between the cover crop and control plots in the topsoil.**
- **While promising, these results are from one trial on one soil and more work is needed to determine the cause and if the effect occurs at other sites and soils.**

BACKGROUND

Duplex soils, with a loam topsoil overlaying a clay sub-soil, are common throughout the eastern Riverine Plains of the Murray Valley. The clay B horizon in these soils has a low bearing capacity when wet, which predisposes the soils to compaction if trafficked and/or cultivated in a wet, plastic condition. Sodicity exacerbates these processes.

The nature of the clays in these soils means that they are not able to "repair" themselves when this occurs, unlike clays that shrink and swell strongly and where a deep drying cycle will restore structure and porosity. While structure and porosity in such non-shrink/swell clays may be re-built by plant roots and microbial activity, it takes time to create macropores and to "glue" soil particles into stable aggregates.

AIM

The aim of this trial was to identify whether summer cover-cropping in the winter-dominant rainfall environment of northern Victoria increased the plant available water capacity (PAWC) in the medium term by improving root-soil interaction and soil structure.

METHOD

SITE AND SOIL

Summer cover cropping treatments were established in January 2020 at a trial site near Burramine, Victoria, as part of the Soil CRC-funded project *Plant-based solutions to improve soil performance through rhizosphere modification.* In 2023, the project *Soil water storage: Increased access and tools for assessment* was established at the site, adding value to the existing research site.

As part of this project, pairs of soil water content and soil water (matric) potential sensors were installed in each of the three replicate plots of two of the existing treatments;

- Control (canola in winter 2023, wheat in winter 2024), and
- Three-species summer cover crop (millet, cowpea, sunflower in summer 2023–2024) plus winter crops as per the control treatment).

Agronomic management of these treatments is described in the article *Investigating summer cover cropping and intercropping to improve soil health (resilience) and productivity on* pages 82 of this publication.

During 2022, poor conditions for establishment and subsequent waterlogging led to failure of the 2022 canola crop. To make the most of residual soil water millet was sown across the whole site early in the summer of 2022–2023. However, neither the millet nor the subsequent summer cover crop established well.

Soil assessment showed the Burramine field site to be a Brown Sodosol with an acidic sub-surface, a strongly compacted sub-surface and sub-soil, and a strongly dispersive sub-soil and topsoil in places (Tables 1 and 2).

Table 1 Soil chemical properties at the Burramine site (mean, n=3)

DEPTH	PH$_{WATER}$	EC$_{1:5}$	ORGANIC CARBON	CEC	ESP	Ca:Mg	P(COLWELL)
(cm)		(dS/m)	(%)	(cmolc/kg)	(%)		(mg/kg)
5-15	5.9	0.04	0.71	6.5	3	2.6	48
25-35	7.5	0.06	0.45	15.6	5	1.1	5
45-55	8.1	0.13	0.39	20.2	7	0.8	6

Table 2 Soil physical properties at the Burramine site (range or mean, n=3, SWC; soil water content)

DEPTH	DISPERSION @10MIN	COARSE SAND	FINE SAND	SILT	CLAY	AIR-DRY SWC	BULK DENSITY	SATURATED SWC*	FIELD CAPACITY SWC*
(cm)	-	(%)	(%)	(%)	(%)	(% v/v)	(g/cm3)	(% v/v)	(% v/v)
5-15	none-moderate	4	44	26	31	1.7	1.56 (n=48)	41	36
25-35	slight-strong	2	27	18	56	3.9	1.63 (n=35)	38	33
45-55	slight-strong	1	19	17	66	4.9	1.69 (n=4)	36	31

*Derived from bulk density, particle density of 2.65 g/cm^3 and assumed air-filled porosities of 0% (saturated) and 5% (field capacity)

SOIL WATER MEASUREMENTS

Soil water content and matric potential sensors were installed in pairs at multiple depths throughout the soil profile in each replicate plot of the control and cover crop treatments. Soil water content was measured using Wet150® (Delta T, UK) sensors in the topsoil and EnviroPro® (Entelechy, Australia) sensors in the sub-soil. Watermark® (Irrometer, California) sensors were used to measure matric potential (how tightly water is held by soil). Measurements were logged every four hours. Water content sensors were calibrated using soil samples obtained across a range of depths and moisture contents and measured gravimetrically.

Plant available water capacity (PAWC) was estimated from the difference between the upper and lower limits of plant available water obtained using both laboratory and field methods. In the first field method, profile water content (PWC) was estimated from the sum of the calibrated water content sensor readings at a site. PAWC was then determined from the difference between the PWC measured 24–48 hours after the wettest observed conditions (drained upper limit, DUL, on 26 August in 2023) and the driest observed conditions (crop lower limit, CLL) under the wheat (2023) and canola (2024). Dry conditions in 2024 meant the soil profile was not filled and DUL was not observed that year.

In the second field method, and the two lab methods, PAWC was estimated from the difference in soil water contents at matric potentials representing field capacity (-10 kPa) and permanent wilting point (-1500 kPa). These soil water contents were estimated from soil water retention curves fitted using a Fredlund-Xing model to paired soil water content and matric potential measurements obtained under drying conditions from:

1. paired sensor readings in control and cover crop plots - second field method
2. soil core samples from control plots using Hyprop (Meter Group, USA) and Filter paper lab methods

RESULTS & DISCUSSION

YIELDS

Above average wheat yields in both treatments in 2023 reflected good starting moisture and above average in-crop rainfall (413 mm April–November) (Figure 1, Table 3). Above-ground biomass in the cover crop treatment in 2023–2024 represented about 25 percent of the cumulative summer cover crop biomass grown since 2020, highlighting the need for timely and sufficient summer rainfall for achieving summer cover crop growth. Canola yields in 2024 were around average, reflecting below average rain over summer through to September, but with sufficient late rain to finish the crop.

In 2023, wheat yield was greater in the cover crop treatment (6.1 t/ha) than in the control (5.6 t/ha), while in 2024, the canola yield was lower in the cover crop treatment (1.8 t/ha) than in the control (1.9 t/ha) (Table 3), though these differences were not significant. Based on a simple water balance that assumed no runoff or deep drainage, water use by the wheat in the cover crop treatment was 30 mm higher than in the control in 2023, whilst water use by the canola in the cover crop treatment was 23 mm lower than in the control in 2024. Assuming 20 kg wheat grain per ha per mm and 12.5 kg canola grain per ha per mm, these observed water use differences correspond to yield differences of 0.6 t/ha in wheat and -0.3 t/ha in canola — this is close to the yield difference observed for the wheat in 2023, but not for the canola in 2024.

Canola yields from the cover crop and the control treatments in 2024 were similar, despite the cover crop treatment starting with a 30 mm drier profile at sowing (Figure 2) and using 23 mm less water over the season. The lack of yield difference is attributed to the indeterminate nature of canola and its ability to compensate for early drought stress if rain occurs after the start of flowering, as well as deeper extraction of water in the cover crop treatment.

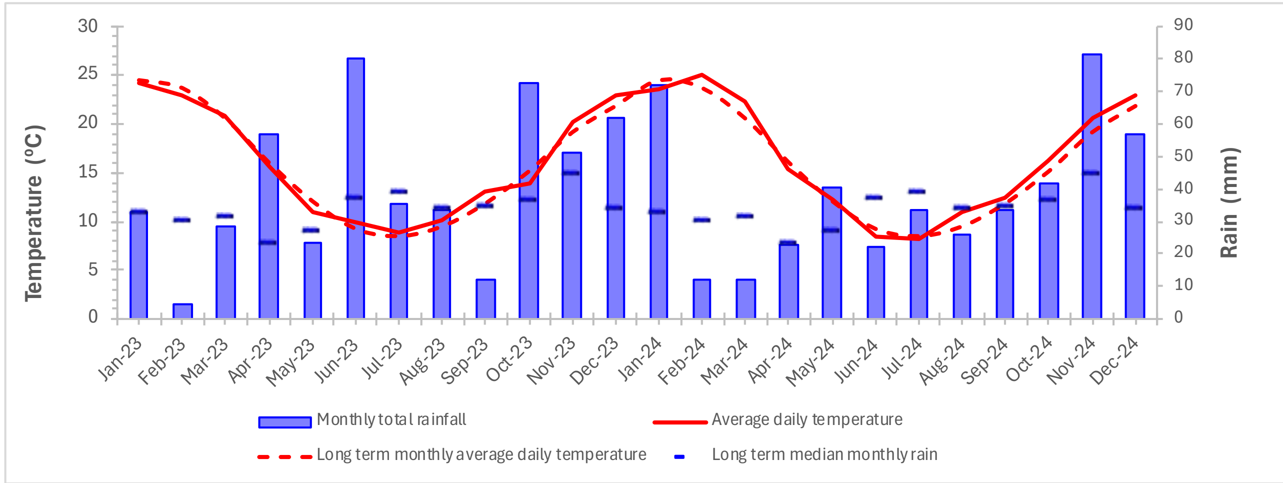

Figure 1 Monthly total rainfall (mm) and daily average temperature (°C) at the Burramine site 2023–2024

Table 3 Treatment mean yield and biomass. Means in rows followed by the same letter are not significantly different (P<0.05, n=3).

	CONTROL			COVER CROP		
Year & season	**Crop**	**Biomass (t/ha)**	**Yield (t/ha)**	**Crop**	**Biomass (t/ha)**	**Yield (t/ha)**
2022–23 summer	Fallow	-	-	Millet, cowpea, sunflower	0	-
2023 winter	Wheat	14.0	5.6 a	Wheat	14.0	6.1 a
2023–24 summer	Fallow	-	-	Millet, cowpea, sunflower	1.2	-
2024 winter	Canola	7.6	1.9 a	Canola	6.2	1.8 a
2020–24 cumulative biomass (winter & summer)		38.6 (38.6 & 0)			39.7 (35.2 & 4.5)	

Note: statistical analysis was done using a pairwise comparison in 2024 and ANOVA amongst all site treatments in 2023, with data sourced from the *Building soil resilience and carbon through plant diversity* Soil CRC project.

PLANT AVAILABLE WATER

There was no difference in the PAWC of the topsoil (0–25 cm) between the control and the cover crop treatment. However, in the sub-soil (25–85 cm) PAWC was larger in the cover crop treatment than in the control by about 30 mm (Table 4). The soil water retention curves for the topsoil and sub-soil (Figure 3) suggest different soil pore volumes in the sub-soil of the control and cover crop plots caused the difference in sub-soil PAWC.

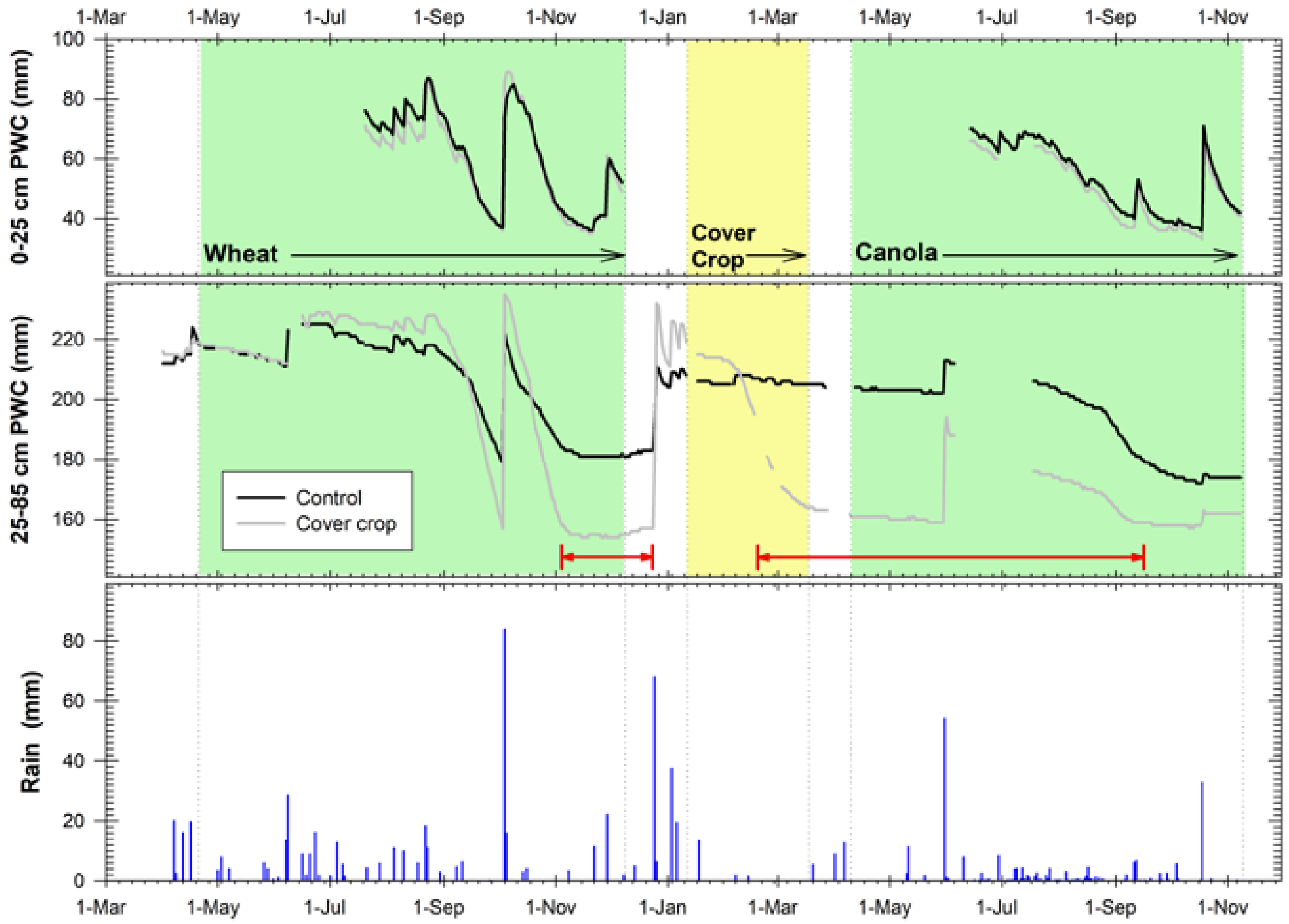

Figure 2 Mean profile water content (PWC) of the topsoil (0-25 cm) and sub-soil (25-85 cm) in the control and cover crop treatments at Burramine 2023–2024, compared with daily rainfall at the site. The horizontal red arrows indicate periods when the PWC of the sub-soil under the control and cover crop treatments were significantly different (P<0.05).

Table 4 Plant available water capacity (PAWC, mm) estimated using a range of methods. DUL; drained upper limit, CLL; crop lower limit.

PAWC METHOD		LABORATORY		FIELD	
		Hyprop	Filter paper	Paired sensors	Soil water sensors
Soil depth (cm)	Treatment	Difference between SWC at -10 kPa & -1500 kPa (mm)			DUL – CLL (mm)
0-25	Control	46	38	42	47
	Cover crop	--	--	41	48
25-85	Control	39	67	67	43
	Cover crop	--	--	**104**	**73**
0-85	Control	85	105	109	90
	Cover crop	--	--	145	121

This difference in PAWC is explained by an examination of the soil water retention curves from the sub-soil of the two treatments. The soil water retention curve describes the relationship between how much water is in a soil (soil water content) and how tightly that water is held by that soil (soil matric potential) (Figure 3). In wet soil, water is available to plants in large pores, so it does not take much energy for the plant to "suck" water into roots. As soil dries, water is only available to plants in progressively smaller pores which hold it at greater negative matric potentials (= suction), and it takes more energy to extract it. Soils with different texture and structure have different quantities of large, medium and small soil pores, and therefore differently shaped soil water retention curves and different plant water availability.

There was no difference between treatments in the water retention curves for the topsoil (Figure 3-left), indicating that the distribution of pores in the topsoil of the control and cover crop treatments were the same and unaffected by the treatment. However, the sub-soil of the cover crop treatment had a higher water content at saturation (matric potential < 4 kPa; Figure 3-right) indicating a greater volume of macropores (pores >75 µm diameter) or cracks. The sub-soil of the cover crop treatment also had a lower water content at the dry end of the curve (matric potentials >80 kPa, Figure 3-right), indicating more micropores of less than about 4 µm diameter. The greater difference between wet and dry soil in the cover crop treatment indicates a larger volume of pores in the suction range that was available to plants and thus greater plant available water capacity. These differences might have been caused by greater soil micro-cracking during summer and/or more root biomass under the cover crop treatment.

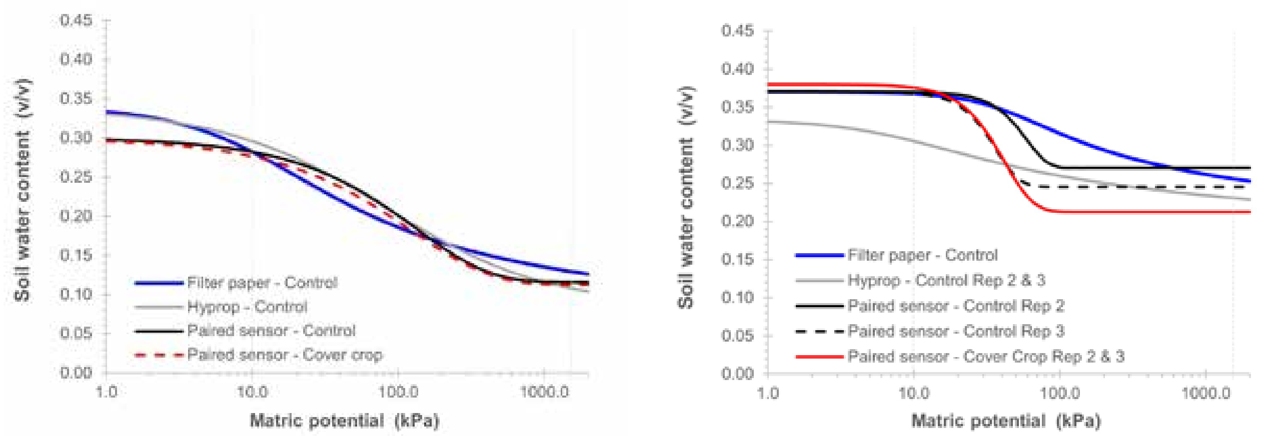

Figure 3 Soil water retention curves for the topsoil (10 cm depth, left) and sub-soil (30 cm depth, right) at Burramine developed using two lab-based methods (Filter paper and Hyprop) and one field method (paired sensor). Unless stated in the legend, curves are the mean of three replicates.

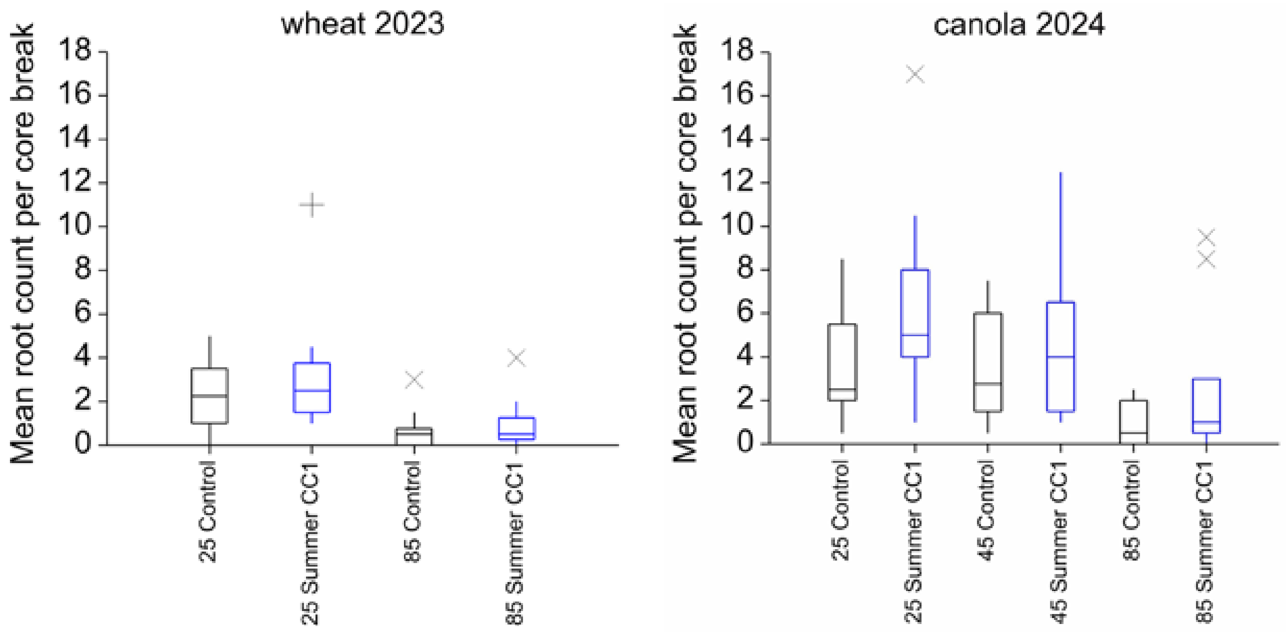

Figure 4 Mean number of roots observed across both faces of soil cores broken at 25, 45 or 85 cm depth at the milk development stage of the wheat crop (24 October 2023, n=12 cores per treatment and depth) and the end of canola flowering (25 September 2024, n=18 cores per treatment and depth) in the control and cover crop (Summer CC1) treatments. The middle line of each box represents the median.

ROOT GROWTH

The water content sensor readings indicated the maximum rooting depth was around 75 cm for both crops and treatments, though root observations at flowering in 2023 and 2024 showed some roots at 85 cm depth. These observations clearly showed that under the wheat in 2023 and the canola in 2024, roots were present in every sample at 85 cm in the cover crop treatment but not in the control (Figure 4). This supports the observation of greater water extraction from deeper soil by the wheat and canola in the cover crop treatment.

CONCLUSION

We don't know what created the changes to the subsoil in the summer cover crop treatment plots that allowed the winter crops to extract more soil water than the winter crops growing in the control plots. However, we think there are two likely possibilities:

1. greater drying over summer in the sub-soil of the cover crop plots, allowing the heavy clay sub-soil to crack and create zones of weakness for the following winter crop to exploit;
2. and/or extra root biomass input by the summer cover-crop treatment to the sub-soil, creating soil structures and macropores that allow for deeper root growth and water extraction by subsequent winter crops.

There also appears to be greater water entry to depth in the cover crop treatment.

Over the long-term, the combined effect of these changes in the summer cover crop treatment should be a decrease in waterlogging and run-off which should also lead to an increase in average yields through greater crop water availability.

Canopy management will be critical for achieving any benefit, as any advantage from good soil water availability early in the season will be lost if large canopies are allowed to develop and use all the water prior to grain filling. Row spacing and seeding rates need to be matched to expected "target" yields, with sufficient pre-plant fertiliser to establish the crop and then later application(s) matched to in-crop rainfall.

Results from one trial on one soil do not justify wide adoption of summer cover cropping as a technique for increasing PAWC on constrained soils. Validation is needed on a wide range of soils, with further investigation to determine how the observed effect on sub-soils is generated, as well as an examination of crop sequencing effects.

However, conservation agriculture principles (minimum tillage, stubble retention, controlled traffic and avoiding bare fallows) are proven to increase PAWC and should be adopted where practicable. An example of how adoption of these principles can improve productivity and farm profitability on similar soils in the southern Riverina to this study can be found at www.researchgate.net/publication/371701131_DPI_Primefact_-_CaseStudy_-_Sustainable_cropping_systems

ACKNOWLEDGEMENTS

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The project team thanks farmer collaborator, Nathan Lawless, for providing property access to run the field trial and host field days, and for sharing knowledge of past practices and rainfall records. Thanks to the team from Soil CRC-funded projects *Plant-based solutions to improve soil performance (2019–2022)* and *Building soil resilience and carbon through plant diversity (2023–2026)*, led by Prof. Terry Rose (Southern Cross University) for sharing data, resources and knowledge of biomass, yield and gravimetric soil water data measurements.

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INVESTIGATING SUMMER COVER CROPPING AND INTERCROPPING TO IMPROVE SOIL HEALTH, PRODUCTIVITY

KEY MESSAGES

- **Temporary intercropping, (when two crops are sown in the same paddock at the same time, before one is terminated) and synchronous intercropping (when two crops are sown and harvested at the same time) are promising methods for building diversity in cropping systems, especially where traditional cropping practices such as tillage or monocultures have led to a decline in soil fertility and soil carbon.**
- **Variable summer rainfall at the Burramine trial site highlighted the difficulty in establishing summer cover crops, with overall biomass production highly dependent on follow-up rainfall.**
- **Summer cover cropping was associated with an emerging trend for declined water availability at the time of winter crop sowing, as well as yield penalties.**
- **Temporary intercropping with vetch did not reduce the yield of wheat sown at the same time in this trial.**
- **While temporary intercropping showed a small additional biomass gain, there has been little-to-no impact on soil health or carbon to date.**
- **Future work needs to quantify the variability of biomass and yield production in these systems and relate this to soil nutrient and carbon cycling (resilience).**

BACKGROUND

Ensuring long-term soil sustainability is a major challenge for Australia's cropping systems.

Increasing plant diversity in the temperate cropping systems of the Northern Hemisphere, through intercropping (growing two or more crops at the same time, also known as companion cropping) and summer cover cropping, has been shown to build soil carbon and fertility with minimal impacts on yields. However, the water and climate dynamics of these Northern Hemisphere systems are fundamentally different to the hot, dry summers and winter-dominant rainfall that drives traditional cropping systems in southern Australia.

In the Riverine Plains region, cereal–canola or cereal–canola–legume rotations are typical, however farmers are looking to increase the level of diversity of their systems, to build soil resilience in the face of an increasingly variable climate.

This project was established to assess the suitability and impact of summer cover crops, temporary intercrops and synchronous intercrops for the Riverine Plains region.

SUMMER COVER CROPS

Summer cover crops are intended to replace either the whole, or part of, the traditional summer fallow. Summer cover crops may offer benefits of soil protection from erosion, as well as increased plant inputs to the soil. Having living roots in the ground, as opposed to just stubble, is seen as a key reason why summer cover crops may result in improved soil health and carbon. On the other hand, water used over the fallow and subsequent mineral nitrogen tie-up may result in a yield penalty for the winter crop sown after the summer cover crop.

INTERCROPPING (COMPANION CROPPING)

Intercropping, also known as companion cropping, is when two or more crops are grown at the same time. These can be planted and harvested at the same time (synchronous intercropping/companion cropping) or one crop can be terminated to reduce resource competition (temporary intercropping/companion cropping). Plant interactions in these systems can lead to overyielding, which is when there is a higher biomass or yield in the intercrop compared to respective monocultures, while planting cash crops alongside legumes can add nitrogen to the system. These benefits may then translate to improved soil health and increased carbon.

AIMS

Using a replicated field trial, this project aims to assess the scope for diverse cropping systems to build soil fertility and carbon, thereby building more resilient cropping systems.

Specifically, the project aims to:

1. Understand yield impacts (penalties or overyielding) of implementing summer cover crops, temporary intercropping and synchronous intercropping.
2. Identify the impacts of diverse cropping systems on soil health and soil carbon.

METHOD

A long-term trial site was established by Riverine Plains at Burramine in north east Victoria to monitor the effects of increasing plant diversity over the medium term (4–7 years). This site has been looking at the effects of summer cover crops and winter intercrops on yield and soil health.

TRIAL LAYOUT AND TREATMENTS

The site was originally established in 2019 as part of the Soil CRC project *Increasing plant species diversity in cropping systems*, with treatments focusing on locally grown summer cover crops, with additional species incorporated to ensure a mix of root mass and legumes.

The treatments were refined over time, and by 2023, the trial featured seven treatments, including a control, three species cover crop, nine species cover crop, temporary intercropping treatments (wheat and vetch), as well as a maximum diversity treatment with both summer cover cropping and winter intercrops (Table 1). Synchronous intercropping with canola paired with field and faba bean was then assessed in 2024. Treatments were replicated three times in plots measuring 8m (4 x 2) x 18 m^2. The summer cover crop and temporary intercrops are being repeated in 2025.

The summer cover crop treatments in this trial were sown when there was enough rainfall to germinate the crop; this was highly dependent on summer storms to provide enough moisture, as well as follow-up rainfall for biomass production. Summer cover crops were terminated after 8-12 weeks of growth using 570 g/L glyphosate at a rate of 2 L/ha in preparation for the winter crop. Winter crops were sown in autumn, according to the rotation specified in Table 1.

2023

In 2023, limited sowing opportunities and poor follow-up rainfall meant the summer cover crops failed to establish after being sown on 2 February.

In the winter crop phase, Illabo wheat was sown at a standard rate of 70kg/ha in all treatments, including the intercrop, while the vetch intercrop was sown at a rate of 40 kg/ha. All winter plots received 80 kg/ha MAP at sowing, with in-crop urea applied at 100-110 kg/ha.

Vetch in the temporary intercrop treatments was terminated with 700 g/L 2, 4-D at 1.5 L/ha on 26 July 2023.

Soil water and mineral nitrogen were assessed prior to winter crop sowing, at vetch termination and again at anthesis using 90 cm soil cores. Cores were sectioned into 10 cm increments and then aggregated into 0–10, 10–30, 30–60 and 60–90 cm depths for analysis, with mineral nitrogen results still pending. Soil health samples were also collected at each stage to 10 cm depth using a push corer and dried at 40°C, with the measurements summarised in Table 2. Wheat and vetch biomass were also sampled at vetch termination.

ANOVA analysis was used to determine statistical significance, using a 0.05 significance level.

Final yield was determined from header yields, and grain protein content was determined by a laboratory nitrogen and protein analyser.

2024

In 2024, summer cover crop treatments were sown on 11 January 2024 before being terminated on March 18.

For the 2024 winter crop rotation, canola (cv Hyola Blazer TT) was sown at a standard rate of 3 kg/ha on 10 April, 2024, while intercropped field peas (cv Morgan) and faba beans (cv Bendoc) were sown with an inoculant at 100 kg/ha and 150 kg/ha respectively. Fertiliser application rates were the same as for the 2023 trial.

Biomass was sampled just prior to termination.

Winter crop treatments were harvested using a plot harvester at crop physiological maturity.

Soil water and nitrogen measurements were repeated for the synchronous intercrop treatments, however, deep coring did not occur at anthesis for soil water and mineral nitrogen due to the high levels of biomass present.

Table 1 Treatments in the Burramine *Building soil resilience and carbon through plant diversity* trial, 2023 – 2024

TREATMENT	SUMMER CROP (2023-2024)	WINTER CROP ROTATION		
		2023	2024	2025
Control	Fallow	Wheat	Canola	Wheat
Three species summer cover crop	Sunflower, millet, cowpea	Wheat	Canola	Wheat
Nine species summer cover crop	Sunflower, safflower, sorghum, millet, cowpea, buckwheat, radish, turnip, sunnhemp	Wheat	Canola	Wheat
Temporary intercrop	Fallow	Wheat & vetch	Canola	Wheat & vetch
Peaola (synchronous intercrop)	Fallow	Wheat	Canola & field pea	Wheat
Beanola (synchronous intercrop)	Fallow	Wheat	Canola & faba bean	Wheat
Maximum diversity	Sunflower, safflower, sorghum, millet, cowpea, buckwheat, radish, turnip, sunnhemp	Wheat & vetch	Canola & field pea	Wheat & vetch

Note: the maximum diversity treatment is a combination of summer cover crop, temporary intercrop and synchronous intercrop treatments

Table 2 Soil health measurements used in the Burramine *Building soil resilience and carbon through plant diversity* trial

MEASUREMENT (UNITS)	DESCRIPTION
***Soil carbon (%)**	Soil carbon (soil organic carbon) is the concentration of carbon in the soil and is an indicator of ecosystem productivity. Higher carbon indicates the potential for more in-crop biomass production and higher soil microbial biomass.
***Soil nitrogen (%)**	A basic indicator of nitrogen available in the system as it does not differentiate between organic (in soil organic matter) and inorganic (ammonium, nitrate) nitrogen. Carbon to nitrogen ratios can be a useful soil health indicator.
Carbon: nitrogen ratio	Calculated as soil carbon divided by soil nitrogen. Soil organic matter formation occurs within an ideal carbon: nitrogen range of 10-20 and maintaining this range may help prevent degradation of soil organic matter through nitrogen tie-up.
Permanganate oxidisable carbon (mg carbon / (i.e. mg carbon/g soil) g soil)	Abbreviated as POXC. It is seen as a measure of organic matter that is labile (its form changes readily in soil) or is recently derived from plant material and is therefore a potential early indicator for soil carbon building.

*Determined via LECO laboratory analysis

RESULTS & DISCUSSION

2023

SUMMER COVER CROP BIOMASS PRODUCTION

In 2023, limited sowing opportunities and follow up rainfall meant the summer cover crops failed to establish, highlighting the difficulty of growing rain-fed summer crops in a winter-dominant rainfall environment.

TEMPORARY INTERCROP BIOMASS PRODUCTION

The wheat and temporary intercrop vetch were planted on 19 April 2023 into good soil moisture. At vetch termination on 26 July 2023, there was an average 3.05 t/ha wheat biomass in the control treatment (Table 3). This was significantly higher ($p < 0.05$) than the average wheat biomass measured in the temporary intercrop (1.44 t/ha) and maximum diversity treatments (2.70 t/ha). Vetch biomass averaged 1.09 and 1.24 t/ha in the temporary intercrop and maximum diversity treatments respectively. Wheat seeding rates in the intercrop treatment were the same as the control (70 kg/ha), with the lower wheat biomass in the intercrop likely reflective of the increased competition for resources by the vetch. By anthesis, there were then no significant differences between treatments in biomass, with values ranging from 3.7–4.0 t/ha.

YIELD

In 2023, the control produced an average wheat yield of 5.6 t/ha while the three species summer cover crop, nine species cover crop, temporary intercrop and maximum diversity treatments had average wheat yields of 6.1, 5.7, 5.9 and 6.0 t/ha respectively, with these differences not significant ($p > 0.05$). Grain protein content was between 10 and 11 percent for all treatments (not presented).

Table 3 Winter crop biomass and yield, 2023 at the *Building soil resilience and carbon through plant diversity* project trials at Burramine

TREATMENT	SUMMER CROP BIOMASS^	WHEAT BIOMASS (T DM/HA)	VETCH BIOMASS (T DM/HA)	AVE BIOMASS (T DM/HA)	WHEAT GRAIN YIELD (T/HA)
Sample date		Vetch termination, 26 July		Anthesis, 23 October	Harvest, 11 November
Control	Fallow	3.0	-	3.7	5.6
Three species summer cover crop	Nil	-	-	4.0	6.1
Nine species summer cover crop	Nil	-	-	3.8	5.7
Temporary intercrop	Fallow	1.4	1.0	3.7	5.9
Maximum diversity	Nil	2.7	1.2	3.8	6.0

^Summer cover crop growth was poor, and biomass was not measured

2024

SUMMER COVER CROP BIOMASS PRODUCTION AND WATER USE

In 2024, summer cover crops sown in mid-January established well and showed good early vigour, helped by summer storms, before conditions turned dry in February and March, reducing biomass production. Summer crop treatments were terminated in mid-March, after approximately eight weeks growth, to allow preparation for the 2024 winter crop season.

In 2024, the three species cover crop produced an average of 1.43 t/ha biomass, while the nine species summer cover crop produced an average of 1.29 t/ha biomass and the summer cover crop in the maximum diversity treatment produced an average of 1.28 t/ha biomass (Table 4). There was no statistically significant difference between treatments and biomass production was below the 2 t/ha recommended to prevent erosion.

Across the three replicates there was an average of 206 mm of soil water stored in the control prior to sowing of the 2024 winter crop. The results showed an average of 194 mm in the three species cover crop mix, 188 mm in the nine species cover crop mix and 174 mm in the maximum diversity treatment (Table 3). All summer crop treatments had significantly lower soil stored water than the control ($p < 0.05$), but there was no significant difference in stored water between the individual cover crop treatments. This shows how summer cover cropping can deplete soil moisture reserves ahead of the winter crop when rainfall isn't sufficient to refill the profile.

Table 4 Summer cover crop biomass, stored soil water prior to sowing the winter crop, winter crop biomass and yield, at the *Building soil resilience and carbon through plant diversity* trial at Burramine, 2024

TREATMENT	SUMMER BIOMASS AT TERMINATION (T DM/HA)	STORED MOISTURE 0-90CM (MM)	FLOWERING CANOLA BIOMASS (T DM/HA)	LEGUME BIOMASS (T DM/HA)	GRAIN YIELD (T/HA)
Control	Fallow	206	4.0	-	Canola: 1.9
Three species summer cover crop	1.4	194	3.6	-	Canola: 1.8
Nine species summer cover crop	1.3	188	3.4	-	Canola: 1.5
Temporary intercrop	Fallow	-	4.7	-	Canola: 1.9
Peaola* (synchronous intercrop)	Fallow	-	2.6	1.2	Canola: 1.8 Field pea: 0.6
Field pea	Fallow	-	-	1.6	Field Pea: 1.0
Beanola# (synchronous intercrop)	Fallow	-	2.6	2.0	Canola: 2.2 Faba bean: 1.3
Faba bean	Fallow	-	-	4.3	Faba bean: 2.5
Maximum diversity	1.3	174	2.5	1.1	Canola: 1.7 Field pea: 0.64

SYNCHRONOUS INTERCROP BIOMASS PRODUCTION

Average canola flowering biomass in the control treatment was 4 t/ha (Table 4). There were no significant differences in canola biomass between the canola-field pea, canola-faba bean and maximum diversity treatments with flowering biomass ranging from 2.5-2.6 t/ha.

Field pea flowering biomass in their monoculture was 1.6 t/ha, while average treatment field pea biomass was 2.25 t/ha in the canola-field pea treatment and 1.12 t/ha in the maximum diversity treatment ($p > 0.05$ between intercrop treatments).

When biomass (or yield) for a synchronous intercrop species is more than 50 percent of its monoculture counterpart, the system is overyielding. For 2024, the canola-faba bean system outperformed the monocultures.

YIELD

Average canola yield for the control in 2024 was 1.91 t/ha; this was not significantly different to the three species summer cover crop treatment (1.78 t/ha) and nine species summer cover crop treatment (1.45 t/ha). While the pairwise comparisons in this year are not able to be separated statistically, they do represent an emerging trend of suppressed yield due to cover crop growth when data is analysed across this trial and a paired trial with Central West Farming Systems (data not yet published). The synchronous intercrop yields were similar to the monoculture yields, indicating overyielding (Table 4).

SOIL HEALTH AND SOIL CARBON

Soil health measures related to carbon cycling have not shown any significant treatment differences since 2019. Mean soil carbon levels have varied between 1.1–1.5 percent over the duration of the trial, which is fairly typical of cropping soils in the region, with soil nitrogen ranging between 0.1 and 0.15 percent. At anthesis in 2023, there were no treatment effects on soil carbon, soil nitrogen, carbon to nitrogen ratio and permanganate oxidisable carbon (Figure 1). Results for flowering-maturity in the 2024 canola-intercrop season are pending analysis.

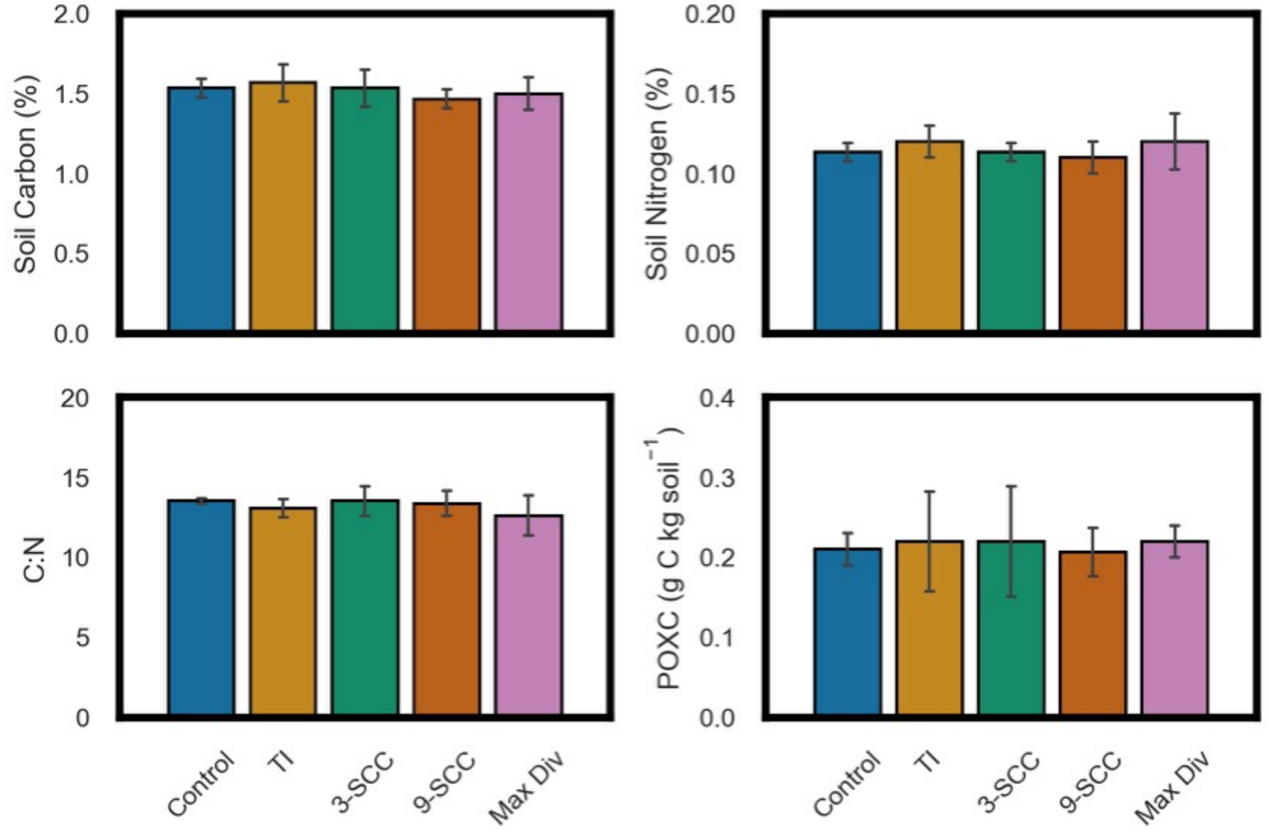


Figure 1 Soil carbon, soil nitrogen, carbon to nitrogen ratio (C:N) and permanganate oxidisable carbon for the control, temporary intercrop (TI), three species summer cover crop (3-SCC), nine species cover crop (9-SCC) and maximum diversity (Max Div) treatments at anthesis in 2023

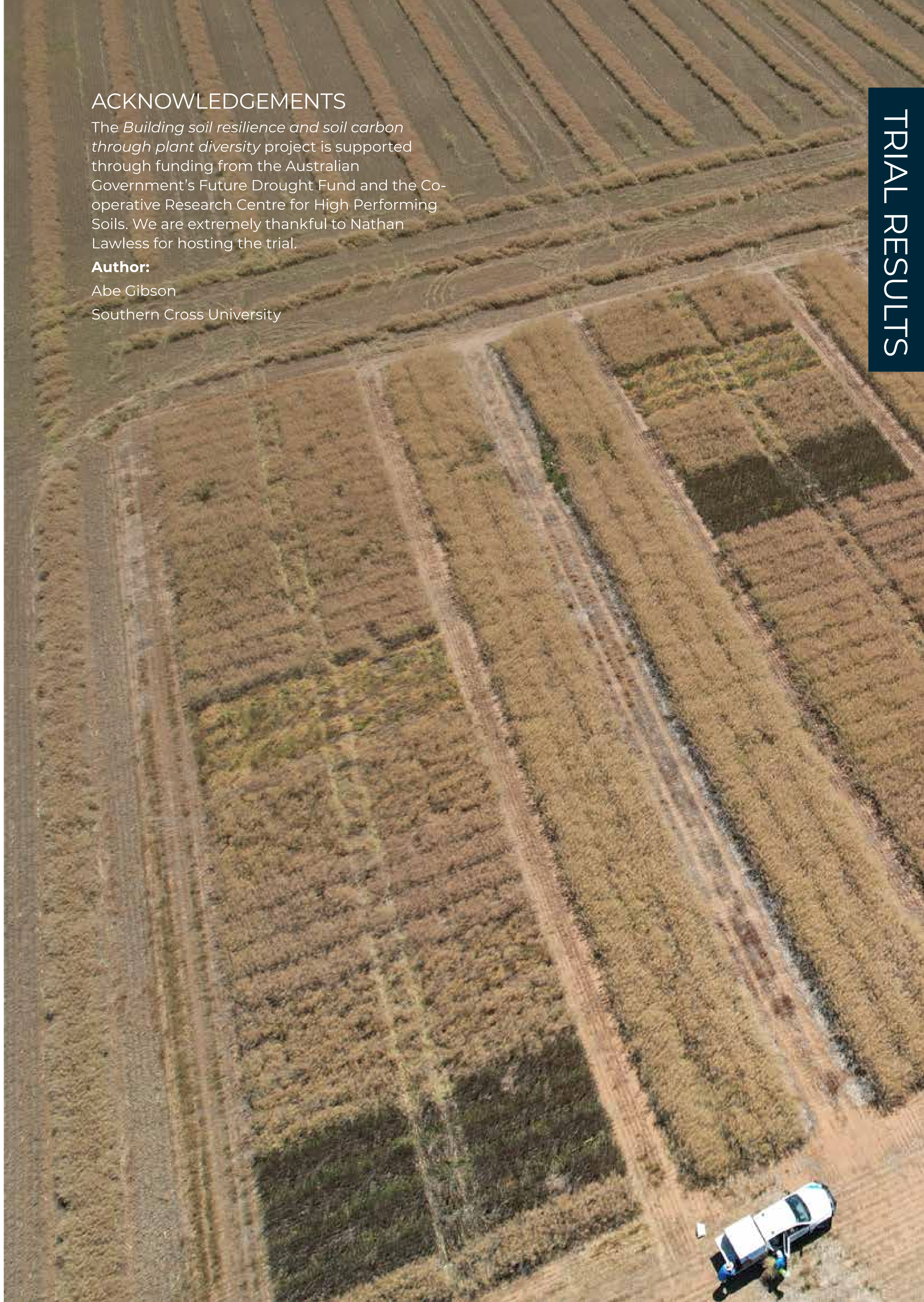
An increase in saturated hydraulic conductivity—the rate that water moves through the soil pore system when saturated—was observed in the summer cover crop treatments following a large biomass cover crop in 2021. We believe this may be due to improved soil aggregation—soil particles joining together and creating pore space for water and air to move through—due to the root growth and their exudates. This result is still to be revisited to determine the drivers of this change and if this effect has persisted.

OBSERVATIONS

Improving soil health and carbon requires a sustained increase in plant biomass production over multiple seasons. Establishing summer cover crops is difficult given the extreme water limitation over this period and so their impact on soil health has been limited in this trial. When they are established, there is an emerging trend for declined water availability at sowing and yield penalties. This is consistent with previous work looking at the importance of summer fallow rainfall and water and nitrogen use of summer weeds. Further, in this and similar trials conducted in other regions, summer cover biomass has often been less than the 2 t/ha recommended to protect the soil from erosion. In wet summers, biomass production above 3 t/ha can occur with some improvement in infiltration rates observed after this cover crop year. Therefore, while summer cover cropping is emerging as an opportunistic practice, farmers require further data to make informed decisions about the likelihood of success each season.

Temporary intercropping has not been shown to reduce yield of the main winter crop in this trial, supporting results from other studies. While temporary intercropping showed a small additional biomass gain in this trial, this has not impacted soil health or carbon. However, synchronous intercrops could have a role to play in building soil health by promoting more biomass production per unit of land area, while also providing plant-to-soil input diversity.

Due to the availability of moisture in the growing system, summer cropping and intercropping may be easier options to target for generating positive outcomes from plant diversity in Australian cropping systems, however ongoing work is required to optimise these systems for our conditions.



ACKNOWLEDGEMENTS

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COMPARING NITROGEN RETURNS FROM DIFFERENT LEGUME ROTATIONS FOR A MAIZE CROP AT HOWLONG

Results from the Riverine Plains and GRDC Irrigation Discussion Group maize focus paddock

KEY MESSAGES

- **A demonstration trial at Howlong highlighted how poultry manure applied at 6t/ha, a high-density legume mix brown manure and adzuki bean rotation can provide significant amounts of nitrogen to the following maize crop (105 kg N/ha, 130 kg N/ha and 169 kg N/ha respectively).**
- **In contrast to other rotations, a high-density legume mix made into silage significantly reduced the amount of nitrogen available to the following maize crop (54 kg N/ha) due to removal (offtake) of nitrogen in the silage.**
- **Brown manuring a high-density legume mix was significantly less profitable than harvesting high density legume as silage, even when the additional nitrogen fixed by the brown manure over a six-month period was taken into account.**
- **A nitrogen budget is useful for determining how much nitrogen to apply — for a 20 t/ha maize crop, the total nitrogen requirement is 512 kg N/ha. A deep soil nitrogen test taken after a legume crop allows farmers to more accurately calculate the requirements for the following maize crop.**
- **Poultry manure can also be a source of nitrogen and other nutrients including potassium, sulfur and phosphorus for irrigated crops, but these won't all be available in the year of application.**

BACKGROUND

Nitrogen input costs are a significant expense for farmers, especially when growing high-yielding irrigated crops such as maize, which have a large overall nitrogen requirement. For example, a 20 t/ha maize requires 512 kg N/ha, with about half the nitrogen requirement removed with the grain and the other half remaining in the crop residue.

Previous work by Riverine Plains through the Grains Research and Development Corporation's (GRDC) Irrigated Discussion Group project investment, identified that local farmers are interested in alternatives to synthetic nitrogen inputs for high yielding irrigated crops, including nitrogen from sources such as legumes and animal manures. While some local irrigated farmers currently make use of animal manures for crop nutrition, legume crops are not commonly used, mainly because of their yield instability under irrigation. Animal manures are commonly used overseas as a source of nutrition for grain crops and the idea to trial poultry manure on crops originated with an overseas study tour to America, organised by AgNVet.

This trial concept arose from previous nitrogen discussions that took place within the Riverine Plains and GRDC Irrigation Discussion Group meetings.

AIM

This demonstration trial aimed to quantify the nitrogen supplied by legumes, including a high-density legume mix brown manure crop, high-density legume mix silage and an adzuki bean fallow for the following maize crop.

DEMONSTRATION DETAILS

Location	**Howlong**
Crop type	**Maize**
Irrigation system	**Overhead spray (pivot) irrigation**

METHOD

Two case study paddocks at Howlong were selected to compare the amount of nitrogen supplied by different legume crops.

One paddock was sown to adzuki beans in the summer of 2022–2023 before being sown to Pioneer P1837, a hybrid maize for feed grain or silage, on 1 November 2023.

The other paddock was sown to a high-density legume mix of 40 kg/ha of Volga vetch, 7.5 kg/ha of Persian clover and 7.5 kg/ha of Tetila Rye on 27 April 2023. An inoculant was applied, along with MAP at a rate of 50 kg/ha. The high-density legume mix paddock was then split into two, with one section cut for silage (sold standing to a contractor) and the other section sprayed-out (brown manured) on 6 September 2023. The brown manure was then incorporated to a depth of 20 cm using a Horsch Tiger on 20 October 2023 and strip tilled, before also being sown to P1837 hybrid feed grain or silage maize on 30 October 2023.

The maize paddocks were both pre-spread with 6 t/ha poultry manure and received two applications of urea (first application of 600 kg/ha, second application 200 kg/ha), totalling 800 kg urea/ha. The poultry manure provided 105 kg N/ha, while the urea provided 368 kg N/ha. This meant the total nitrogen applied through both sources was 473 kg N/ha, or 92 percent of the requirements of a 20 t/ha maize crop.

The adzuki bean, high-density legume mix silage and high-density legume mix brown manure paddocks were sampled for deep soil nitrogen (DSN) on 17 October 2023, just prior to spreading of the poultry manure and the maize crop being sown. The samples were incremented in 30 cm segments to a depth of 0–90 cm, with the sample sites being GPS referenced. The DSN sample sites from October 2023 were then retested on 21 May 2024 after the maize was harvested to compare changes in nitrogen status.

RESULTS & DISCUSSION

Table 1 shows that at the October 2023 sampling date (pre-sowing), the highest DSN nitrogen levels were found in the adzuki bean paddock (169 kg N/ha), followed by the high-density legume mix brown manure paddock (130 kg N/ha), with the high-density legume mix silage section having the lowest soil nitrogen (54 kg N/ha) of the three comparisons.

For the high-density legume mix paddock, the lower rates of soil nitrogen in the silage section can be attributed to higher rates of product and nitrogen removal compared to the brown manure crop, which retained its biomass within the paddock.

The segmented soil tests also showed that most of the nitrogen was in the top 30 cm at all three sites. However, the adzuki paddock had a more even spread of nitrogen across the soil profile than the high-density legume mix paddocks. There was an interval of around six months between adzuki harvest and DSN sampling, which likely facilitated the breakdown of residue and subsequent release and movement of nitrogen through the profile.

The maize grown in the adzuki bean paddock yielded 16 t/ha, compared to the high-density legume mix silage and brown manure rotations, which both yielded 19.1 t/ha. The lower yields in the adzuki bean rotation were attributed to poorer maize germination, possibly due to the paddocked being overworked, as well as under-watering part of the paddock. The yields in the under-watered section were sub 10 t/ha, whereas the rest of the paddock yielded on par with the yields in the high-density legume mix rotation.

There was no difference in maize yield between the high-density legume mix silage and brown manure crops. A 20 t/ha maize crop requires approximately 512 kg N/ha and there was an ample supply of nitrogen to achieve the target yield in both the silage and brown manured sections. Because nitrogen was not limiting, no yield response was seen to the additional nitrogen available in the brown manured section (the farmer did not reduce nitrogen application rates, despite the higher amounts available).

It's also likely that warm, wet conditions over spring 2023 and summer 2024 increased mineralisation rates in all paddocks, increasing the supply of nitrogen to the subsequent maize crop.

After the maize crop was harvested, follow-up DSN testing showed the highest nitrogen levels in the high-density legume mix brown manure rotation (313 kg N/ha), followed by the adzuki bean rotation (133 kg N/ha), with the lowest nitrogen found in the high-density legume mix silage rotation (90 kg N/ha). Despite the high application rates of poultry manure and in-crop urea, there was a decrease in total nitrogen between maize sowing and harvest for the adzuki bean rotation in the 0-30cm segment, suggesting that the maize crop drew on soil nitrogen reserves in this layer. Poultry manure can take one to two seasons to fully breakdown, so it's likely that not all nitrogen from the manure was available at the time of testing.

In comparison, the high-density legume mix brown manure rotation showed a substantial increase in soil nitrogen to 60cm between maize sowing and harvest, likely due to the breakdown of the high-density legume mix residue over the summer, and the subsequent release of mineralised nitrogen back into the soil. The high-density legume mix silage also showed a slight increase in soil nitrogen between sowing and harvest, although not to the same extent as the brown manured crop.

Table 1 Deep soil nitrogen and subsequent maize yield results from three different legume treatments at Howlong.

		DSN PRE-SOWING OCT 2023	DSN POST-HARVEST MAY 2024	MAIZE YIELD 2024
Rotation	**DSN sample depth (cm)**	**(kg N/ha)**	**(kg N/ha)**	**(t/ha)**
Adzuki beans 2022–2023, maize 2023–2024	0-30	79	36	16.0
	30-60	58	58	
	60-90	32	40	
Total (0-90 cm) nitrogen		169	133	
High-density legume mix brown manured 2023, maize 2023–2024	0-30	90	223	19.1
	30-60	14	68	
	60-90	25	22	
Total (0-90 cm) nitrogen		130	313	
High-density legume mix silage 2023, maize 2023–2024	0-30	25	43	19.1
	30-60	11	29	
	60-90	18	18	
Total (0-90 cm) nitrogen		54	90	

GROSS MARGINS - LEGUMES

For the high-density legume mix silage and brown manure treatments, the cost of the seed mix was $160/ha, while the legume inoculant cost $40/ha. MAP cost $68/ha and the cost of sowing the paddock was $35/ha.

The high-density legume mix silage was sold standing, yielding 6.35 t/ha. Once the costs of seed and sowing were considered, the gross margin was $808/ha (Table 2).

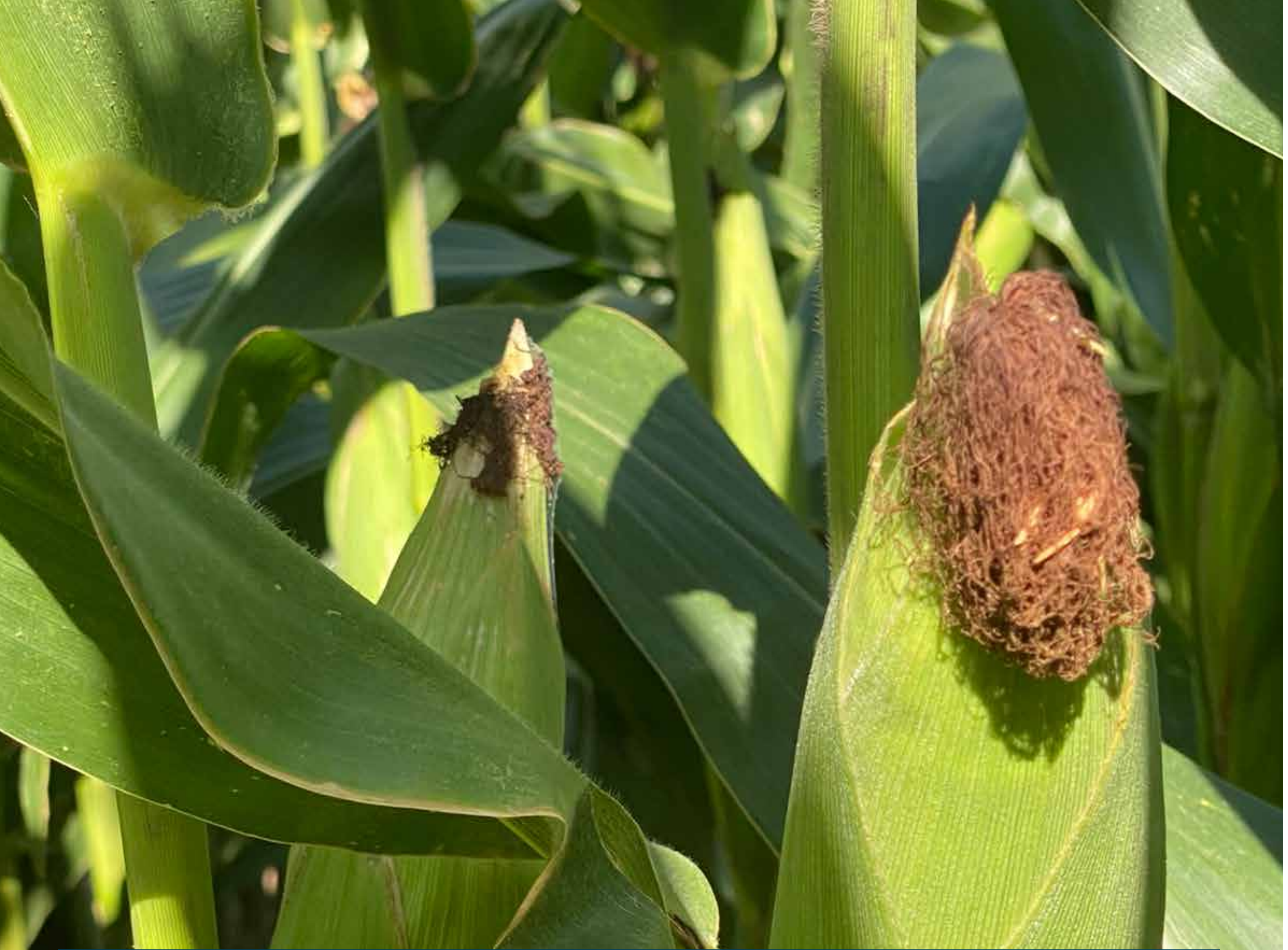
Table 2 High-density legume mix silage gross margin for a standing crop sold at Howlong, 2023.

	DETAILS	$/HA
Income	Silage (6.35 t/ha at $175/t)	1111
Less costs	Sowing	35
	Seed & inoculant	200
	MAP	68
Gross margin		**$808/ha**

The high-density legume mix brown manure crop income was based on the value of the additional nitrogen fixed compared to the silage, as measured in October 2023 and again in May 2024 (Table 3). An additional 76 kg N/ha was added to the soil by the brown manure treatment compared to silage in October 2023, while an additional 223 kg N/ha was added by the brown manure by May 2024. Based on a urea price of $852/t, the value of the nitrogen added to the soil was $553/ha. The costs of the brown manure treatment included seed and sowing of the high-density legume mix, spraying out the brown manure and cultivation using a Horsch Tiger. After costs were considered, the gross margin of the brown manure was $99/ha.

Table 3. High-density legume mix brown manure gross margin at Howlong, 2023

	DETAILS	$/HA
Income		
Additional N compared to silage (Oct 2023)	76 kg N/ha valued at $1.85 kg N	140
Additional N compared to silage (May 2024)	223 kg N/ha valued at $1.85 kg N	413
Income	Total	553
Less costs	Sowing	35
	Seed & inoculant	200
	MAP	68
	Spray out high-density legume mix pasture	51
	Cultivate Horsch Tiger	100
	Total	454
Gross margin		**$99/ha**



CONCLUSION

The demonstration showed that legume crops, such as adzuki beans and a high-density legume mix for silage or brown manure, can contribute significant amounts of nitrogen to an irrigated farming system. It also showed that brown manuring a high-density legume mix provided longer lasting and higher amounts of residual nitrogen compared to high-density legume mix for silage or adzuki beans. This is because brown manuring keeps all the nitrogen in the system, rather than removing it from the paddock through silage or grain.

Although brown manuring can provide significant amounts of nitrogen over an extended period, it means that there is no cashflow in the winter the crop is brown manured. In contrast, a grain crop such as adzuki beans (summer crop) or faba beans (winter crop) can provide some income through grain sales, as well as some residual nitrogen. However, its important farmers also consider the tight timelines between the harvest of a winter crop and the sowing of a summer crop (double cropping) such as maize, and how this might affect harvest logistics and time of sowing.

It's recommended farmers do a nitrogen budget, based on their target yield and maize protein, as well as a deep soil nitrogen prior to sowing. This information can be used to guide nitrogen decisions.

If using animal manures, it's important to get a nutrient analysis, to understand the amount of nutrient applied. Consider also that not all the nutrient is available in the year of application.

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COMPANION CROPPING LEGUMES FOR LOWER-COST NITROGEN SUPPLY – RESULTS FROM THE REPLICATED TRIALS AT SANGER

KEY MESSAGES

- **At a replicated trial site established at Sanger during 2024, there were no significant differences in nitrogen levels at anthesis between wheat sown on its own in a monoculture and wheat sown with vetch in a companion crop.**
- **There were no significant differences in wheat yield or quality when grown in a monoculture compared to being grown as a companion crop with vetch, except when the companion crop with 50 percent nitrogen was terminated in September, which yielded significantly less.**
- **Vetch and wheat biomass increased as the season progressed, however vetch biomass was highest at the September termination, while wheat was highest at the October termination, suggesting wheat was better able to compete for resources.**
- **Vetch biomass production was relatively low when sown as part of a companion cropping mix with wheat, likely due to factors relating to the dry season, as well as competition by the wheat.**
- **The estimated nitrogen benefit of the vetch varied between 0.4 kg–6 kg N/ha, with the highest nitrogen benefit occurring at the end of September.**
- **Vetch sown in a monoculture yielded poorly in this trial (approximately 0.1 t/ha), likely due to seasonal conditions.**

BACKGROUND

Australian grain growers are increasingly reliant on inorganic (synthetic) nitrogen (N) fertilisers to meet the nitrogen demands of crop production.

Australian wheat production currently sits at around 30 million tonnes annually, which requires an estimated 1.2 million tonnes of nitrogen to be supplied from the soil. Currently a bit less than half (45 percent) of this nitrogen is supplied by synthetic nitrogen fertilisers and grain growers are increasingly looking for new, affordable and more environmentally friendly ways to manage their nitrogen supply.

One established approach is to incorporate legumes in the farming systems—this adds nitrogen to the soil in organic form that is later mineralised and taken up by subsequent non-leguminous crops. However, this approach requires the dedication of a full-year of winter crop production to the pulse crop, which can be challenging given many growers grow pulses one-in-six years, while others remain reluctant to grow pulses at all.

A different approach involves sowing a companion legume (e.g. vetch), every year together with a non-leguminous crop, with the companion legume terminated by desiccation before it impacts on the yield of the main crop. This is also known as temporary intercropping.

By integrating companion legumes annually, grain growers can enhance nitrogen fixation without sacrificing the productivity of their non-leguminous crops.

AIM

This project is testing the effects of different desiccation timings of companion legumes (vetch) on the non-leguminous crop, as well as the nitrogen fixation contribution to the farming system and the costs associated with sowing and desiccation.

METHOD

A demonstration trial has been established at Sanger, in southern NSW, to investigate the amount of nitrogen fixed by leguminous companion crops (vetch) and the optimal timing of their desiccation (termination).

SOIL SAMPLING

On 2 June 2024, soil samples were collected for soil mineral nitrogen analysis in 0–10, 10–30, 30–60, 60–90 cm increments. Soil characterisation was also conducted to establish the baseline conditions of the paddock. A second round of soil testing occurred prior to anthesis on 16 October 2024. Follow-up soil testing will be repeated prior to sowing the 2025 wheat crop, to assess the treatment effects on soil mineral nitrogen.

SITE PREPARATION

The trial site was burnt prior to sowing in 2024, ensuring the removal of crop residue. It was sown to wheat (cv Scepter) at approximately 80 kg/ha, vetch (cv Morava) at approximately 40 kg/ha, or a combination of wheat and vetch in a companion cropping mix on 6 June, via direct drill.

The trial was sown in a complete randomised block design that included nine treatments, each with either high nitrogen (120 L UAN/ha), or 50 percent of high nitrogen (60 L UAN/ha) applied in late August (Table 1). Each plot measured 1.4 x 12 m, and treatments were randomised across four replicates. Buffer strips planted with Catapult wheat were also established around the trial.

Granular mono-ammonium phosphate (MAP) was applied at sowing as a source of nitrogen at a rate of 80 kg/ha. While soil tests indicated sufficient soil nitrogen reserves to meet target crop yields at the start of the season, a lack of rainfall during the growing season meant that expected mineralisation did not occur. This meant a top up of nitrogen was required. Given the risk of urea losses were high as a result of dry conditions, liquid urea ammonium nitrate (UAN) was chosen as the nitrogen source, applied as foliar spray at varying rates across all treatments in late August (Table 2). Each treatment had different level of nitrogen inputs.

Vetch grown as a companion crop together with wheat was terminated at different timings during July, August, September or October using Amicide Advance 700 (700 g/L 2,4-D present as the dimethylamine and monomethylamine salts) (Table 2).

Wheat, as the main crop, was harvested on 14 December, using a plot harvester, with wheat quality analysis also conducted. The vetch monoculture treatments (high nitrogen and 50 percent high nitrogen) were also harvested on the same day as the wheat, to provide a baseline vetch yield.

Crop establishment counts were conducted on 24 July 2024. Wheat and vetch biomass cuts were taken before each termination timing, with samples oven-dried for 48 hours at 70˚C to calculate the final dry weight biomass.

Table 1 Treatment details for the Riverine Plains wheat and vetch companion cropping trial at Sanger, 2024

TREATMENT	CROP	NITROGEN APPLIED LATE AUGUST	VETCH TERMINATION DATE
Wheat monoculture, 50% of high nitrogen	Wheat	UAN 60L/ha late August	Nil
Wheat monoculture, high nitrogen	Wheat	UAN 120 L/ha, late August	Nil
Vetch monoculture, 50% of high nitrogen	Vetch	UAN 60L/ha late August	Nil – vetch taken to harvest
Vetch monoculture, high nitrogen	Vetch	UAN 120 L/ha,	Nil – vetch taken to harvest
Companion crop, terminated July	Wheat/Vetch	UAN 60L/ha late August	End July
Companion crop, terminated August	Wheat/Vetch	UAN 60L/ha late August	End August
Companion crop, terminated September	Wheat/Vetch	UAN 60L/ha late August	End September
Companion crop, terminated October	Wheat/Vetch	UAN 60L/ha late August	End October
Companion crop, high nitrogen, terminated September	Wheat/Vetch	UAN 120 L/ha	End September

RESULTS AND DISCUSSION

EMERGENCE

The highest establishment for wheat was observed in the wheat monoculture treatment (82 plants/m²) and the lowest in the companion crop, terminated August treatment (66 plants/m²). For vetch, the highest establishment was observed in the vetch monoculture, high nitrogen treatment (41 plants/m²) and the lowest in the companion crop, terminated October treatment (27 plants/m²). The higher emergence seen in the wheat treatments is due to its faster germination, greater seed uniformity, and ability to establish well at standard sowing depths. In contrast, vetch emergence is often lower due to hard seed coat dormancy, slower germination, and greater sensitivity to sowing depth, factors that can especially affect performance in mixed cropping systems.

BIOMASS

Biomass was measured for wheat and vetch in the companion cropping treatments only.

There was an increase in mean biomass between July and October, reflecting the normal pattern of plant dry matter accumulation over the growing season (Table 3). Biomass for both wheat and vetch was low (0.30 t/ha and 0.02 t/ha respectively) in the companion crop, terminated July treatment, which was in-line with the early termination and measurement for this treatment. Wheat biomass was highest in the companion crop, terminated October treatment (4.95 t/ha), which was a marked increase from September (3.6 t/ha), highlighting the rapid biomass accumulation that occurs during spring. Vetch biomass was highest in the companion crop, terminated September treatment (0.30 t/ha); vetch biomass did not increase beyond September, with the October vetch termination biomass yielding 0.23 t/ha. This suggests that the wheat outcompeted the vetch for resources in the companion crop system. Adding 120L/ha UAN at the end of August did not increase wheat or vetch biomass compared to the nil nitrogen treatment when measured at the end of September, likely because the dry spring conditions limited further biomass accumulation.

Given the relatively low amount of biomass produced by the vetch at the time of termination in September and October, it's estimated that only a modest amount of nitrogen was fixed by the vetch crop, in the range of 4.6–6t kg N/ha.

Table 2 Emergence and biomass accumulation for the different companion cropping termination timings, Sanger, 2024.

TREATMENT	EMERGENCE (PLANTS/M²)		BIOMASS (T DM/HA) *		ESTIMATE OF NITROGEN FIXED BY VETCH (KG N/HA) **
	Wheat	Vetch	Wheat	Vetch	
Wheat monoculture, 50% of high nitrogen	82	-	-	-	-
Wheat monoculture, high nitrogen	74	-	-	-	-
Vetch monoculture, 50% of high nitrogen	-	33	-	-	N/A
Vetch monoculture, high nitrogen	-	41	-	-	N/A
Companion crop, terminated July	76	33	0.2	0.02	0.4
Companion crop, terminated August	66	37	1.0	0.12	2.4
Companion crop, terminated September	73	34	3.6	0.30	6.0
Companion crop, terminated October	70	27	5.0	0.23	4.6
Companion crop, high nitrogen, terminated September	78	36	3.3	0.29	5.8

*Biomass cuts taken either 24 July, 26 August, 26 September 24 October, depending on termination treatment

** Based on the rule of thumb that legumes fix 20 kg N/ha per tonne of dry matter produced

TOTAL NITROGEN ANALYSIS AT SOWING AND ANTHESIS

Soil nitrogen content (0-90 cm) at sowing was variable across treatments, highlighting paddock variability in the first year of the trial. The highest nitrogen was recorded in the companion crop, terminated July treatment (93.9 kg/ha), which was significantly higher than the nitrogen in the companion crop terminated in August treatment (59.8 kg./ha) and October treatment (54 kg/ha). All other treatments, including wheat monoculture at both nitrogen rates, vetch monoculture at both nitrogen rates, and other companion crop termination dates had average soil nitrogen of between 60–78 kg/ha, with no significant differences across treatments.

From sowing to anthesis, the total soil nitrogen levels across all companion crop treatments decreased in line with crop use, with anthesis averages ranging between 31.5kg N/ha and 50.1 kg N/ha and no statistical difference between treatments (Table 3). This could be due to a combination of factors, including poor nodulation and nitrogen fixation by the vetch, combined with dry conditions (Note: nodulation was not scored in this trial). Pulse residues can take time to break down, so it's also likely the nitrogen provided by the vetch had not had a chance to break down and add nitrogen back into the soil. Based on the rule of thumb that legumes can fix 20 kg N/ha per tonne of dry matter produced, the amount of nitrogen fixed in the companion cropped vetch was estimated to be between 0.4 kg N/ha and 6.0 kg N/ha, depending on the timing of termination (Table 3).

The impact of the companion cropped vetch will be clearer after soil sampling is completed ahead of sowing in 2025.

Table 3 Nitrogen at sowing, anthesis and grain yield across different wheat and vetch treatments at Sanger, 2024

TREATMENT	SOIL NITROGEN AT SOWING (KG N/HA)	SOIL NITROGEN AT ANTHESIS (KG N/HA)	GRAIN YIELD (WHEAT OR VETCH) (T/HA)
Wheat monoculture, 50% of high nitrogen	71.5 ab	49.4 a	4.65 c
Wheat monoculture, high nitrogen	78.0 ab	23.7 a	4.65 c
Vetch monoculture, 50% of high nitrogen	65.0 ab	47.1 a	0.14 a
Vetch monoculture, high nitrogen	65.7 ab	50.1 a	0.07 a
Companion crop, terminated July	93.9 a	31.5 a	4.15 bc
Companion crop, terminated August	59.8 bc	38.0 a	4.14 bc
Companion crop, terminated September	61.4 abc	36.1 a	3.88 b
Companion crop, terminated October	54.0 c	44.2 a	4.10 bc
Companion crop, high nitrogen, terminated September	61.8 abc	50.1 a	3.92 b

Notes: Numbers followed by the same letter are not significantly different from each other ($P < 0.05$)

YIELD AND GRAIN RESULTS

The wheat monoculture treatments yielded the highest, with both nitrogen treatments performing similarly to each other (4.65 t/ha). While the wheat monoculture yields at either nitrogen rate were significantly higher than the companion crop vetch terminated in September treatment (3.88 t/ha) and the high nitrogen terminated in September treatment (3.92 t/ha), there were otherwise no significant differences in wheat yield across the treatments.

Although not statistically significant, both the wheat monoculture treatments (high nitrogen and 50 percent of high nitrogen) showed a trend to higher yields (4.65 t/ha), compared to wheat sown in the companion crop mix (range 3.88–4.15 t/ha).

There was no difference in grain quality, including protein, moisture and screenings, between treatments (data not presented).

The vetch in the monoculture treatments was also harvested, with the high nitrogen rate yielding 0.07 t/ha and the 50 percent nitrogen rate yielding 0.14 t/ha (not significantly different). The low vetch yield was likely due to a combination of later-than-ideal sowing and dry seasonal conditions.

OBSERVATIONS AND COMMENTS

At sowing, all treatments had similar nitrogen levels, except for the companion cropping terminated July treatment, which had significantly higher nitrogen than the treatment terminated in October, likely indicating paddock variability. There was no difference in total soil nitrogen levels difference between wheat as a monoculture and wheat and vetch grown in a companion cropping system at anthesis, regardless of whether nitrogen was applied at a high rate, or 50 percent of the high rate. Several factors likely contributed to this outcome, including reduced mineralisation of soil nitrogen due to low in-season rainfall and poor nodulation and activity as a result of dry seasonal conditions. The long interval between vetch termination, vetch residue breakdown and the release of nitrogen back into the soil is also likely to have contributed to the lack of difference between treatments.

While there was a trend towards lower wheat yield the longer the vetch remained as a companion crop, these differences were not statistically significant.

Additional data will be needed to determine the optimal timing for termination of the companion crop. In the coming year, nitrogen applied at both high and low rates will be paired with a nitrogen budget, informed by seasonal outlooks, to gain a clearer understanding of the nitrogen contribution from vetch as a companion crop.

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DE-RISKING EARLY SOWN CROPS – RESULTS FROM THE SOWING SPEED AND HERBICIDE EFFICACY DEMONSTRATION TRIALS AT RAND AND MURCHISON

KEY MESSAGES

- **A demonstration trial at Rand highlighted how natural paddock variability can cause moisture to depth to vary across a paddock, which can impact on the success of dry sowing.**
- **Using a slower speed at Rand caused clods to form, compared to a higher speed which generated more soil throw.**
- **A herbicide trial at Murchison highlighted the impact of rainfall on pre-emergent herbicide efficacy, as well as the importance of understanding the target species, moisture requirements and herbicide tie-up in stubble before selecting a herbicide.**
- **Discussions with farmers highlighted knowledge gaps and interest in long coleoptile wheats to better manage sowing depth in dry soils, cutoff dates for dry sowing and how small amounts of soil moisture can affect the success of dry-sowing.**

BACKGROUND

Dry and early sowing of cereal crops is a practice commonly used by farmers in southern Australia to combat erratic and late opening season rainfall, and to effectively manage the sowing program on increasingly large farms.

There has been a large amount of research and development on dry and early sowing by key research and development organisations such as the Grains Research and Development Corporation (GRDC), CSIRO, and state agencies into seeding strategies, nutritional requirements, and machinery setup for dry sown crops.

However, many growers have either not accessed the information or are seeking to develop a more strategic approach that is tailored to their specific district and property requirements. Additionally, there are opportunities to increase the success of early sowing by combining management approaches and strategies.

Two sites were established at Rand and Murchison during 2024 to demonstrate different strategies when managing a dry start to the season. The demonstration strategies were developed after conducting a survey with Riverine Plains members on what they'd like to see.

RAND, SITE 1

METHOD

The Rand site was established to look at the effects of the speed of sowing on establishment and yield. The trial evaluated three different speeds of sowing—6 km/hr, 8 km/hr and 10 km/hr—with all paddock treatments otherwise the same. The paddock was sown to canola (cv HyTTech Trophy® Hybrid TT) on 10 April 2024 at a rate of 3 kg/ha.

RESULTS & DISCUSSION

The Rand site was relatively dry when sown in mid April. While there had been some good summer rain at the end of January, by sowing there was large variability in soil moisture across the paddock and down the profile, as indicated by deep soil sampling (Table 1).

Table 1 Soil moisture measured down the profile at the Rand De-risking early sown crops trial site, 2024

	SPEED OF SOWING (KM/HR)		
Treatment	**6**	**8**	**10**
Depth (cm)	Soil moisture (%)		
0-10	11.7	12.1	10.8
10-30	14.9	16.8	14.8
30-60	15.6	19.3	12.4
60-90	13.6	15.1	10.7

Post sowing, the soil surface was noticeably different across the different sowing speed treatments, with the lowest speed leaving the surface with large clods of soil, while the highest speed had thrown the soil further.

Plant counts conducted on 15 May only showed a small difference in establishment between the sowing speed treatments, with the 8 km/hr treatment having the lowest emergence (34 plants/m^2) and the 10 km/hr treatment having the highest (39 plants/m^2).

Yield results for the different sowing speed treatments were inconclusive for this trial, due to the combination of severe frost damage and heavy rain at harvest time, which all negatively impacted grain yield. The yields in the paddock ranged from 0.1 - 1.0 t/ha.

MURCHISON, SITE 2

METHOD

The Murchison site evaluated different pre and post emergent herbicide options, applied as per Table 2. The paddock had a pasture history, with a high weed burden. A combination of herbicides and control strategies were used in the trial, including:

- Trifluralin incorporated by sowing (IBS), followed by Mateno® at the one leaf stage (GS11) – targeting annual grasses and broadleaf weeds both at sowing and early post emergence.
- Trifluralin + Terrain® Flow (IBS), followed by Mateno at the one leaf stage (GS11) – targeting annual grasses and broadleaf weeds, specifically wild radish using a knock down and residual control strategy at sowing, followed by grass and broadleaf control early post emergent.
- Trifluralin (IBS) – targeting annual ryegrass and wireweed.
- Trifluralin + Sakura® (IBS) – targeting annual ryegrass, barley grass, silver grass, toad rush, plus suppression of brome grass and wild oats.
- Trifluralin + Sakura + Voraxor® (IBS), as per previous treatment, with longer lasting pre-emergent residual plus suppression of capeweed and wild radish.

The entire site was sown on 3 May, 2024 to wheat (cv Scepter) at a rate of 75 kg/ha.

RESULTS & DISCUSSION

The trial was sown into dry soil, with the site receiving 18 mm one week after sowing, with a follow-up rain of 36 mm occurring at the end of the month. This was critical to the success of the application of the pre-emergents, which were applied within 24 hours of sowing and needed moisture for activation. Following crop emergence, Mateno® Complete was applied to two of the treatments at early tillering (GS13-21) on May 27, just before the rain event at the end of the month.

Weed species assessments were done at emergence (data not shown) and then again on 23 July. The weed species present included annual ryegrass, capeweed, erodium and onion grass. Table 2 shows the differences in population of weeds, with a trend to higher broadleaf weed populations in the Trifluralin and Trifluralin + Sakura treatments, compared to when Mateno, Terrain Flow or Voraxor was added to the mix. Grass weed populations were similar across treatments, although there was a trend to lower populations when Trifluralin and Mateno were used in combination.

Table 2 Herbicide treatments, applications details and weed counts conducted at the Murchison De-risking early sown crops trial, 2024

TREATMENT	APPLICATION RATE	APPLICATION DATE	GRASS WEEDS (PLANTS/M²)	BROADLEAF WEEDS (PLANTS/M²)
			23 July	
Trifluralin	1.5 L/ha	3 May	40	90
Trifluralin + Mateno	1.5 L/ha + 1 L/ha	3 May + 27 May	21	34
Trifluralin +Terrain Flow + Mateno	1.5 L/ha + 125 ml/ ha + 1 L/ha	3 May + 27 May	40	17
Trifluralin + Sakura	1.5 L/ha +118 g/ha	3 May	29	74
Trifluralin + Sakura + Voraxor	1.5 L/ha +118 g/ha +200 ml/ha	3 May	32	28

LEARNINGS AND NEXT STEPS

It's recommended that farmers ensure the correct depth of seed placement and the spatial separation of crop seed and herbicide when dry sowing. It's also recommended that farmers avoid sowing into paddocks with high weed seedbanks until an effective knockdown strategy is implemented.

Field days and paddock walks held at the Rand and Murchison demonstration sites as part of the project also provided an opportunity for farmers to further discuss the above strategies, as well as other challenges and decisions they face when dry sowing. Feedback obtained at these events indicated a knowledge gap and further interest around dry sowing and:

- new varieties, including long coleoptile varieties
- understanding the cutoff date for dry sowing
- half germination – what percentage losses are occurring with small amounts of rain and does this contribute to poor germination?
- optimising pre-emergent chemistry efficacy, including the timing between herbicide application and sowing
- Rotation and how to adjust this in response to a late break (eg. lupins to field peas, or wheat to barley)

These topics will be used to inform future work in this area.

ACKNOWLEDGEMENTS:

The *De-risking the seeding program: Adoption of key management practices for the success of dry early sown crops* project is supported by Ag Excellence Alliance Inc, through funding from the Australian Government's Future Drought Fund. Thank you to our farmer cooperators, the Webster family (Rand) and the Brown family (Murchison)

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UREA VOLATILISATION AND GREEN UREA NV PRODUCT PERFORMANCE IN MITIGATING LOSSES

BACKGROUND

Urea is the most used nitrogen (N) fertiliser by farmers. However, losses from urea can be high under certain conditions and there is considerable interest in improving the efficiency of its application.

When applied to soil, urea is hydrolysed in the presence of moisture to ammonium, facilitated by the action of the urease enzyme present in the soil. The hydrolysis process is usually completed within 1–4 days.

During hydrolysis, the area surrounding the granules become temporarily alkaline, even in acid soils. Under alkaline or high pH conditions, the ammonium (NH_4^+) can be converted to ammonia gas (NH_3) which can be lost through volatilisation from the soil, especially when urea is surface applied. Other loss pathways for applied urea include leaching of nitrate (NO_3^-) and denitrification of nitrate, mainly as nitrous oxide (N_2O—a potent greenhouse gas) and dinitrogen (N_2) under very high soil moisture content (Figure 1).

Incitec Pivot Fertilisers Green Urea NV® is an enhanced efficiency fertiliser that contains a urease inhibitor which slows the conversion of urea to ammonium, which is subject to loss as ammonia gas. The Green Urea NV minimises nitrogen losses, leading to more retention in the system for a crop and pasture production.

Extensive research trials by Incitec Pivot Fertilisers, with the help of co-operators including Riverine Plains at Murchison East in 2024, measured ammonia gas volatilisation from Green Urea NV compared to urea at 11 sites across Australia. with varying soil types and over multiple top-dressing applications.

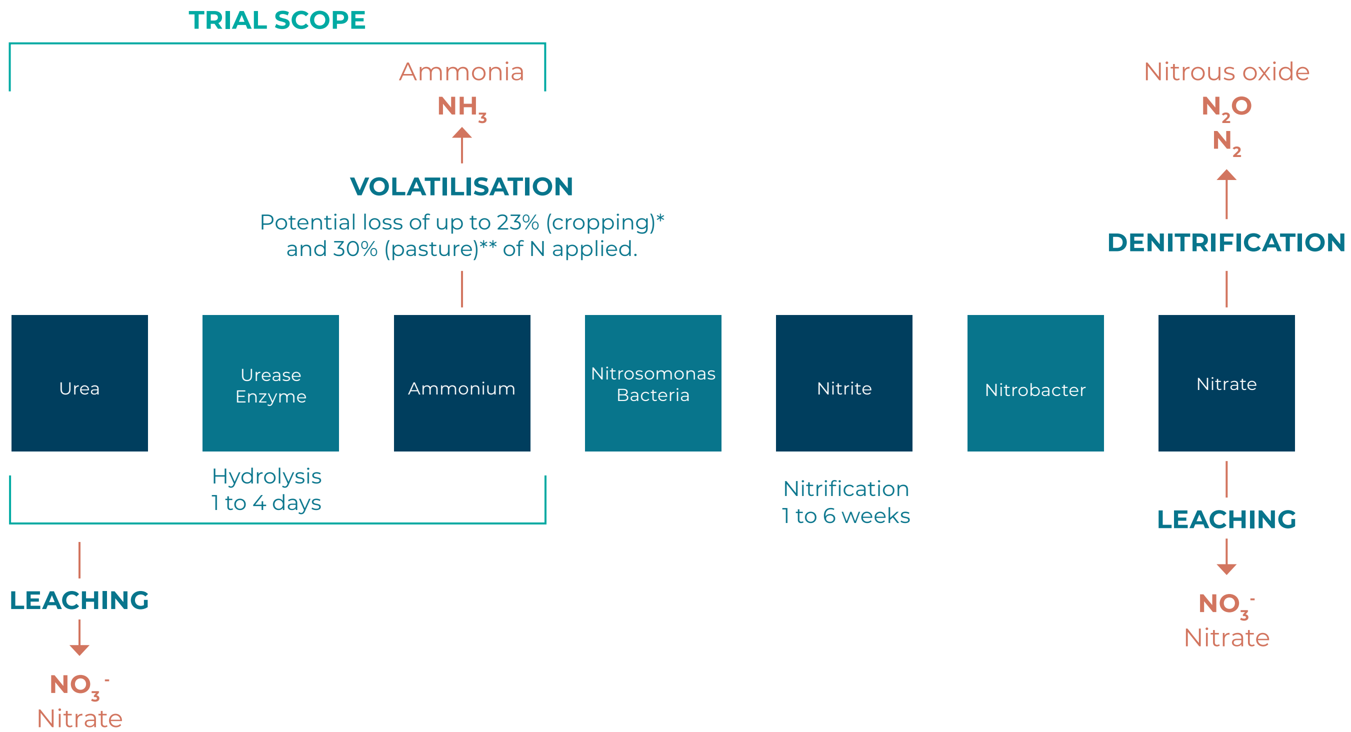

Figure 1 Nitrogen transformation and loss pathways for applied urea. The urease inhibitor in Green Urea NV slows the urease enzyme responsible for the rapid hydrolysis of urea to ammonium, which can be lost as ammonia gas under certain soil and climatic conditions.

FACTORS IMPACTING AMMONIA VOLATILISATION

Soil pH

High soil pH drives ammonia gas volatilisation. At high pH, the ammonia-ammonium equilibrium is shifted towards ammonia, leading to high volatilisation losses. Regardless of soil type, soil pH under the urea granule will increase, converting ammonia to ammonia gas and leading to nitrogen loss. Green Urea NV slows this pH rise, reducing volatilisation losses.

Cation exchange capacity

Soils with a high cation exchange capacity (CEC) can retain ammonium (NH_4^+) on its exchange (negatively charged surfaces), leading to a reduction in the ammonium available for conversion to ammonia gas. This results in lower volatilisation losses in soil with high CEC, such as soils high in clay and organic matter. Sandy soils have a low cation exchange capacity, meaning they don't hold nutrients well. Green Urea NV reduces nitrogen loss, keeping more available for crop uptake.

Organic material (pasture thatch, crop residues, stubble, trash)

Organic material can trap urea granules above the soil surface, exposing them to volatilisation. Green Urea NV slows urea breakdown, helping retain nitrogen until it is incorporated.

Low rainfall or dew conditions

When urea granules dissolve but are not incorporated deeply enough into the soil, volatilisation risk increases. The amount of rainfall needed to reduce losses varies by soil type: sandy soils require >10mm, loam soils >16mm, and clay soils >25mm.

AIM

This trial focused on the measurement of ammonia gas volatilisation from top-dressed or surface-applied urea, and the performance of Green Urea NV® in mitigating the volatilisation losses.

METHOD

At all the trial sites, ammonia gas measurement was achieved using 150 x 300 mm PVC chambers with a cap and an acid-treated foam. The enclosed chamber, which was driven into the soil over the top-dressed area, holds a foam which traps ammonia gas above the soil surface, whilst the cap excluded moisture for the duration of measurement. The foam was replaced at weekly intervals for two weeks for continuous trapping of ammonia gas from both the urea and Green Urea NV treatments. The ammonia gas in the foam was subsequently extracted for analysis at the Nutrient Advantage Laboratory.

Winter crops including wheat, barley and canola were sown across the 11 trial sites, with the Murchison East site sown to canola in 2024. The sites received three separate top dressings of nitrogen as either standard urea or Green Urea NV in mid-June, mid-July and mid-August, applied at a rate of 46 kg N/ha.

Chambers for ammonia gas measurement in the field

RESULTS

Figure 2 shows how many kilograms of nitrogen was lost as ammonia gas at each topdressing (mid May, mid June and mid August) at the Murchison East site. Table 1 shows the percentage reduction in ammonia gas lost from each Green Urea NV application, relative to standard urea.

At the Murchison East site, between 8.2 and 10.1 kg N/ha out of the 46 kg N/ha applied at each top dressing was lost through ammonia gas volatilisation. This equated to a loss of between 17–21.9 percent for each application. In contrast, Green Urea NV losses were between 3.2–4.1 percent of the total applied. Compared to the standard urea, Green Urea NV reduced ammonia gas loss by 76, 82 and 83 percent for the June, July and August applications respectively.

An average of 72 percent of the total nitrogen lost occurred in the first week of urea application.

Results for the remainder of the trial sites can be found on the Incitec Pivot website.

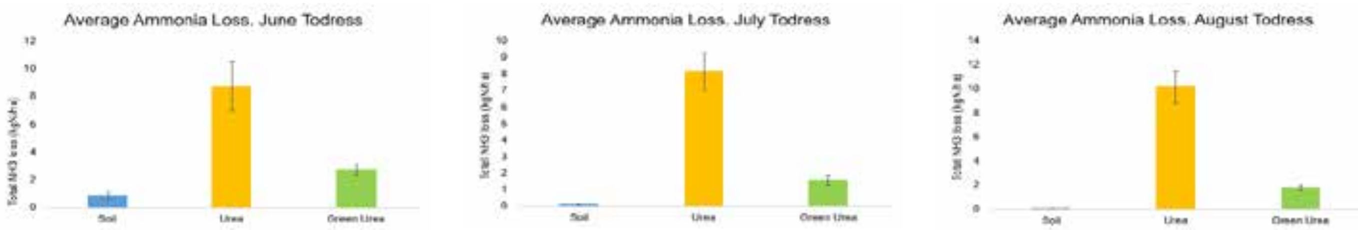

Figure 2 Total ammonia lost (kg N/ha) across at the Murchison East trial site. Bars represent standard error of means (n=4).

Table 1 Amount of nitrogen lost (percentage of applied) for urea and Green Urea NV across multiple topdressings from June–August at the Murchison East trial site, 2024.

TIMING	MID JUNE TOPDRESS		MID JULY TOPDRESS		MID AUGUST TOPDRESS	
	Urea	Green Urea	Urea	Green Urea	Urea	Green Urea
Nitrogen lost (% of application)	17.3	4.1	17.5	3.2	21.9	3.7

Ammonia nitrogen lost from the cropping system can be accounted for in two ways; as a direct cost of the ammonia loss and as the opportunity cost of lost grain yield and/or protein.

OBSERVATIONS & COMMENTS

Trial results from Murchison East and other sites across Australia show the high volatility of surface-applied urea in winter crop applications. As farming scale has increased, along with the rate of nitrogen required in modern cropping systems, urea applications are often applied in situations that promote volatilisation losses. Factors such as rainfall forecast accuracy and logistical demands can also affect the optimal timing of urea applications, increasing the risk of losses.

Green Urea has shown to be highly effective in reducing the ammonia losses from surface applied urea, providing a potential management tool in reducing the risk of nitrogen loss.

ACKNOWLEDGEMENTS

This trial work was undertaken by Incitec Pivot Fertilisers. Riverine Plains provided in-kind support to the Murchison East trial site.

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CASE STUDIES

OPTIMAL SOIL AND WATER MANAGEMENT INCREASES DROUGHT RESILIENCE — FROM THE PLOT TO THE PADDOCK

Drought is an inevitable part of farming in Australia, but outcomes from the *Improved drought resilience through optimal management of soils and available water* project are equipping farmers with a host of additional strategies with which they can prepare for the inevitable.

Numerous small-scale field trials across southern NSW have shown that early sowing of slower-maturing crops, diverse legume rotations and nitrogen banking can all increase profitability and productivity by increasing soil moisture availability and preventing carbon and nutrient loss under drought conditions. But proving these practices are profitable on a paddock scale is key to ensuring grower adoption.

Using on-farm demonstrations, this project has demonstrated how growers can apply the theoretical strategies profitably on a paddock scale, across different soil types, environments and land uses.

Charles Sturt University, under the Southern NSW Drought Resilience Adoption and Innovation Hub, led the project in partnership with Farming Systems Groups Riverine Plains, FarmLink Research, Central West Farming Systems and Southern Growers, in collaboration with CSIRO and the NSW Department of Primary Industries. The collaboration saw management strategies that had been tried and tested by researchers, over six years on four sites, validated on farm with growers and advisors.

The project was supported through funding from the Australian Government's Future Drought Fund Drought Resilient Soils and Landscapes Grants Program and is co-funded by the Grains Research and Development Corporation.

DIVERSE LEGUME (PULSE) ROTATIONS

Incorporating pulse crops into a typical wheat–canola rainfed or irrigated rotation offers long-term benefits for subsequent crops. The primary goals are to manage disease and weeds more effectively and to enhance soil health. Pulse crops fix atmospheric nitrogen, providing an immediate benefit for the current season and potentially storing nitrogen for future crops.

LEGUME ROTATION RELIEVES PRESSURE AS FERTILISER PRICES SOAR

Farmer:	Trevethan family
Location:	Howlong, NSW
Soil type:	Clay loam
Rainfall (annual):	588 mm
Growing season rainfall:	292 mm
Enterprises:	Cropping (wheat, canola, maize), Merino sheep

Management strategy:	Diverse rotations
Treatments	Comparing canola (2023) on failed faba beans and wheat (2022)
Sowing date:	16 May 2023
Sowing rate:	2.5 kg/ha (canola)
Crop species:	Canola
Variety:	NeSeed Eagle Truflex RR
Row spacing:	6.5 inch (16.51 cm)
Equipment:	Disc seeder

AT A GLANCE

- **Deep nitrogen analysis and farmer observations showed incorporating a legume into the cropping rotation provided more nitrogen than a cereal crop for the following season.**
- **Nitrogen application based on deep nitrogen soil testing, nitrogen budgeting and farmer observations, balanced the in-crop nitrogen status of the paddock.**
- **Soil testing for sulphur at the same time as testing for nitrogen is recommended to ensure it does not limit yield.**
- **Soil water analysis prior to sowing canola revealed the wheat stubble stored more water than the faba bean stubble — likely a result from increased ground cover over the summer.**

Despite challenging seasonal conditions and inconclusive yield results, a two-year paddock-scale investigation has given the Trevethan family, Howlong NSW, the confidence to continue incorporating a legume into their cropping rotation.

On the back of escalating fertiliser prices and a desire to reduce nitrogen inputs to the system, it was a 'no brainer' for the Trevethan family to partake in the *Improved drought resilience through optimal management of soils and available water* project.

The Trevethans typically employ a wheat–canola rotation, followed by a maize crop over summer, on their irrigated property between Howlong and Corowa, NSW. They also run a sheep enterprise on their dryland block, about 10 km north of Howlong.

"We're not set on any particular rotation, we're just trying to find what makes us money and to be honest, we are still trying to work out the best rotations to do this," said Tim.

The family saw the project as an opportunity to test a different cropping system and explore the impact of incorporating a legume crop on nitrogen levels and soil water.

"At the end of the day, we want to reduce our nitrogen spend in-crop and lower our cost base," Tim said.

"We also want to understand how much the nitrogen fertiliser input for the following crop might be reduced and whether we can grow high-yielding crops using organic nitrogen instead of applying large amounts of fertiliser."

As outlined in the following case study, deep nitrogen analysis and farmer observations show a legume history can provide more nitrogen than a cereal history for the following crop.

For the Trevethans, replacing wheat with faba beans in their traditional wheat–canola rotation reduced their in-crop nitrogen requirements for the canola phase by 58 kg N/ha. At $700/t and an application cost of $7.50/ha this equates to a saving of $95.70/ha.

WET CONDITIONS HAMPER 2022 RESULTS

During April 2022 the Trevethans sowed half a 104 ha paddock to faba beans and half to wheat, following a previous wheat crop across the entire paddock. Table 1 shows the soil test results for 2022 and 2023.

The extremely wet season saw both crops fail. The paddock was extensively waterlogged and the predicted 6–8 t/ha yield for wheat dropped to 2.5 t/ha, while the faba beans went from a potential 5–7 t/ha crop to yield only 0.98 t/ha.

Although the yield results were disappointing, soil nitrogen levels following the 2022 harvest revealed a total of 233 kg N/ha following the faba beans and 165 kg N/ha following the wheat, with most of the additional nitrogen from the beans being held in the 30–60cm layer of the soil profile (Figure 1). Based on the rule of thumb of 80 kg N to grow 1 t/ha of canola there was the potential to support a 2.1 t/ha canola crop following wheat and a 2.9 t/ha crop following the faba beans.

Table 1 Soil test results from a split paddock of faba beans and wheat (2022) followed by canola (2023), Howlong, NSW.

ROTATION 1: FABA BEANS, CANOLA			
	2022 AMBERLEY FABA BEANS		**2023 CANOLA**
Soil properties	**Pre-sowing**	**Post-harvest**	**Pre-sowing**
Nitrogen (kg N/ha)	122.2	232.7	249.3
Soil moisture (PAW mm)	78.5	17.6	106.6
ROTATION 2: WHEAT, CANOLA			
	2022 COOTA WHEAT		**2023 CANOLA**
Soil properties	**Pre-sowing**	**Post-harvest**	**Pre-sowing**
Nitrogen (kg N/ha)	112.6	164.8	171.1
Soil moisture (PAW mm)	103.4	90.3	157.9

NB. 2023 canola followed wheat in 2022. Paddock was sown to maize after canola harvest in 2023 and no soil sampling was done.

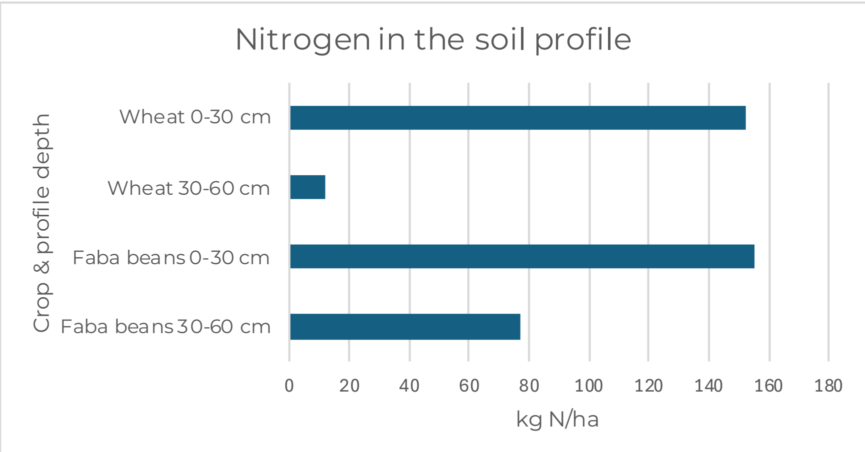

Figure 1 Post-harvest nitrogen (kg N/ha) in the soil profile for a split paddock of wheat and faba beans sown in 2022 at Howlong, NSW (sampled 27 January, 2023).

According to Riverine Plains Project Manager, Kate Coffey, the higher levels of soil nitrogen after the failed faba bean crop were likely a result of unused mineral nitrogen and the breakdown and mineralisation of crop residue.

Soil moisture levels under the faba bean crop fell by 60.9mm from sowing (May 2022) to post-harvest (January 2023). In comparison, the reduction in soil moisture under the wheat crop was only 13.1mm, possibly as a result of more ground cover from the wheat stubble compared with the faba bean stubble, over summer.

Kate indicated the limited plant available soil moisture (PAW) following the faba beans could impact the yield of the 2023 canola crop.

IMPACT OF LEGUMES VERSUS CEREALS ON SUBSEQUENT CANOLA

During May 2023 the Trevethans sowed the entire paddock to Eagle Truflex canola. Deep soil nitrogen and soil water tests were taken before sowing to determine the quantity of nitrogen and moisture available for the canola crop, based on the previous year's crop (Table 1).

Sulphur, soil pH and sodicity were also measured before sowing and plant counts, NDVI imagery and RGB were used to assess nitrogen treatments applied during the growing season.

Including faba beans in the rotation during 2022 reduced the fertiliser inputs for the following canola crop, with the deep soil nitrogen tests showing the faba bean stubble had 78 kg N/ha more nitrogen compared with the wheat residue before sowing the canola.

Based on the soil tests and in-crop observation, the Trevethans applied 58 kg N/ha and 14 kg S/ha across the whole paddock on 25 May 2023 a week after sowing. In July, they applied a further 58 kg N/ha and 14 kg/ha of sulphate of ammonia to the canola sown into the wheat stubble.

"The soil test results showed marginal results, particularly in the 0–60 cm layer, where the sulphur is needed, hence the application of sulphate of ammonia to boost sulphur levels and allow the canola to better utilise the nitrogen," Kate explained.

"To validate the soil test results, a nitrogen-rich strip (72 m wide) was applied on the faba bean half of the paddock, which didn't receive the second nitrogen application."

"Unfortunately, due to a technical issue, the yield data was not able to be analysed and we were unable to determine the impact of the nitrogen-rich strip."

Soil moisture tests showed the wheat stubble stored 51.3 mm more water than the faba bean, which was consistent with previous soil moisture test results.

With a full soil moisture profile, the Trevethans decided to sow the canola shallow — around 10 mm with some slightly shallower — to avoid bogging the sowing equipment and tearing up the paddock.

"The residual trash from the wheat and faba bean crops meant seed placement was probably too shallow and as a result plant numbers and field establishment suffered," Tim said.

"We were aiming for 35–40 plants/m^2, but we ended up with only 19–22 plants/m^2," Tim explained.

"NVDI imagery taken mid-late July showed large variability across the paddock post-sowing. Visual observation of uneven plant establishment and growth, particularly in the centre of the paddock where the centre pivot is located, reinforced the variability," said Kate.

"Throughout the season we also had issues with slugs, especially on the faba bean stubble. We baited post-sowing, pre-emergent with 3 kg/ha of Metarex® and didn't see any slugs for the remainder of the season. A fungicide was also applied mid-July to treat blackleg in the canola."

The paddock received around 430 mm of rainfall (annual) to the end of September. Following a hot, dry September, 50 mm of irrigation was applied during October.

LEGUME ROTATION PROVES ITS WORTH

Although a technical fault meant the yield data for the treatments could not be analysed, a visual assessment showed the best-performing parts were where the canola was grown on faba bean stubble.

Figure 2 shows the NVDI image of the paddock, with canola sown into the wheat stubble on the left (western side of the paddock) and sown into the faba bean stubble on the right (eastern side).

The darker colours on the image show the best-performing parts of the paddock. The NDVI is calculated by comparing the reflectance of near-infrared light (NIR) to red light. Values range from -1 – 1; values closest to 1 indicate healthy, dense vegetation and values closer to -1 indicate minimal or no vegetation.

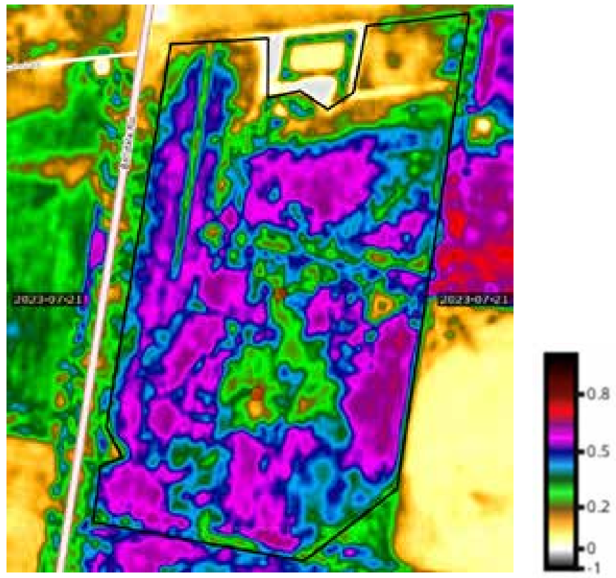

Figure 2 NVDI imagery taken 21 July, 2023 showing canola sown into wheat stubble on the left and canola sown into faba bean stubble on the right

Although the Trevethan's normally direct head their canola, with the paddock being sown to maize over the summer and the urgency to get the crop off, the crop was windrowed and harvested on 19 November. The paddock was split into a dryland section and an irrigated section — the whole paddock yielded an average of 2.4 t/ha. Although the Trevethan's were targeting 4 t/ha with their nitrogen applications, the dryland section yielded about 3.5 t/ha, and it was estimated the irrigated part yielded less than 2.5 t/ha.

"While soil tests and budgets suggest nitrogen was not limiting yield, in the absence of yield map analysis, we are unable to confirm this."

"One possible reason for the yield variability may be windrowing rather than direct heading the canola — generally speaking, the direct headed canola yielded higher than the windrowed canola under the irrigation circle," Tim said.

LEGUMES IN FUTURE ROTATIONS

While the Trevethan's plan to continue including a legume in their cropping rotation, it probably won't be faba beans.

The family has sown faba beans for the past two years, but they have also been growing vetch/clover/ryegrass pastures on their dryland block, where they run their sheep enterprise.

"The biggest disadvantage I see with faba beans is if they fail due to wet conditions or disease, you can't graze them. This is where vetch-based pasture has the upper hand."

"This allows us to graze our pasture base over the winter–spring period before brown manuring in preparation for sowing wheat or canola the following season — a value-add to the grazing operation," he explained.

"The project has 'backed up' what we already knew — we expected the canola on wheat to need more nitrogen than the canola sown into the faba bean stubble and that was the case.

The biggest takeaway from the trial for the Trevethans has been knowing the nitrogen spend is less when there is a legume in the rotation — and this is backed up by the soil data. With high fertiliser prices and availability issues, they have enjoyed not putting out as much urea this year.

"There is a pile of research about incorporating legumes into cropping rotations and the benefits of doing this, but it's good to do the research on your own farm to really understand the results and what they mean to your farming system," Tim emphasised.

This case study was authored by Toni Nugent as part of the *Improved drought resilience through optimal management of soils and available water project.*

This project is supported through funding from the Australian Government's Future Drought Fund Drought Resilient Soils and Landscapes Grants Program and is co-funded by the Grains Research and Development Corporation.

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EARLY SOWING OF LONGER-SEASON VARIETIES

Research carried out by CSIRO in small-scale plot trials indicates early sowing of longer-season varieties can provide multiple benefits depending on the weather and type of enterprise. Early sowing can:

- **utilise residual soil moisture from late summer or an early season break**
- **match crop phenology with the sowing date, capturing optimal flowering windows and reducing the risk of adverse seasonal conditions**
- **offer dual-purpose options, such as integrating grazing into the farming system**
- **provide logistical advantages by lengthening the sowing window.**

EARLY SOWING – DUAL-PURPOSE COMBINATION SUPPORTS ADAPTIVE MANAGEMENT IN VARIABLE SEASONS

Farmer:	Lawson Thomas
Location:	Mulwala, NSW
Soil type:	Medium–heavy clay
Rainfall (annual):	504 mm
Growing season rainfall:	304 mm
Enterprises:	Cropping (wheat, canola, barley), sheep (first-cross ewes, prime lambs)

MANAGEMENT STRATEGY:	Early sowing
TREATMENTS	Comparing early sown wheat (Illabo) under irrigation, with timely sown barley (Planet)
Sowing date:	15 April 2023 (Illabo); 3 May 2023 (Planet)
Sowing rate:	90 kg/ha (Illabo) and 80 kg/ha (Planet)
Crop species:	Wheat and barley
Variety:	Illabo and Planet
Row spacing:	7.5 inch (19.05 cm)
Equipment:	Tine seeder

AT A GLANCE

- **Early sowing allows farmers to capitalise on favourable weather patterns (early moisture) and extend their growing season to reduce the risk of adverse weather conditions later in the season, with or without grazing.**
- **Dual-purpose crops boost the feedbase and reduce the feed gap over the winter months.**

After incorporating an early sown crop of Illabo wheat into his cropping program for the first time in 2023, Mulwala farmer Lawson Thomas is convinced of the benefits of the innovative practice. Not only did the dual-purpose crop provide bountiful additional feed, boosting his grazing operation, it went on to yield more than 5 t/ha of quality grain.

"Early sowing isn't something we have done in the past — it's not something we would normally do as part of our conventional cropping program," Lawson admitted.

"Boosting our feedbase for our sheep enterprise, having the option to produce hay or silage if needed, reducing feed gaps over the winter and running higher winter stocking rates is definitely a bonus, and something we will continue to do as part of our mixed-farming operations into the future."

The Thomas family traditionally implements a wheat–canola–barley rotation across their 1000 ha property. Having a smaller cropping program allows them to sow paddocks during the optimal sowing window — at standard sowing times — without the need to start sowing early. But the ability to boost their feedbase and provide additional options and flexibility in their farming system, particularly under irrigation, saw the mixed-farming operators trial the system during 2023 as part of the *Improved drought resilience through optimal management of soils and available water* project.

"After pre-watering the paddock, two applications of 25mm irrigated rainfall, and a pre-emergent spray, we sowed Illabo wheat under the centre pivot on 15 April 2023," Lawson said.

"We put 1500 ewes and lambs on the 100ha paddock for six weeks during July as the crop matured and they didn't even make a dent in it. There was ample feed in front of the mob — they couldn't keep up with it."

"The crop was quick to bounce back and proceed to grain fill after Lawson removed the sheep from the paddock, yielding 5.1 t/ha at the end of the season.

"It was great to have the extra feed available during the season, while still being about to take the crop through to harvest with a reasonable grain yield," Lawson said.

REAPING THE BENEFITS OF EARLY SOWING

Early sowing allows farmers like Lawson to capitalise on favourable weather patterns (early moisture). It also allows them to extend their growing season to reduce the risk of adverse weather conditions later in the season, with or without grazing.

Riverine Plains Project Officer Rhiannan McPhee said, "more and more we are seeing farmers able to select varieties and sowing windows that will result in good outcomes in terms of feed and grain yields."

Rhiannan emphasised the key to optimising grain yield is to remove stock before stem elongation so as not to remove the reproductive heads.

"Grain yield is also impacted by residual biomass, so it's important farmers allow enough time for crops to recover post-grazing," she noted.

"When water is available, they are confident to sow early and utilise dual-purpose crops in their systems. But under drier conditions, they tend to place less emphasis on post-grazing yields."

"It's also important farmers understand their soil conditions at the start of the season, as well as during the season to achieve positive outcomes with early sowing."

Plant counts were taken at crop emergence in both the irrigated and dryland paddocks, to assess potential differences in crop establishment.

"There was a significant difference between the paddocks — the irrigated paddock had a higher plant count — rather than a notable difference between early and standard sowing times," Rhiannan explained.

Table 1 shows the pre-sowing and post-harvest soil test results for the irrigated and dryland paddocks.

Biomass cuts were taken before harvest from the early sown paddock to calculate harvest index, yield and seed protein estimates. Yield measurements were also taken at harvest (see Table 2).

Table 1 Pre-sowing and post-harvest soil test results for the irrigated and dryland paddocks sown at Mulwala, NSW during 2023

PROPERTIES	DEPTH (CM)	IRRIGATED + GRAZED ILLABO WHEAT (EARLY)		DRYLAND PLANET BARLEY (STANDARD)	
		Pre-sowing	Post-harvest	Pre-sowing	Post-harvest
Nitrogen (kg N/ha)	0–90	127	42	72	13
Soil moisture (PAW mm)	0–90	111	145	319	248

Table 2 Yield measurements for early sown Illabo wheat sown during 2023, at Mulwala NSW.

	ILLABO WHEAT (IRRIGATED + GRAZED)
Total dry matter (t/ha)	17.73
Harvest index	0.36
Actual grain yield (t/ha)	5.10

The wet season saw Lawson apply fungicide to the crop under the centre pivot earlier than he would normally. While fungicide applications are often applied as part of their conventional sowing program, Lawson believes fungicide applications could increase depending on the scale of the program under irrigation with seasonal conditions and appetite to risk.

Concerns with increased frost susceptibility and lodging of early sown varieties are something that are front and centre of mind for Lawson. But despite this, he believes the benefits of early sowing still outweigh the potential challenges.

"Good drainage in paddocks plays a crucial role in preventing waterlogging and lodging issues," he said.

"Increasing our urea applications would also optimise yields."

LOOKING TO THE FUTURE

The inclusion of dual-purpose varieties in his rotation as a risk management tool, is something Lawson is keen to continue into the future.

"The more options and flexibility in our system the better," he said.

"Early sowing with dual-purpose crops allows us to respond in a timely manner to seasonal fluctuations in the weather and livestock prices."

Lawson is conscious the benefits of early sowing need to be balanced against the increased risk of frost damage as the crops mature.

"The increased chance of frost damage and crop loss with earlier-sown varieties is something we will definitely consider when making decisions around paddock selection into the future. Careful paddock selection — sowing earlier varieties on our higher country — will help to mitigate the frost risk."

Despite the risk, Lawson is keen to embrace the benefits of early sowing in his mixed farming system.

"Dual-purpose crops will also assist us to re-establish clean pastures after the cropping phase," Lawson added.

Looking to 2024, Lawson will grow dual-purpose crops on his dryland country, so will be watching the weather forecasts and hoping for rain early in the season.

This case study was authored by Toni Nugent as part of the *Improved drought resilience through optimal management of soils and available water project.*

This project is supported through funding from the Australian Government's Future Drought Fund Drought Resilient Soils and Landscapes Grants Program and is co-funded by the Grains Research and Development Corporation.

OPTIMAL SOIL AND WATER MANAGEMENT INCREASES DROUGHT RESILIENCE — FROM THE PLOT TO THE PADDOCK

Drought is an inevitable part of farming in Australia, but outcomes from the *Improved drought resilience through optimal management of soils and available water* project are equipping farmers with a host of additional strategies with which they can prepare for the inevitable.

Numerous small-scale field trials across southern NSW have shown that early sowing of slower-maturing crops, diverse legume rotations and nitrogen banking can all increase profitability and productivity by increasing soil moisture availability and preventing carbon and nutrient loss under drought conditions. But proving these practices are profitable on a paddock scale is key to ensuring grower adoption.

Using on-farm demonstrations, this project has demonstrated how growers can apply the theoretical strategies profitably on a paddock scale, across different soil types, environments and land uses.

Charles Sturt University, under the Southern NSW Drought Resilience Adoption and Innovation Hub, led the project in partnership with Farming Systems Groups Riverine Plains, FarmLink Research, Central West Farming Systems and Southern Growers, in collaboration with CSIRO and the NSW Department of Primary Industries. The collaboration saw management strategies that had been tried and tested by researchers, over six years on four sites, validated on farm with growers and advisors.

The project was supported through funding from the Australian Government's Future Drought Fund Drought Resilient Soils and Landscapes Grants Program and is co-funded by the Grains Research and Development Corporation.

EARLY SOWING OF LONGER-SEASON VARIETIES

Research carried out by CSIRO in small-scale plot trials indicates early sowing of longer-season varieties can provide multiple benefits depending on the weather and type of enterprise. Early sowing can:

- **utilise residual soil moisture from late summer or an early season break.**
- **match crop phenology with the sowing date, capturing optimal flowering windows and reducing the risk of adverse seasonal conditions**
- **offer dual-purpose options, such as integrating grazing into the farming system**
- **provide logistical advantages by lengthening the sowing window.**

EARLY SOWING REDUCES RISK, INCREASES OPTIONS FOR LARGE-SCALE CROPPING

Farmer:	Sam Kellock
Location:	Mulwala, NSW
Soil type:	Sandy clay loam
Rainfall (annual):	504 mm
Growing season rainfall:	304 mm
Enterprises:	Cropping (wheat, canola)

Management strategy:	Early sowing
Treatments	Comparing early sown wheat (Illabo) — irrigated and dryland with timely sown wheat (Scepter)
Sowing date:	7 April 2023 (Illabo); 1 May 2023 (Scepter)
Sowing rate:	90 kg/ha (Illabo) and 70 kg/ha (Scepter)
Crop species:	Wheat
Variety:	Illabo and Scepter wheat
Row spacing:	12 inch (30.48 cm)

AT A GLANCE

- **Early sown crops provide diversification in the system — opportunities for grazing, hay and silage and grain harvest.**
- **Early sowing allows crops to be sown during the optimal sowing window, reducing the risk of seasonal events, such as frosts.**

Although Mulwala farmer Sam Kellock routinely implements early sowing as a risk-management strategy in his large-scale cropping operation, a better understanding of the agronomics that sit behind the innovative approach has refined his decision-making when it comes to variety and paddock selection.

The biggest benefits of early sowing for Sam are the timeliness of operations and logistics for his cropping program — getting the crop in during the optimal sowing window.

"I'd rather start sowing earlier than finish sowing late and outside the ideal sowing window," Sam said.

"We have been caught out before in drier years where we have finished sowing too late, so if we have varieties that allow us to sow early, keep the seeder going and still reap the rewards, it's a no brainer," Sam said.

The Kellock family crops 2,225 hectares across three properties at Mulwala and Barooga, NSW and Katandra and Lake Rowan, Victoria. The cropping rotation is typically wheat-canola-wheat, with the inclusion of dual-purpose wheat varieties to provide opportunistic grazing, hay and silage options.

"We always commence our wheat program early due to the scale of our operation, and the number of hectares we have to get across, to ensure paddocks are sown within the optimal sowing window. But if we can understand the agronomic benefits better, this adds another tool to our toolkit we can use for our decision making."

"Early sown dual-purpose varieties allow us to drought-proof our operation and it's a value add for our grazing program."

Sam has a small herd of black baldy cows and opportunistically trades lambs — depending on the season.

"Having dual-purpose crops in our program provides us with options if we need them and offers us flexibility in our system," he said.

ASSESSING THE BENEFITS OF EARLY SOWING

During 2023, as part of the Improved drought resilience through optimal management of soils and available water project, Sam and the project team set out to compare the impact of sowing time and irrigation in wheat.

Sam sowed a flood-irrigated paddock to Illabo wheat on 7 April 2023 and sowed a dryland paddock half to Illabo and half to Scepter wheat on 1 May (standard sowing time). With a wetter than expected season, the paddocks were not grazed.

Plant counts were taken at emergence and showed significant differences between the dryland and irrigated paddocks, with the irrigated crop having higher plant counts. There was no notable difference between early and standard sowing times.

Sam explained the main differences between the two varieties was the early growth.

"We didn't see a difference in the number of plants, but greater vigour was noted in the early varieties. If we have ideal conditions, this means the crop can put on a good amount of biomass early," Sam said.

"With such a wet start to the season — full moisture profile and warm weather — the early sown Illabo got away pretty quick and had a lot of bulk, but as the season progressed, and being a shorter season variety, the Scepter, sown at the standard time, caught up," Sam said.

In addition to manipulating sowing time, Sam uses irrigation to mitigate risk, ensuring that in drier seasons he can provide enough in-crop moisture to fill grain and optimise yield. But during 2023, the application of irrigation pre-sowing was followed by substantial rainfall, resulting in severe waterlogging, creating extra headaches for Sam with regards to disease management and paddock access. The spring of 2023 was drier, and the crop benefited from a second irrigation.

"The wet conditions presented some challenges with disease in the early sown crops, in both the irrigated and dryland paddocks, and while we didn't apply any more fungicide than we would normally (two applications), we did apply it earlier compared with our standard crops, giving us piece of mind and ensuring protection of the crop," Sam said.

"The rain came later than was ideal for the dryland paddock, but it was sufficient to get us over the line with a decent yield of 8 t/ha for the irrigated crop and 7.5 t/ha for the dryland Illabo and Scepter crops."

Sam noted that protein levels were lower in 2023 due to seasonal constraints. The year was predicted to be dry and Sam was concerned with 'loading up' the crop with nitrogen. He applied 250 kg/ha of urea across each paddock and had a high amount of nitrogen in the soil prior to sowing, giving him the confidence to achieve his yield target of 7.5 – 8 t/ha.

THE DETAIL LIES IN THE DATA

Riverine Plains Project Officer, Rhiannan McPhee, collected a range of data on both paddocks and the early sown and standard sown crops, which paints a clearer picture of what was happening in the two paddocks.

"Having the irrigated paddock right next door to the dryland paddocks — early and standard sowing times — has allowed us to compare three different sowing options, side by side," said Rhiannan.

To gauge the success of the early sown crops, and potential differences between irrigated and dryland sowing, soil tests for carbon, nitrogen and water holding capacity were taken pre-sowing (early April) and post-harvest (February 2024) (see Table 1).

Biomass cuts were taken prior to harvest from the early sown paddocks to calculate harvest index, yield estimates and seed protein estimates. The dryland Scepter paddock had already been harvested when biomass cuts were taken, so the research team were unable to calculate yield and seed protein estimates for the standard sowing time. Yield measurements were also taken at harvest (see Table 2).

"The visual differences between the management practices during the season were quite distinct and the results were reflected in the soil tests, and yields," Rhiannan observed.

Table 1 Soil test results from wheat sown early and at a standard time of sowing in 2023 at Mulwala, NSW

	DEPTH (CM)	IRRIGATED ILLABO (EARLY SOWING)		DRYLAND ILLABO (EARLY SOWING)		DRYLAND SCEPTER (STANDARD SOWING)	
PROPERTIES		Pre-sowing	Post-harvest	Pre-sowing	Post-harvest	Pre-sowing	Post-harvest
Nitrogen (kg N/ha)	0–90cm	174	45	130	28	130	38
Soil moisture (PAW mm)	0–90cm	235	211	259	240	259	200

*Pre-sowing soil testing was carried out across the paddock, without the knowledge that the paddock was sown to two varieties, while post-harvest soil testing was specific to each variety.

Rhiannan noted the early sown irrigated crop used more nitrogen than the dryland crops, and the early sown dryland crop used more than the standard sown crop.

"Early sowing means crops are in the ground longer and use more nitrogen early to grow biomass. It's important to look at the amount of nitrogen used by the crop and the relevant yields to understand the overall efficacy," she explained.

"Having higher nitrogen levels in the irrigated paddock at the start of the season worked in our favour, reducing the need for additional nitrogen to be applied during the season," Sam said.

"The soil test results confirmed what we were visually seeing across the paddocks. Above the ground, the early sown, longer-season varieties appeared to be sucking the moisture from the profile."

Comparing the soil profile water content from pre-sowing to post-harvest, the results show the early sown Illabo was more efficient at using water compared to the Scepter on the dryland paddock.

Table 2 Yield measurements for irrigated and dryland Illabo sown during early April 2023 at Mulwala, NSW

	ILLABO WHEAT (IRRIGATED)	ILLABO WHEAT (DRYLAND)
Total dry matter (t/ha)	18.7	19.3
Harvest index	0.4	0.4
Estimated grain yield (t/ha)*	8.2	8.3
Actual grain yield (t/ha)	8	7.5

*No biomass cuts were taken for the Scepter wheat, thus no estimations were calculated for this variety.

PRACTICAL APPLICATIONS AND MEASURES OF SUCCESS

The flexibility that early sown dual-purpose crops give the Kellocks cannot be understated — and it's something they will continue to do as part of their farming system.

"In better seasons, if we choose not to graze, we can focus on getting the most out of our cropping operation. But if we need to graze paddocks to reduce or remove the need to supplementary feed, we have the option to do so," Sam said.

"Dual-purpose crops also provide the opportunity to winter clean and/or renovate our pasture paddocks."

For the Riverine Plains project team, the paddock-scale investigations are providing an invaluable opportunity to road test results from plot trials at the paddock scale and offer growers greater confidence to adopt a range of innovative approaches to manage risk.

"We are taking the results from small plot trials conducted by CSIRO and implementing them on farm to assess increases in profitability and productivity, through increases in soil moisture availability and the prevention of carbon and nutrient loss during drought," Rhiannan said.

"If other farmers see these management strategies are boosting profits and productivity, on a paddock scale, under similar environments, soil types and land use to their own properties, the adoption of early sowing and other management strategies will increase."

"This outcome equals project success."

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COMBINING TRADITION AND INNOVATION TO BOOST CANOLA ESTABLISHMENT

In the face of increasing climate variability, integrating traditional knowledge systems with modern agricultural practices will become critical for sustainable food production.

Innovative startup Rainstick is pioneering a novel approach to seed treatment, combining traditional knowledge with modern technology to influence and improve crop growth, yields and resilience.

Rainstick co-founder and Chief Rainmaker Darryl Lyons said, "Our people, the Maiawali tribe — a rainmaking tribe from southwest Queensland — with a rich history of over 60,000 years of sustainable land management practices, have long recognised the benefits of thunderstorms for agriculture."

"While many growers attribute plant growth after rainfall primarily to nitrogen fixation, Rainstick aims to explore the broader implications of bioelectricity and its relationship to climate-driven agricultural practices.

"We're blending traditional knowledge with modern science, looking to enhance crop establishment and yields, particularly in canola, to address ongoing climate challenges."

Darryl's co-founder, and Rainstick's Chief Thunderstorm Creator, Mic Black have drawn on their previous experiences in agricultural technology and biotech startups to guide their current venture. Lessons learned from their earlier startup projects have provided essential insights into risk management and market dynamics, which are informing their current strategies.

This pragmatic approach enables them to navigate the complexities of innovation in agriculture, with a clear understanding that success will require perseverance, collaboration, and continuous validation of their technologies.

EARLY TRIALS YIELD PROMISING RESULTS

The Rainstick team is taking a pragmatic approach towards developing its technology, ensuring that any innovations introduced on modern farms are both effective and financially beneficial.

"When introducing new technologies on-farm, growers want to know it's going to work and it's going to give them a return on their investment," Darryl said.

"We know it's a long haul and we're here to do the hard work and get the results, working hand-in-hand with growers across the country."

Starting with lab trials, followed by nursery trials and small-scale paddock plot trials involving more than 75,000 seedings across 220 trials, the team is now focussed on extensive field trials in canola addressing challenges faced by growers.

"We initially focused on wheat, off the back of the large research project by CSIRO and the University of Queensland with APSIM modelling, showing that if you can double the size of wheat seedlings in the first month, this leads to increased growth and biomass and an increase of an average of 16 percent crop yield across Australia's growing regions," Darryl said.

Rainstick co-founder and Chief Thunderstorm Creator Mic Black said, "We have run over 70 tests and 11,000 seedlings over three varieties of canola seed under controlled growing conditions. We have observed multiple trials having a significant 10 percent or greater increase in hypocotyl length and thickness, as well as increases in biomass."

"It's about balancing the right treatment recipe to influence the traits important to that variety, under specific growing conditions for individual growers needs. There is always a trade-off."

Germination issues cost the Australian canola industry around $100—$200 million annually. By enhancing germination rates and promoting early vigour without relying on heavy chemical inputs, Rainstick's treatments offer a potential pathway to improve canola yields in a sustainable manner.

NAVIGATING THE TRADE-OFFS TO BOOST CANOLA ESTABLISHMENT

A GRDC survey of canola growers and agronomists across Australia in 2020, found the most common causes of poor establishment were marginal soil moisture (76 percent), incorrect sowing depth (65 percent) and soil crusting (29 percent).

In Australia, growers are increasingly opting to sow canola crops earlier to optimise yield potential. But this approach comes with trade-offs including the risk of poor crop establishment (50—60 percent) due to factors such as false breaks, inadequate soil moisture, and elevated soil temperatures. The small and oil-rich canola seeds typically struggle with emergence when sown at depths greater than 30mm, particularly in soils that are prone to crusting. The preferred seeding depth for canola is generally shallow, around 20mm, but this shallow sowing depth increases the likelihood of false breaks and limits the ability to access stored moisture deeper within the soil profile.

Research investments aimed at developing genetic solutions to enhance canola establishment—focusing on early vigour and longer hypocotyls for deeper sowing to access soil moisture—have identified multiple overseas varieties that demonstrate improved vigour and/or longer hypocotyls, and these varieties show better emergence when sown at depth.

RAINSTICK

Founded in January 2022, Rainstick aims to enhance plant vigour without requiring farmers to alter their existing practices. This innovative non-chemical seed treatment is designed to improve seedling growth during the crucial first 14 days post-sowing.

Rainstick uses electricity to replicate the natural impact of lightning, promoting faster and more sustainable crop growth, while maintaining existing on-farm infrastructure and management practices.

The team is focused on increasing yields without altering on-farm practices. Collaborating with established seed treatment companies and key producers, Rainstick employs a complementary process that resembles the current methods used in conventional chemical-based seed treatments.

Through innovation and engagement, Rainstick is working to reduce the impact of extreme weather and climate change on the agricultural landscape.

Electric seed treatments offer a chemical-free method for growers to boost yields and decrease their environmental impact, helping to provide clean food for an additional two billion people by 2050.

GRASSROOTS COLLABORATION

Key to success is understanding local farming challenges. Through collaboration with growers, the team aims to refine their technology further, to develop solutions tailored to specific crops and regional conditions.

“We are looking to conduct extensive trials across seasons and different soil types, over the next two years, enabling us to validate the findings and make necessary adjustments as we progress,” Mic said.

“We don’t have all the answers, and that’s why it’s so important to gain feedback and insights from growers, to guide and work with us to shape the technology and treatments for different canola varieties.”

Darryl agreed, “Our goal is to deliver commercial products that address the evolving challenges faced by Australian growers across different growing regions.”

“Working with growers from the outset, will ensure our treatments align with practical farming goals and operations.”

Fostering a culture of experimentation and engagement, Rainstick aspires to play a pivotal role in shaping the future of Australian agriculture, providing resilient solutions for current and future generations.

ACKNOWLEDGEMENTS

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